FRONTIERS IN HIGH-SPEED RAIL DEVELOPMENT

Edited by Yoshitsugu Hayashi, Werner Rothengatter, and KE Seetha Ram

ASIAN DEVELOPMENT BANK INSTITUTE
Frontiers in High-Speed Rail Development

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Yoshitsugu Hayashi, Werner Rothengatter, and KE Seetha Ram
# Contents

Tables, Figures, and Boxes ........................................ vii  
Abbreviations ...................................................... xiv  
Contributors ....................................................... xviii  
Acknowledgments ................................................... xxii  

Preface ........................................................................ xxiv  
1. Introduction .......................................................... 1  
   KE Seetha Ram, Yoshitsugu Hayashi, Werner Rothengatter,  
   and Ayushman Bhatt  

PART I: Impacts of COVID-19 on Transport and Logistics  
Key Messages .......................................................... 9  
   Junyi Zhang, Yoshitsugu Hayashi, KE Seetha Ram,  
   Ayushman Bhatt, and Veronica Ern Hui Wee  
2. The COVID-19 Pandemic and Transport Policy:  
   State-of-the-Art and State-of-the-Practice ................. 17  
   Junyi Zhang, Yoshitsugu Hayashi, Werner Rothengatter,  
   and KE Seetha Ram  
3. Impacts of COVID-19 on the Transportation Sector,  
   Policy Recommendations, and Future Research:  
   A Report on the United States ................................. 73  
   Nicholas Johnson, Jai Malik, and Giovanni Circella  
4. A Transport Policy Model for COVID-19 Response:  
   A Mosquito/Malarial Analogy ................................. 111  
   Yoshitsugu Hayashi and Hiroyuki Takeshita  

PART II: Wider Economic Impacts and Quality of Life  
Implications of Transport Infrastructure  
Key Messages .......................................................... 127  
   Werner Rothengatter and Ayushman Bhatt  
5. Frontiers in Wider Economic Impacts of Transport  
   Infrastructure Development .................................... 133  
   Werner Rothengatter
6. Assessing the Wider Economic Impacts of Transport Infrastructure Investment with an Illustrative Application to the North–South High-Speed Railway Project in Viet Nam
Truong Thi My Thanh and Sybil Derrible

7. Estimating the Environmental Benefits from the Development of High-Speed Rail in Viet Nam
Pham Thi Kim Ngoc, An Minh Ngoc, and Le Thu Huyen

8. Empirical Analysis on Industrial Sectors for Quality of Life Improvement along High-Speed Rail Corridors
Shuji Sugimori, Yoshitsugu Hayashi, and Hiroyuki Takeshita

9. Planning, Power, and Deliberation: Lessons from High-Speed Rail Expansion in Spain
Ángel Aparicio

PART III: Impacts of High-Speed Rail on Other Modes of Intercity Travel

Key Messages
Yoshitsugu Hayashi, KE Seetha Ram, Veronica Ern Hui Wee, and Ayushman Bhatt

10. Does High-Speed Rail Have a Spillover Effect on the Mode Shift for Intercity Travel
Xiaohong Ren, Zhenhua Chen, Ting Dan, Chunyang Wang, and Wei Wang

11. Sine Qua Non: High-Speed Rail Forms and Roles in Intercity and Urban Areas
Eugene Chao and Vukan R. Vuchic

12. Transportation Mode Choice in Viet Nam Intercity Trips
Le Thu Huyen and An Minh Ngoc

PART IV: Transport–Urban Development Interactions

Key Messages
K. V. Krishna Rao, Veronica Ern Hui Wee, and Ayushman Bhatt

13. Factors Influencing the Ridership of a Proposed Metro Rail System
Chetan Kumar Hanni, Mayank Bansal, and K. V. Krishna Rao
14. Land Value Capture for Transit-Oriented Development in the North–South Commuter Railway Extension Project in the Philippines  
Akihiro Sato  
376

15. Exploring a Dynamic Relationship Between Transportation Strategies and Community Livability: The Case of the Kolkata Urban Agglomeration  
Arpan Paul and Joy Sen  
399

16. Socioeconomic, Environmental, and Accessibility Assessment of High-Speed Rail Station Location Using a Geographic Information System Network Analyst  
Sandeepan Roy, Avijit Maji, and Prasanta Sahu  
415

17. Transport Investment and Quality of Life: Evidence from Asian Countries  
Md Aslam Mia  
434

18. Urban Transportation Systems in Selected Small Developing Island States: A Comparative Analysis  
Urwah Khan and Juan Gonzalez  
455

PART V: Research and Innovation for High-Speed Rail Development in Developing Nations

Key Messages  
Sudhir Misra, Ashwin Mahalingam, KE Seetha Ram, and Ayushman Bhatt  
485

19. Indigenous Solutions and Opportunities for High-Speed Rail in India  
Achal Khare  
493

20. Policies and Priorities for Developing Capacity to Build High-Quality Infrastructure  
Santhosh Loganathan, Chandra Sekhar Bahinipati, KE Seetha Ram, and Satyanarayana N. Kalidindi  
510

21. Artificial Intelligence-Based Spatial Exploration for Computer-Aided High-Speed Rail Alignment Development  
Sandeepan Roy and Avijit Maji  
526

22. Estimating Direct, Indirect, and Induced Employment from Highway Construction in India  
Vinod Vasudevan, Sudhir Misra, Tanika Chakraborty, Prasanna Kumar Behera, and Ayushman Bhatt  
545
PART VI: High-Speed Rail for the People

Key Messages 565
   KE Seetha Ram, Nikhil Bugalia, Ayushman Bhatt, and Veronica Ern Hui Wee

23. Deriving Policies from Land Use–Transport Interactions for Sustainable High-Speed Rail Development in Asia 569
   Francesca Pagliara, Yoshtsugu Hayashi, and KE Seetha Ram

24. Graduate Students’ Recent Research on High-Speed Rail 588
   Nikhil Bugalia and Daniel del Barrio Alvarez

25. Of the People, for the People: Economic Corridors, High-Speed Railways, and Quality of Life in Post-COVID-19 Asia 595
   Richa Jayal

Conclusions and Way Forward 615
   KE Seetha Ram, Werner Rothengatter, and Yoshitsugu Hayashi
# Tables, Figures, and Boxes

## Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Selected Major National Level Policies with a Potential Direct Impact on the Transport Sector</td>
<td>79</td>
</tr>
<tr>
<td>4.1</td>
<td>Comparison between Mosquito Bites and Infections</td>
<td>116</td>
</tr>
<tr>
<td>4.2</td>
<td>Assumption of Parameters</td>
<td>122</td>
</tr>
<tr>
<td>6.1</td>
<td>Population Size and the Rate of Increase</td>
<td>182</td>
</tr>
<tr>
<td>6.2</td>
<td>Demographic Data (2018) of Six Provinces of High-Speed Railway Ha Noi–Vinh Section</td>
<td>186</td>
</tr>
<tr>
<td>6.3</td>
<td>Required Travel Time among Major Stations by Conventional and High-Speed Rail</td>
<td>187</td>
</tr>
<tr>
<td>6.4</td>
<td>Passenger Time Savings</td>
<td>189</td>
</tr>
<tr>
<td>6.5</td>
<td>Changes in Total Business Enterprises as a Consequence of the North–South High-Speed Rail Project</td>
<td>191</td>
</tr>
<tr>
<td>6.6</td>
<td>Changes in Employment as a Consequence of the North–South High-Speed Rail Project</td>
<td>192</td>
</tr>
<tr>
<td>7.1</td>
<td>List of Input Parameters for Developing Scenarios</td>
<td>201</td>
</tr>
<tr>
<td>7.2</td>
<td>Energy Consumption by Fuel Type under Business as Usual</td>
<td>208</td>
</tr>
<tr>
<td>7.3</td>
<td>Projection for Share of Passenger Kilometers Traveled with the Existence of High-Speed Rail</td>
<td>208</td>
</tr>
<tr>
<td>7.4</td>
<td>Demand for High-Speed Rail Segmented by Distance</td>
<td>209</td>
</tr>
<tr>
<td>7.5</td>
<td>Energy Consumption by Fuel Type under High-Speed Rail Scenario</td>
<td>209</td>
</tr>
<tr>
<td>8.1</td>
<td>Input-Output Ratio for Employment: $\theta$</td>
<td>222</td>
</tr>
<tr>
<td>8.2</td>
<td>Weight of Each Explanatory Variable for Each Industry</td>
<td>223</td>
</tr>
<tr>
<td>10.1</td>
<td>Summary Statistics of the Survey Respondents</td>
<td>280</td>
</tr>
<tr>
<td>10.2</td>
<td>Description of the Key Variables</td>
<td>284</td>
</tr>
<tr>
<td>10.3</td>
<td>Result Comparison Based on Respondents’ Responses to Whether a Direct High-Speed Rail is Available for Their Trip</td>
<td>286</td>
</tr>
<tr>
<td>10.4</td>
<td>Comparison Based on the Availability of High-Speed Rail Services at the Respondent’s Origin</td>
<td>289</td>
</tr>
<tr>
<td>10.5</td>
<td>Result Comparison Based on Respondents Whose Residential Location and the Train Station are at Different Distance Ranges (with the Consideration of Price Scenarios)</td>
<td>292</td>
</tr>
</tbody>
</table>
10.6 Result Comparison Based on Respondents Whose Residential Location and the Train Station are at Different Distance Ranges (without the Consideration of Price Scenario) 294
A10.1 Correlation Matrix of All the Variables 299
11.1 System Performance for Different Generic Classes of Transit Modes 301
12.1 Vehicle Accessibility 334
12.2 Willingness to Pay 343
13.1 Factors Affecting Transit Ridership 359
13.2 Stated Preference Attributes and Levels for Level of Service 363
13.3 Stated Preference Attributes and Levels for Last Mile Connectivity (Two-Wheeler Park and Ride Availability) 363
13.4 Stated Preference Attributes and Levels for Last Mile Connectivity (Bus Feeder Service Availability) 364
13.5 Stated Preference Attributes and Levels for Last Mile Connectivity (Walkway and Walkalator Availability) 364
13.6 Subjective Values of Parameters Derived from Logit Models of Stated Preference Survey Data 370
13.7 Impact of Influencing Factors on Metro Ridership 373
14.1 Target Sample Locations and Random Points per Sampling Region 380
14.2 Description of Database Items (or Amenities) 381
14.3 Expected Signs of Explanatory Variables 386
14.4 Parameters and Statistics for Commercial Areas 389
14.5 Parameters and Statistics for Residential Areas 390
14.6 Commercial and Residential Areas in the Affected Areas 393
15.1 Initiation of Variables 407
15.2 Degree of Impacts of the Initiated Factors on Community Livability 409
16.1 Parameters and Corresponding Values 422
16.2 Available Data for Spatial Analysis 422
16.3 Total Utility Scores for Planned High-Speed Rail Station Locations 429
17.1 Descriptive Statistics of the Variables 442
17.2 Pairwise Correlation and Variance Inflation Factors among Independent Variables 443
17.3 Factors Affecting Quality of Life and Its Components, Models 1–8 444
17.4 Factors Affecting Quality of Life and Its Components, Models 9–16 445
A17.1 Variables and Definition 453
18.1 Selected Country Indicators 464
18.2 Passenger Perceptions of the Best Features of Bus Services 466
18.3 Respondents’ Views on the Level of Bus Fares and Willingness to Pay to Save 20 Minutes 467
18.4 Types of Public Motor Vehicles in Port Moresby 468
18.5 Survey Results on Bus Transport Service 469
18.6 Sustainable Urban Transport Index Indicators Normalized Values 474
A18.1 Explanation of Sustainable Urban Transport Index Indicators 480
19.1 Simulation Studies 499
19.2 Snapshot of the Proposed High-Speed Rail Corridor 504
20.1 Employment in Indian Construction by Education Level of Workers 513
20.2 Comparison of Factors Related to Construction Labor Productivity in India and Other Countries 517
21.1 Input Parameters for Railway Alignment Design and Ant Colony Optimization 535
21.2 Objective Values of Representative Alignment Optimization Solutions 538
22.1 Direct and Indirect Employment Estimates for Each Project 554
22.2 Direct Employment Estimates per Lane Kilometer 555
22.3 Direct and Indirect Employment per Million ₹ Invested 557
22.4 Ratio of Indirect to Direct Employment 557
22.5 Number of Businesses in Population and Surveyed 558
24.1 List of Presentations 589

Figures
3.1 Number of COVID-19 Cases in the United States (January 2020 to March 2021) 76
3.2 Number of COVID-19 Related Deaths in the United States (January 2020 to March 2021) 76
3.3 TSA Passenger Throughput Counts (January 2019 to December 2019) 82
3.4 TSA Passenger Throughput Counts (January 2020 to March 2021) 83
3.5 Mobility Trends in the United States (January 2020 to March 2021) 85
3.6 Transit Use Trends in the United States (January 2020 to March 2021) 88
3.7 Transit Use Trends in Selected US States (January 2020 to March 2021) 88
3.8 Driving Trends in the United States (January 2020 to March 2021) 91
3.9 Driving Trends in Selected US States (January 2020 to March 2021) 91
3.10 Walking Travel Trends in the United States (January 2020 to March 2021) 94
3.11 Walking Travel Trends in Selected US States (January 2020 to March 2021) 95
4.1 Number of Overnight Stays in Japan, 2019 and 2020 112
4.2 Relationship between Activity and Travel 117
4.3 Relationship between Protection and Activity 118
4.4 Relationship between Protection and Number of Cases 118
4.5 Matrix for Estimating the Number of Cases 119
4.6 Number of Overnight Stays With and Without the “Go to Travel” Campaign 120
4.7 Estimated and Actual Numbers of New Cases 123
5.1 Benefit Measurement in Cost-Benefit Analysis 135
5.2 Benefit Profile of Wider Economic Impacts (Stylized) 160
5.3 High-Speed Freight Train Concept Developed by German Aerospace Center 172
5.4 Development of E-Commerce Worldwide 173
6.1 Changes in Travel Time of the Proposed North–South High-Speed Railway 188
7.1 Approach Framework 202
7.2 Number of Registered Vehicles in the Road Sector 204
7.3 Passenger Volume by Transport Subsector 204
7.4 Mode Share of Passenger Kilometers Traveled per Capita 205
7.5 Percent Increase of On-Road Passenger Kilometers Traveled 206
7.6 Projection of Passenger Kilometers Traveled on Long-Distance Services (under Business as Usual) 206
7.7 Kilometers Traveled by Vehicle Type 207
7.8 Emissions from Transport, 2018–2050 210
7.9 Total Emissions by Subsector 211
8.1 Quality of Life Model 219
8.2 Size of Trade and the Dependence Direction between Industrial Sectors 223
8.3 The t-Value for the Explanatory Variable InterD 224
8.4 Increase Rate of Employees (2005–2015) 225
8.5 Share of Employment of 12 Selected Cities in the Whole of Japan 226
9.1 1989 and 2009 Journey Times between High-Speed Rail Stations in the European Core 230
10.1 Evolution of High-Speed Rail Ridership and Track Length in the People’s Republic of China 276
10.2 Proportion of Respondents with a Different Travel Time from Origin to Departing Train Station 281
10.3 Socioeconomic Characteristics of Respondents’ Origin with a Variation in Travel Time from the Railway Stations in Chongqing 281

11.1 Relationship Between Capacity, Investment Cost, and Passenger Attraction of Different Generic Classes of Transit Modes 303

11.2 Radial Networks with Different Layouts 305

11.3 High-Speed Rail Connects Major Center Cities via Rail Radial and Tangential Lines to New Growth Areas 307

11.4 Area Coverage, Load Section, Capacity, and Passenger Profile: Trunk Line with Two Branches 307

11.5 Geometric Types of Rail Lines and Network 309

11.6 Visual Comparison of Dead-End Terminal vs. Through-Running Station 311

11.7 Examples of Station Design with Train Bypassing Capabilities 312

11.8 Operation Value Creation of Through-Running Station 313

11.9 Effects of Adding a Station to an Existing Line 318

11.10 Types of Accelerated Operations 319

11.11 Comparative Analyses of Skip-Stop and Standard Operations 319

11.12 Philadelphia Dead-End Terminal (Left) Upgraded to Two Sets of Radial Services in 1983 to Form a Series of Diametrical Lines with Through-Running Trunk Operation (Right) in the Center City 321

11.13 Boston North South Rail Link Existing Dead-End (Left) vs. Proposed Through-Running (Right) 322

11.14 Comparison of Existing Dead-End Terminals vs. Single-Core (Left) and Futuristic Through-Running and Multicore (Right) in the New York Area 323

11.15 The Bigger Apple Plan: Transition from the Single-Core Development Mindset to Multicore Regional Growth 324

11.16 The Bigger Apple Plan: Roadmap for the Virtuous Growth Cycle 325

11.17 The Bigger Apple Plan: Through-Running Trunk Lines (RUN 34 and 42) for the Multicore Development 325

12.1 Comparing Different Modes of Transport 338

12.2 Reasons for Different Mode Choice 341

12.3 Mode Choice in Different Journeys (Real Preference Interview) 342

12.4 Passenger Selection of Mode for Specific Routes 344

12.5 Expectations for High-Speed Rail Operation 345

13.1 Modal Share in Indian Cities 356

13.2 Modal Split by Income Level in Pune 357
Tables, Figures, and Boxes

13.3 Pune Metro Master Plan 360
13.4 Proposed Alignment of Pune Metro Line 3 (Civil Court to Megapolis Circle) 361
13.5 Questions Related to Trip Frequencies for Station Area Development 362
13.6 Typical Stated Preference Card with Respect to Level of Service Factors 365
13.7 Typical Stated Preference Card with Respect to Last Mile Connectivity Factor 365
13.8 Calibrated Parameters of Four-Stage Travel Demand Model 366
13.9 Mode Choice, Age, and Income Distribution of Survey Respondents 368
13.10 Summary of User Responses for Station Area Development 369
13.11 800-Meter Buffer Zones around Proposed Stations of Pune Metro Line 3 371
13.12 Digitized Built-Up Area within 800-Meter Buffer Zones of Proposed Metro Stations 372
14.1 Analytical Diagram 379
14.2 Image of Change in Current and Future Land Use (Sample Case in Calumpit) 393
14.3 Comparison of Current and Future Land Value 395
14.4 Comparison of Increased Land Value and Project Cost 396
15.1 Schematic of the Research Idea 401
15.2 Socioeconomic Profile of the Respondents 405
15.3 Housing Choices of the Respondents 406
16.1 Difference between Buffer-Based and Network-Based Accessibility 420
16.2 Study Area with Infeasible Regions and Feasible Grid Locations 424
16.3 Utility Score—Accessibility to Existing Transportation Facilities 425
16.4 Utility Score—Downtown Proximity 426
16.5 Utility Score—Avoiding High-Cost Right-Of-Way 427
16.6 Total Utility Score of All Feasible Grid Locations 428
17.1 Framework of Transport and Communication Investment and Quality of Life 437
18.1 Logistics Performance Index Key Dimensions 460
18.2 Logistics Performance Index Ranking Comparison 460
18.3 Logistics Performance Index Score and Dimension for Infrastructure Comparison 461
18.4 Comparison of the Notre Dame Global Adaptation Initiative Country Index 462
18.5 Vulnerability and Readiness Score Comparison for Selected Countries 462
18.6 Vulnerability and Readiness Score Comparison for Top Performing Countries 463
18.7 Motor Vehicles Registered in Fiji 465
18.8 Sustainable Urban Transport Index Spider Diagram 475
19.1 Continuous Monitoring for a Safe and Comfortable Journey 496
19.2 Items Identified for “Make in India” 497
20.1 Age Distribution of Construction Workers 515
20.2 Average Age of Construction Workers across Different Countries 516
21.1 Geometrical Components of the Horizontal Curve 528
21.2 Representation of Halton Point Set Superimposed over a Real-World Map 532
21.3 Representation of Feasible Neighborhood of Points for Selection of Points of Intersection 533
21.4 Optimized High-Speed Rail Alignment Generated 537
21.5 Variation of the Total Construction Cost with the Number of Iterations 539
22.1 Methodology for Estimating Direct and Indirect Employment Generation 550
22.2 Survey Form Used to Collect Data on Induced Employment Generation 553
23.1 Relationship between the Transportation and Activity Systems 570

Boxes
5.1 A Case of Manipulation with Cost-Benefit Analysis 138
19A.1 Quick Facts on the Wildlife Overpass Planned between Sanjay Ghandi National Park and Tungareshwar Wildlife Sanctuary 508
20.1 A Day in the Life of a Migrant Construction Worker 514
Abbreviations

AARP American Association of Retired Persons
ACO ant colony optimization
ADB Asian Development Bank
ADBI Asian Development Bank Institute
ADIF Administrador de Infraestructuras Ferroviarias (Administrator of Railway Infrastructures)
AMTDC Advanced Manufacturing Technology
AOI area of interest
ASEAN Association of Southeast Asian Nations
ATC automatic train control
AVE Alta Velocidad Española
BAU business as usual
BEST Brihanmumbai Electric Supply and Transport
BNL binary logit
BRI Belt and Road Initiative
BRTS bus rapid transit system
CAM cement asphalt mortar
CBA cost-benefit analysis
CEP courier, express, and parcel
CGE computable general equilibrium
CO₂ carbon dioxide
CO₂e carbon dioxide equivalent
DAFTC digital audio frequency track circuit
DfT Department for Transport (of the United Kingdom)
DMC developing member country
DOTr Department of Transportation (of the Philippines)
DS-ATC digital shinkansen-automatic train control
EDSA Epifanio de los Santos Avenue
EKC environmental Kuznets curve
EMI equated monthly installment
ERTMS European rail traffic management system
EU European Union
FECI Florida East Coast Industries
FEM fixed effect model
FSI floor space index
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTKT</td>
<td>freight transport kilometers traveled</td>
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<tr>
<td>GA</td>
<td>genetic algorithm</td>
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<tr>
<td>GAMS</td>
<td>General Algebraic Modeling System</td>
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<td>GDP</td>
<td>gross domestic product</td>
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<td>GDPPC</td>
<td>gross domestic product per capita</td>
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<td>Gg</td>
<td>gigagram</td>
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<td>GHG</td>
<td>greenhouse gas</td>
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<td>GIS</td>
<td>geographic information system</td>
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<td>GRH</td>
<td>gross regional happiness</td>
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<td>GRP</td>
<td>gross regional product</td>
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<td>hour</td>
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<tr>
<td>HSR</td>
<td>high-speed rail</td>
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<td>HSRTI</td>
<td>High-Speed Rail Training Institute</td>
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<tr>
<td>IISc</td>
<td>Indian Institute of Science</td>
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<tr>
<td>IIT</td>
<td>Indian Institute of Technology</td>
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<tr>
<td>ILO</td>
<td>International Labor Organization</td>
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<td>IO</td>
<td>input-output</td>
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<tr>
<td>IoT</td>
<td>Internet of Things</td>
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<td>IoT-R</td>
<td>Internet of Things for Railways</td>
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<tr>
<td>IWT</td>
<td>inland waterway transport</td>
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<tr>
<td>JARTS</td>
<td>Japan Railway Technical Service</td>
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<td>JICA</td>
<td>Japan International Cooperation Agency</td>
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<td>JR</td>
<td>Japan Railways</td>
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<td>kg</td>
<td>kilogram</td>
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<td>km</td>
<td>kilometer</td>
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<td>KUA</td>
<td>Kolkata Urban Agglomeration</td>
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<td>LiDAR</td>
<td>light detection and ranging</td>
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<td>LPI</td>
<td>logistics performance index</td>
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<td>LUTI</td>
<td>land-use and transport interaction</td>
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<td>m</td>
<td>meter</td>
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<td>MAHSR</td>
<td>Mumbai–Ahmedabad High-Speed Rail</td>
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<td>MMC</td>
<td>Multi-Modal Corridor</td>
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<tr>
<td>MNL</td>
<td>multinominal logit</td>
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<tr>
<td>Mtons</td>
<td>metric tons</td>
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<td>ND-GAIN</td>
<td>Notre Dame Global Adaptation Initiative</td>
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<tr>
<td>NH</td>
<td>national highway</td>
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<td>NHSRCL</td>
<td>National High Speed Rail Corporation Limited</td>
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<td>NSCR-EX</td>
<td>North–South Commuter Railway Extension</td>
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<td>NSHR</td>
<td>North–South High-Speed Railway</td>
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<tr>
<td>NTV</td>
<td>Nuovo Trasporto Viaggiatori</td>
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<tr>
<td>NUTS</td>
<td>nomenclature des unités territoriales statistiques (nomenclature of territorial units for statistics)</td>
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<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>O&amp;M</td>
<td>operation and maintenance</td>
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<tr>
<td>OD</td>
<td>origin and destination</td>
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<td>ODA</td>
<td>official development assistance</td>
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<td>OHE</td>
<td>overhead equipment</td>
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<td>OLR</td>
<td>ordinal logistic regression</td>
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<td>PARFI Foundation</td>
<td>PanIIT Alumni Reach for India Foundation</td>
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<td>PDI</td>
<td>Plan Director de Infraestructuras (Strategic Infrastructure Plan)</td>
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<td>PEIT</td>
<td>Plan Estratégico de Infraestructuras y Transporte (Strategic Plan on Transport Infrastructure and Services)</td>
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<tr>
<td>PGC</td>
<td>Plan General de Carreteras (Road Infrastructure Plan)</td>
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<tr>
<td>PI</td>
<td>point of intersection</td>
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<td>PIF</td>
<td>Plan de Infraestructura Ferroviaria (Rail Infrastructure Plan)</td>
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<tr>
<td>PIT</td>
<td>Transport Infrastructure Plan</td>
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<tr>
<td>PKT</td>
<td>passenger kilometers traveled</td>
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<td>particulate matter</td>
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<td>PNR</td>
<td>Philippine National Railways</td>
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<td>POLS</td>
<td>pooled ordinary least square</td>
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<td>PPA</td>
<td>public policy analysis</td>
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<td>PPP</td>
<td>public–private partnership</td>
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<td>PPP</td>
<td>purchasing power parity</td>
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<tr>
<td>PRC</td>
<td>People's Republic of China</td>
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<td>PSO</td>
<td>particle swarm optimization</td>
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<tr>
<td>QoL</td>
<td>quality of life</td>
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<tr>
<td>R&amp;D</td>
<td>research and development</td>
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<tr>
<td>RE</td>
<td>reinforced earth</td>
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<tr>
<td>REM</td>
<td>random effect model</td>
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<tr>
<td>RFI</td>
<td>Italian Rail Network</td>
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<tr>
<td>RP</td>
<td>revealed preference</td>
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<tr>
<td>RUN</td>
<td>regional unified network</td>
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<tr>
<td>SAM</td>
<td>social account matrix</td>
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<tr>
<td>SASI</td>
<td>spatial and socioeconomic impacts</td>
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<tr>
<td>SCGE</td>
<td>spatial computable general equilibrium</td>
</tr>
<tr>
<td>SDM</td>
<td>system dynamics model</td>
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<tr>
<td>SEM</td>
<td>structural equation model</td>
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<tr>
<td>SGNP</td>
<td>Sanjay Gandhi National Park</td>
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<tr>
<td>SIDS</td>
<td>small island developing states</td>
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<tr>
<td>SP</td>
<td>stated preference</td>
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<tr>
<td>SPV</td>
<td>special purpose vehicle</td>
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<tr>
<td>SUTI</td>
<td>Sustainable Urban Transport Index</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<td>--------------</td>
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<tr>
<td>SUTI</td>
<td>Sustainable Urban Transport Initiative</td>
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<tr>
<td>TAZ</td>
<td>traffic analysis zone</td>
</tr>
<tr>
<td>TEN-T</td>
<td>trans-European transport network</td>
</tr>
<tr>
<td>TOD</td>
<td>transit-oriented development</td>
</tr>
<tr>
<td>TWLS</td>
<td>Tungareshwar Wildlife Sanctuary</td>
</tr>
<tr>
<td>UIC</td>
<td>Union Internationale des Chemins de fer (Union of International Railways)</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>ULB</td>
<td>urban local body</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
<tr>
<td>VIF</td>
<td>variance inflation factors</td>
</tr>
<tr>
<td>VKT</td>
<td>vehicle kilometers traveled</td>
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<tr>
<td>WCTRS</td>
<td>World Conference on Transport Research Society</td>
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<tr>
<td>WEI</td>
<td>wider economic impact</td>
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<tr>
<td>μg</td>
<td>microgram</td>
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</tbody>
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High-speed rail (HSR) operation started in Japan in 1964 with a link between Tokyo and Osaka. In the next decades, many countries followed, and the HSR length grew worldwide from the initial 515 kilometers (km) to 56,129 km under operation and 22,562 km under construction (UIC 2021a, 2021b). Plans exist for about 40,000 km more, and the latent demand can be estimated even higher considering the missing HSR implementation in North America, Latin America, and Africa. The People’s Republic of China is leading in terms of HSR kilometers (35,388 km), while Spain has achieved the highest HSR density in terms of HSR kilometers per km² or per inhabitant (71 km per million inhabitants).¹ The speed of HSR network extension decreased following the financial crisis in 2008 as private capital owners became unwilling to invest in HSR public/private undertakings and, at the same time, public budgets needed consolidation.

Analyzing the present frontiers in HSR worldwide, one can conclude that the system has brought substantial benefits to the countries and regions that have constructed efficient HSR networks or at least coherent corridors. But there are also many countries that show HSR patchworks rather than networks, and countries that have not fully exploited the potential of HSR because of several existing aspects. These aspects can be addressed in the future by intelligent policies. It is the objective of this volume on frontiers in HSR development to show the prospects of future HSR development starting from the existing frontiers and analyzing the potential for addressing the aspects related to them.

The first aspect that currently limits the prospective development of HSR is the coronavirus disease (COVID-19) pandemic. This pandemic has seriously set back the development of most economies around the world and has hit the transport and mobility sector hard. Mobility has been influenced not only by the temporary decline of economic growth but also by a substantial restructuring of economic activities. People and companies have learned to communicate via electronic media, so the use of video conferences, webinars, and video chats has grown dramatically.

¹ 2019 figures.
People have changed their travel behavior and increasingly avoided the use of mass transport facilities in favor of individual mobility. These behavioral changes are partly driven by the fear of infection through close contact with other passengers in mass transit vehicles and partly by the aversion of people to precautionary measures like wearing face masks. Public policies for reducing tourism and prohibiting cultural or sporting events are reinforcing the antipathy toward mass transport. These have hit not only aviation seriously but also HSR, regional rail services, and urban metro systems to a large extent.

To address this aspect for HSR, it will be necessary to restore confidence in public transport and provide sufficient convenience for passengers. It is hard to predict the medium-term future: Will COVID-19 be overcome soon and life and business return to normal, or instead, will people understand that such a serious crisis provides a chance for changing behavior toward long-term sustainability? It seems most probable that the pandemic will not disappear abruptly or forever in the near future. It may take more than a year to vaccinate all generations of people in industrialized countries (including children). Furthermore, variants (mutations) of the virus may appear, making further vaccination campaigns necessary. Emerging economies as well as developing countries may take several more years to reach herd immunity. From this follows that HSR companies will have to be prepared for a longer intermediate phase in which travel restrictions are relaxed successively while strict precautionary measures remain necessary. HSR companies will have to adjust their services, proactively and make them safe (e.g., by offering rapid testing at stations) and convenient (e.g., by distancing) for passengers. As soon as enough vaccines are available and it is confirmed that vaccination also prevents infecting other people, the unrestricted reservation of seats in HSR could be offered for vaccinated passengers and precautionary measures could be relaxed for them. This could reestablish confidence in the safety and security of HSR services.

A second aspect to be discussed is the appraisal of HSR plans and projects. Conventionally, the performance of HSR investments is measured by the ability of projects to generate (i) positive net present values for the return on capital invested (in particular in the case of public–private partnerships, or PPPs) and/or (ii) reductions of generalized and external costs that outweigh the investment costs. The latter is measured by conventional cost-benefit analysis (CBA), and its application shows that in most cases, the reductions in time and operating costs come out as the most relevant performance indicators. This is, however, a very narrow view for measuring the comprehensive efficiency of large investment projects because it ignores all secondary
and spillover effects. In some countries, the modest rentability and CBA figures give arguments to opponents of large HSR projects for stopping or at least shifting decision processes over time. However, shifting decisions over time may lead to further cost increases through raising construction prices and adding further requirements in the approval processes, which will deteriorate the economic performance figures even more.

This aspect can first be addressed by extending CBA to include wider economic impacts (WEIs). The WEIs include all impacts with respect to space, industrial sectors, and social groups and measure these impacts either by comprehensive welfare approaches or by indicators of social accountability. The WEIs can be extended by integrating strategic analysis of the environmental and energy impacts (fully integrated assessment methods). If the WEIs are measured by macroeconomic approaches, then they can reveal the potential of HSR projects for generating future tax revenues for the state. In particular, if a project is financed by the state or with a major contribution from the public budget in PPPs, then information on the payback period for public capital is helpful in case of the controversial positions of stakeholders. The resistance of opponents can be channeled by organizing mediation meetings accompanying the planning and procurement processes of large projects. This is a particular issue for HSR investments in industrialized countries, in which the “NIMBY” (not in my backyard) resistance against large projects is most pronounced.

A third aspect is the missing integration with regional access networks, which may occur if HSR investments are planned independently from regional public transit networks. This may happen if the regional decision units are less powerful compared with the combined power of the federal state, the industry, and the federal railway companies. It may also happen if promoters regard the HSR project as an instance of the “sublime,” i.e., a unique and most visible economic and technological symbol for the region and for the country. In such cases, the connections to regional and urban networks are given secondary importance. It is then overlooked that HSR needs efficient feeder services that help to improve the economic, social, and environmental efficiency of a project.

This aspect can be addressed by the integrated planning of networks in a way that HSR provides the backbone, and conventional rail networks

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2 The HS2 project in the United Kingdom gives a prominent example.

3 This can be combined with new ways of finance, as suggested in Yoshino, Helble, and Abidhadjaev (2018).
as well as regional rail networks provide accessibility for people living in a catchment area of HSR. This approach avoids, furthermore, an overconcentration of economic growth impacts in agglomerations, which in particular has been observed in the first phase of developing HSR in industrialized countries, when the focus of planning was laid on implementing single HSR projects and not on integrated network development.

A fourth aspect emerges if the HSR stations are not well integrated into urban development planning. This is often caused by heterogenous and conflicting planning institutions. HSR is planned by federal authorities and companies, while the land-use development around stations may be planned by local authorities. This often leads to the result that the benefits of HSR cannot be captured by the organizations planning, providing, and operating HSR, and a substantial part of the positive impacts is not specified and is left vague.

One possibility for addressing this is a clear allocation of property rights for developing the area around planned HSR stations (as has been typical in Japan). If, for instance, HSR stations are planned at the periphery of cities, then it is not enough to construct park-and-ride lots and establish bus connections. Such stations will have to be integrated into the urban rail networks and into urban land-use planning. Furthermore, developing residential and business areas around stations (called transit-oriented development, in Japan) or even developing a sub-city around a big station with its own centrality may foster decentralized city development and avoid overconcentration in agglomerations. This can help to make a city more livable, reduce car mobility, and avoid the congestion of commuting, shopping, and leisure mobility.

The fifth aspect is insufficient research and development (R&D) in the railway sector. Combining the expenditures on R&D of the private and public sectors, road transport has recorded the highest investments into new technology. This reflects in R&D investments in automation, assistance/guidance systems, and multimedia options developed for car and truck users. High-tech companies are developing automated road vehicles, partly together with traditional car manufacturers, and have already achieved levels 3 and 4, which allow for automatic driving in appropriate traffic situations (e.g., in stop-and-go congestion at low speeds). Similar research activities for fostering digital progress in rail technology are lagging behind—except for futuristic concepts like hyperloop transportation. The missing digital innovations for rail technology are explained by lock-in and path dependency.

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4 The Indian National High-Speed Rail Corporation Limited plan gives a positive example.
Lock-in means that rail R&D has developed as a widely separate research area. The resulting innovations are subject to strict sector-internal checks and regulations, and these reduce the willingness of private industry to invest in rail innovation. Path dependency characterizes the preference of private industry to invest in areas that have proven prosperous in the past. From the viewpoint of private industry, the market for road transport is much bigger in most countries, such that the success of innovative products appears bigger for road compared with rail.

This aspect can be dealt with in particular by credible policy declarations with respect to supporting the railway system by infrastructure investment and reducing road and air transport by internalizing external costs. An example is given by the European Commission, which published the Green Deal policy initiatives in 2019. These include a clear political ambition for a carbon-free Europe by 2050 as well as medium-term milestones and actions toward achieving this goal. This implies a substantial restructuring of the economy and the transport sector and supporting transportation modes that have a low-carbon footprint, such as rail. The European Green Deal may provide signals to the industry for redirecting their R&D activities such that innovation in the railway sector will accelerate. HSR is at the top of railway technology and will be an increasingly promising field of R&D. Achieving progress with digitalization and automation technologies in the rail system should be much easier compared with the road system because of the central coordination and control of vehicles’ movements within the rail infrastructure. Investing in HSR digitalization and automation can also foster innovation in other sectors (e.g., freight logistics) and contribute to increased productivity in the economy on the path to sustainability.

A sixth aspect refers to the social integration of HSR. HSR has been regarded in the first phase of implementation as a high-level transport mode for business and tourism for affluent people. This has limited social acceptance by groups that could benefit directly from HSR provision. Examples are people living in peripheral regions that are lagging behind, people with lower incomes who cannot afford high prices, and people living in overcrowded areas around HSR stations.

This aspect can be addressed by internal and external changes to HSR. Offering low-cost tariffs will attract people with lower incomes, such as students and senior people. The OUIGO initiative of the French railways goes in this direction. When it comes to improving the living conditions in remote areas, regional development policy and the improvement of local networks may be appropriate instruments, linking the regions to the backbone HSR network. When it comes to the impact
of HSR stations on urban living, there are a host of possibilities for improving the quality of life around peripheral stations, increasing their autonomy and attractiveness of living. This also holds for peripheral urban districts that are not directly linked to an HSR station but offer good access to feeder services. The appraisal of social progress can be supported by checking criteria on quality of life. Equity issues play an important role in this context to make sure that no one is left behind.

This book is organized along these six aspects of the frontiers in HSR, which provide the guiding principles for its six parts:

- **Part I**: Impacts of COVID-19 on Transport and Logistics
- **Part II**: Wider Economic Impacts and Quality of Life Implications of Transport Infrastructure
- **Part III**: Impacts of High-Speed Rail on Other Modes of Intercity Travel
- **Part IV**: Transport–Urban Development Interactions
- **Part V**: Research and Innovation for High-Speed Rail Development in Developing Nations
- **Part VI**: High-Speed Rail for the People

Readers will find original and stimulating ideas in every part for illuminating the role of HSR as an important factor in the transition to a carbon-free world with a high quality of life for future generations.
References

1

Introduction

KE Seetha Ram, Yoshitsugu Hayashi, Werner Rothengatter, and Ayushman Bhatt

Large demand for the development of high-quality infrastructure projects has been evident and widely acknowledged in the literature (such as Yoshino et al. [2020] and Asian Development Bank [2017]). Meeting this demand globally, and particularly in Asia and the Pacific, is critical not only to catalyze the national economies of the region’s developing member countries but to also improve the quality of life of its residents. However, the prevailing infrastructure investment gaps have put tremendous challenges before such countries to meet this demand solely through public money, and very often the public budget deficits that such large investments can entail are heavily debated. Zhang and Feng (2018) further confirm this investment gap for transportation infrastructure in Asia and highlight that the insufficient amount of infrastructure is one of the crucial bottlenecks. This investment gap can potentially be reduced with official development assistance (ODA). Kato (2018) historically reviews and discusses the policies, trends, and challenges of development assistance to transportation infrastructure in Asian developing countries, emphasizing the diversity in the nature of problems and the related assistance needs even among different countries in Asia. In a discussion related to such diversity, the author points out a fundamental approach to solve the transportation-related problems in four steps: understanding the prevailing condition, identifying the major issue to be addressed, setting up a goal/vision for improvement, and finally taking effective measures based on empirical evidence. Understanding these concepts, transport in Asia and the Pacific is commonly supported by development assistance plans. The supported projects, particularly those requiring large-scale investments and technology transfer, in the region’s developing countries still witness heavy and lengthy debates about their feasibility. There is a dearth of comprehensive evidence that can help in making the final decision.

High-speed rail (HSR) infrastructure is one such large-scale, long-term investment that has lately been at the center of these discussions
as it requires an enormous amount of consideration during its planning, design, construction, operation, and maintenance. The fast train service, incredible efficiency, pristine safety, comfort, dedicated track operation, and punctuality of the Japanese *shinkansen* (bullet train), the first HSR in the world, have fascinated the world since 1964, when the *shinkansen* began operating along the famous Tokaido belt cities of Tokyo and Osaka in Japan. In addition, the impact of this service on Japan’s economy, land use, and the concentration of people revealed a new dimension of how the world could envisage railways to improve regional connectivity. Followed by Japan, active HSR development proceeded in Europe (for instance, the French TGV started in 1981, the Italian *direttissima* line started in 1977, the German InterCity Express started in 1991, and the Spanish Alta Velocidad Española started in 1992), and HSR development emerged as a regional development tool for policy makers, governments, and planners across the globe. The Republic of Korea; Taipei, China; and the People’s Republic of China (PRC) were the first economies in Asia to introduce HSR in 2004, 2007, and 2008, respectively. The PRC, despite being a new player in developing HSR, expedited its implementation and rapidly developed a dense network of over 20,000 kilometers, showing HSR’s large-scale success in Asia and also leaving behind all the countries that already had HSR in terms of network length. HSR has now been adopted or is planned to be adopted in nearly 20 countries, many located in Asia and the Pacific. The coronavirus disease (COVID-19) outbreak has changed the outlook of all transport systems, including HSR, and has further emphasized the urgent need for interdisciplinary research addressing the issues related to sustainable transportation infrastructure development in the post-COVID-19 era.

Motivated by the state of HSR, in 2018–2019, the Asian Development Bank Institute (ADBI) hosted a conference called Spillover Effects of High-Speed Rail and Quality of Life in November 2018 in Tokyo, Japan, and five special sessions on transport and quality of life at the 15th World Conference on Transport Research (WCTR) during 26–31 May 2019 in Mumbai, India. Together, the conference and special sessions highlighted critical issues and delivered key messages on the broad research of spillover effects and quality of life implications of transportation infrastructure development, particularly HSR development. ADBI published selected papers that were presented during these conferences in the *Handbook on High-Speed Rail and Quality of Life* (Hayashi, Seetha Ram, and Bharule 2020) in March 2020. To continue to address the emerging research needs in the area, ADBI in association with the WCTR Society established the Special Interest Group on High-Speed Rail: Policy, Investment, and Impact (WCTRS-SIG: A4) and, despite the challenges posed by the COVID-19
outbreak, organized a three-part webinar series on HSR during May and June 2020 in order to advance the research activities.

Subsequently, under the auspices of this group and along with the support of the Chubu Institute for Advanced Studies at Chubu University, Japan, a 10-session virtual conference (co-chaired by Yoshitsugu Hayashi of Chubu University and KE Seetha Ram of ADBI) called “Transport Infrastructure Development, Spillover Effects, and Quality of Life” was held virtually during 12–16 October 2020. This conference also commemorated the 80th anniversary of Chubu University. Several other entities also supported the above activities. These include the Japan International Cooperation Agency; Ministry of Land, Infrastructure, Transport and Tourism (Japan); East Japan Railway Company; and National High Speed Rail Corporation Limited (India). This edited volume is a compilation of selected scholarly papers and summaries of the expert dialogues and discussions from the 10 thematic sessions of this conference. Over 70 speakers and about 150 registered attendees participated in the conference. These included various academics, policy makers, practitioners, and students, making it a high-level platform for showcasing cutting-edge policy research and exchanging experiences from around the world. The objective of this edited volume is to extend this journey and document the deliberations, discussions, and lessons from this conference. This volume aims to facilitate the enhancement of capacity through increased knowledge among various stakeholders involved in developing sustainable transport infrastructure in Asia. It presents concepts, cases, empirical evidence, and policy-focused research from around the globe for large transportation development, with a special focus on HSR, requiring huge investments and having stepwise, long-term effects on the economy. Each of the six parts of this edited volume also contains, in the form of key messages, a summary of the chapters in each part and the lessons learnt.

Among the many publications in the transport economics literature on transportation development and its multitude of effects, the unique feature of this edited volume is its focus on lessons from global HSR development rather than individual cases. Literature with this focus remains sparse despite some useful contributions (e.g., Lawrence, Bullock, and Liu [2019]; Albalate and Bel [2017]; Chen and Haynes [2015]). This edited volume adds to this literature by combining contributions from developing as well as developed countries with an aim to enhance the capacity for countries planning to develop HSR

projects. It is further worth mentioning that this edited volume is a continuation of the previous one by Hayashi, Seetha Ram, and Bharule (2020), published under the auspices of this same research group’s past activities and conferences. Reference to this past volume is hence also made where appropriate.

The next 24 chapters in this edited volume are divided into six parts, covering a wide range of pertinent topics (as also explained in preface): COVID-19 impacts on transport and logistics (Part I) as a special addition to the theme considering the pandemic’s pertinence in the current world; frontiers in the wider economic impacts and quality of life implications of transport (Part II); the impacts of HSR on other modes of intercity travel (Part III); transport–urban development interactions (Part IV); and research and innovation needs for large-scale transportation infrastructure projects like HSR in the developing world (Part V). Three discussion notes projecting some future research needs are presented in the last three chapters (Chapters 23, 24, and 25) in Part VI to set up an agenda for future work in this direction. This structure and flow should make the contents of this volume convenient and easy for the use of readers from diverse backgrounds of policy making, planning, practice, consulting, and academia. Readers may select particular parts or chapters and utilize the contents depending on their needs and aims. Readers desiring to cover the entire volume may find it helpful to first go over the key messages and chapter summaries of each of the six parts to understand the details of the topics they cover, and then move to the chapters that are most interesting or useful to them.
References


PART I
Impacts of COVID-19 on Transport and Logistics
The coronavirus disease (COVID-19) pandemic is widely argued to affect and be affected by the transport sector to an unprecedented extent. Researchers in the fields of epidemiology and transport planning have been actively responding to the need to understand the causes and risks associated with the virus. However, the scale at which the COVID-19 pandemic has spread raises concerns about the timely consensus and acceptability of different findings from around the world. The pandemic also has had an impact, both directly and indirectly, on the economy, equity, and well-being. These impacts have been quite often mediated not only through the government response strategies to alleviate the spread of COVID-19 but also through the range of public behavior in adhering to the measures undertaken by governments across the world. Given that the infection trends show little sign of abating, even with vaccine rollouts, the business-unusual circumstances remain relevant and so does the unequivocal need for nonmedical COVID-19 countermeasures to continue safe, sustainable, and resilient livelihoods. Understanding this, the World Conference on Transport Research Society (WCTRS) established a COVID-19 Task Force with an aim to unveil the virus’s multitude of impacts and examine, devise, and improve measures adopted in transport policy worldwide. The task force also envisages suggesting how the findings can be generalized for future pandemics, including the likely waves of COVID-19 that (some parts of) the world may experience. To contribute to the task force’s efforts to

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1 With contributions from James Leather (Asian Development Bank), Cheng-Min Feng (National Chiao Tung University), Yacan Wang (Beijing Jiaotong University), Huiyu Zhou (Beijing Jiaotong University), Hitomi Nakanishi (University of Canberra), Holger Dalkmann (Sustain 2030 and High Volume Transport [HVT] Program), and Senathipathi Velmurugan (Central Road Research Institute). Partly drawn from the deliberations and discussions held at the session titled “Impacts of COVID-19 on Transport” held on 12 October 2020 at the ADBI-Chubu University Conference (virtual) on Transport Infrastructure Development, Spillover Effects, and Quality of Life, and at the International e-Conference on Pandemics and Transport Policy (ICPT2020) held 7–11 December 2020. The authors acknowledge the contributions from participants of these sessions.
build an international forum of experts, a session of the ADBI-Chubu University conference was jointly organized aiming to discuss country reports about the impacts of a variety of COVID-19 measures adopted globally, their short- and long-term implications, and the lessons learnt. This session, in particular, marked one of the first few panel discussions organized by the task force and included scholars from the People’s Republic of China (PRC); Taipei, China; India; Australia; and the United States. The panel also discussed the responses in the context of low-income countries (Dalkman 2020). Several speakers during this session noted that the experiences of the 2003 severe acute respiratory syndrome (SARS) epidemic helped the PRC and Taipei, China respond swiftly to the COVID-19 outbreak (Zhou and Wang 2020; Feng 2020). Hence, by disseminating the lessons learned in the initial response to the COVID-19 pandemic, policy makers and transport planners can be better prepared to implement evidence-based responses to reduce infections. A key consideration for all countries that the session chair highlighted is that “current and near-future potential impacts must be addressed in a comprehensive and seamless way,” and transport policy must be integrated with national COVID-19 prevention strategies (Zhang 2020). This requires not only coordination between different sectors but also cooperation between different levels of government and between the people and the government.

To continue and expand this panel with more rigorous consideration of the pertinent issues that the task force had to address, a sequel e-conference focused on pandemics was organized, namely the International e-Conference on Pandemics and Transport Policy (ICPT2020). This forerunner conference was the first pandemics-related conference in the field of transportation. Around 60 presentations represented the state of the art and reflected the state of the practice at the time of the conference. In service of these monumental tasks, we attempt to summarize, in this first part of this edited volume, the extensive research findings and policy recommendations presented in the conference and collated through other platforms. Three chapters, comprising this first part, are refined from the presentations of the authors of the invited papers who participated in the ADBI-Chubu University conference (held virtually during 12–16 October 2020).

Chapter 2 by Zhang et al. summarizes the findings and policy recommendations from the forerunner, ICPT2020, on how transport policy can be designed to prevent the spread of COVID-19. The research presented includes surveys and analyses based on big data and open data, collaborative research between transport and public health researchers, innovative policy making methodologies, cross-country comparisons of policy measures, and immediate measures and long-term strategies.
The chapter discusses the public health risks associated with transport and covers the findings on measures in the areas of air transport, public transport, and active transport. The chapter also covers the analysis of behavioral policies, tourism policies, social distancing measures, and other nationwide policy responses and provides evidence-based evaluation of policy effectiveness. Finally, the authors discuss the “new normal” and provide recommendations from the WCTRS COVID-19 Task Force on further nonmedical countermeasures against COVID-19.

Chapter 3 by Johnson, Malik, and Circella discusses the impacts of the COVID-19 pandemic on the transport sector in the United States. The chapter comprehensively explains the timeline of the pandemic; the evolution in the number of cases during the various waves of the pandemic; policies enacted at the federal, state, regional, and local levels (especially the ones affecting transportation); and the observed changes in travel behaviors throughout the pandemic. Trends in air travel, car travel, the use of public transportation, shared mobility, and active travel are also examined. The use of various methodologies, including stated preference (SP) and revealed preference (RP) surveys, geolocated mobile phone data, travel demand models, scenario planning algorithms, and time series models are made to synthesize this evolving body of research for the United States. Further, building on the context, the authors summarize some of the research efforts that are currently underway to investigate the changes in travel behavior associated with the pandemic and discuss broader social changes, including the adoption of work-from-home solutions, online shopping, the reclaiming of public space for human-scale activity, and outdoor restaurants. Some concerns for the future of transportation in the United States, in case the pandemic results in increased auto ownership and vehicle miles traveled, are also presented. Finally, the temporary vs. longer-term impacts of the pandemic on transportation, planning, and the policy implications, including the difficulties associated with public transportation funding and traffic congestion, are concluded. This chapter constitutes a much-needed empirical effort to understand the effectiveness and impacts of the undertaken strategies for reducing COVID-19 infections, particularly the impacts on mobility and the well-being of different income groups. The in-depth insights that are discussed are crucial for evidence-based policy making on COVID-19 safe transport and mobility infrastructure moving forward.

Chapter 4 by Hayashi and Takeshita proposes the “mosquito hypothesis,” which uses the analogy of mosquito bites to explain how new COVID-19 infections can be estimated by taking into account the movement and activities of people. The authors argue that the process of COVID-19 transmission is analogous to the transmission of diseases
such as malaria by mosquitoes. A flying mosquito, moving freely, comes into the room, bites people, and the unlucky few are infected. In the case of COVID-19, uninfected people and infected people (especially asymptomatic people) move freely, just like the relationship between humans and mosquitoes. It is emphasized that encounters rather than the act of movement itself cause the spread of infection. With the help of this mosquito hypothesis, they explain the spread of the COVID-19 pandemic and check the effectiveness of one of the policies adopted to counter the pandemic in Japan. They study Japan’s “Go to Travel” campaign, which was implemented to promote tourism in Japan at a time when the number of COVID-19 infected people was not yet sufficiently low. Using the data for the number of overnight stays in a considered prefecture of Japan, the extent to which the “Go to Travel” campaign contributed to the spread of the pandemic is discussed. They conclude that the use of this hypothesis for examining the effectiveness of the measures to control the spread and to promote the economy through the factors of travel, activity, and protection is potentially useful for evidence-based policy making. This chapter, hence, provides an important insight of a novel hypothesis and establishes a direction for future work about the policy making process and evaluation of the measures taken during the pandemic.

In addition, some interesting findings and recommendations by speakers are:

- Information transparency by the government is crucial for promoting the trust of citizens and enhancing cooperation with government guidelines and countermeasures (Feng 2020).
- Education must continue on social distancing and maintaining COVID-19 prevention measures, as awareness decreases as cases decrease (Nakanishi 2020).
- Trust in public transport was found to have fallen, and social distancing measures are needed to restore trust in the safety of public transport. Infrastructural interventions, such as dedicated bus lanes to increase the frequency of buses while reducing each vehicle’s passenger load, can support this (Dalkman 2020).
- In countries such as India, where 80% of the workforce is in informal work, access to affordable public transport is still crucial. Although in the long term there can be measures such as working from home or staggered working times, in the short term, public transport needs to be made COVID-safe (Velmurugan 2020). The importance of COVID-safe public transport is further highlighted by the demonstrated correlation between the economy and mobility. Mobility restrictions should
be balanced against economic considerations, such as business openings and the informal workforce, so that the economy can quickly recover post-pandemic (Ukkusuri, Yabe, and Seetha Ram 2020).

• Due to the increased demand for food delivery, hospitality workers shifted into food delivery jobs. However, as most workers are immigrants or international students, these delivery drivers are unfamiliar with traffic rules and thus increase the risk of road accidents (Nakanishi 2020).
References


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2.1 Introduction

According to the COVID-19 Dashboard by the Center for Systems Science and Engineering at Johns Hopkins University, the total global infections confirmed were more than 214 million and total deaths were more than 4.46 million as of 26 August 2021. Seven countries have more than 100,000 deaths and three countries have more than 400,000 deaths (United States: more than 630,000; Brazil: more than 570,000; India: more than 430,000). Looking at deaths, COVID-19 is the ninth most serious pandemic in history and the third most serious pandemic after entering the 20th century (the first was the flu pandemic (40–50 million deaths) in 1918–1919, and the second was HIV/AIDS (25–35 million deaths) since 1981).\(^3\)\(^4\) COVID-19 has imposed a variety of impacts

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\(^3\) https://www.weforum.org/agenda/2020/03/a-visual-history-of-pandemics (accessed 1 January 2021).

on human society. Unfortunately, lessons from human history have not been well learned. Historically, there have been more pandemics after the 20th century than in both the 18th and 19th centuries combined. After entering the 21st century, five major pandemics (severe acute respiratory syndrome [SARS], swine flu, Middle East respiratory syndrome [MERS], Ebola, and COVID-19) occurred, while there were four (Spanish Flu, Asian Flu, Hong Kong Flu, and HIV/AIDS) in the 20th century. Even now, HIV/AIDS and MERS still exist. Pandemics are expected to occur repeatedly in the future.

The transport sector has also been impacted seriously by the COVID-19 pandemic on the one hand, while, on the other hand, it is unclear how transport has contributed to the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causing COVID-19. Therefore, questions remain about how transport policies can help prevent the further spread of COVID-19. In order to fight against COVID-19 and prepare for future pandemics, it is important to exchange research findings about what is known, what is unknown, what should be done, and what should not be done, about COVID-19 and other pandemics. Experts from the transport, logistics, supply chains, regional development, urban planning, and tourism sectors from different parts of the world must pool their knowledge. Under such circumstances, the World Conference on Transport Research Society (WCTRS) COVID-19 Task Force organized the International e-Conference on Pandemics and Transport Policy (ICPT) on 7–11 December 2020. This chapter summarizes and discusses the key issues, the major research content, key findings, policy recommendations, and important research issues derived from the conference.

### 2.2 About the International e-Conference on Pandemics and Transport Policy 2020

In April 2020, the WCTRS COVID-19 Task Force was formally established. It aims to investigate the impacts of COVID-19, to clarify how society had prepared for such a pandemic, to reveal what measures society is currently taking to fight against this pandemic, to suggest what society should do after this pandemic, and how to generalize the findings from the above tasks to tackle the next waves of COVID-19 and future pandemics. Since April 2020, the task force members have made various efforts, including writing reports on specific countries and topics, conducting literature reviews and surveys, and making policy recommendations, among others. There are also other researchers working on similar topics.

Two special issues are scheduled to be published in the journal “Transport Policy” in 2021, titled “Impacts of COVID-19 and Other
Pandemics on the Passenger Transport Sector and Policy Measures” and “Impacts of COVID-19 and Other Pandemics on the Freight Transport, Logistics and Supply Chains, and Policy Responses”. A handbook titled “Transportation Amid COVID-19 and Pandemics: Practices and Policies” is further scheduled to be published in 2021 as one of the Elsevier WCTRS series. It aims to summarize the clarified evidence, policies, and their effects, which will be useful to tackle the next waves of COVID-19 and to be inherited by the next generations.

Thus, to achieve the abovementioned aims and publications, it was necessary to share up-to-date research and practices by gathering experts from all over the world, as early as possible. With such a motivation, the WCTRS COVID-19 Task Force organized the International e-Conference on Pandemics and Transport Policy (ICPT2020). This was the first pandemic conference in the transportation field. There were more than 60 presentations (authored by more than 140 researchers from all over the world) made during the conference, representing the state-of-the-art and reflecting the state-of-the-practice at the time of the conference.

The ICPT2020 included the following 10 sessions, each of which included six presentations: (1) public and air transport, (2) risk-sensitive social distancing and design; (3) behavioral policy in passenger transport; (4) accessibility, lifestyle changes, and equity; (5) spatial relationship and behavior; (6) change in urban transport and sustainability; (7) policy interventions in transport and tourism; (8) social distancing policy; (9) new normal and long-term impacts; and (10) nationwide policy responses, in addition to the opening and closing sessions.

### 2.3 Risks of Pandemics and Their Association with the Transport Sector

Risks of pandemics via person-to-person transmission can be defined as follows, where Pr is an abbreviation of probability.

\[
\text{Risk of pandemics} = Pr(\text{viruses}) \times Pr(\text{intensity} | \text{viruses}) \times Pr(\text{Transmission} | \text{Intensity}) \times Pr(\text{Exposure} | \text{Transmission}) \times Pr(\text{Consequency} | \text{Exposure} \times \text{Transmission}) \times \text{Consequences (infections, deaths, economic/social impacts, etc.)}
\]

where,

\[
Pr(\text{Exposure} \times \text{Transmission}) = Pr(\text{Trip making} | \text{Activities})
\times Pr(\text{Activities} | \text{Needs in life})
\]
Generally speaking, the risk of an event is the product of the probability of event occurrence and the expected consequences of the event. In the case of a pandemic (via a virus), infections, deaths, economic and social impacts, among others, are examples of the expected consequences, and defining the probability of event occurrence needs to further reflect the intensity (e.g., frequency, spatial coverage) of the virus, person-to-person transmission, and exposure of people to the virus. Probabilities of transmission of and exposure to the virus may differ between trip making and activity participation, which are derived from needs in people’s lives. Trip making is derived from activity participation. Probabilities of transmission of and exposure to the virus may further differ across transport modes (within vehicles and on the platform) and across activities (types and locations as well as the environment). The density and duration of person-to-person contacts are expected to be positively associated with risks of infections, which are expected to be influenced by what kinds of physical distancing measures are taken while traveling and during activity participation. The transmission and exposure probabilities in transport may be lower than that in activity participation; however, transmission and exposure in transport and activity participation are not independent of each other, because transport is responsible for moving people from one place to another for participating in activities. Even assuming that the transmission and exposure probabilities are zero, transporting more people obviously increases the population participating in activities at destinations, which may lead to more infections at destinations (even assuming that the infection probability at destination is unchanged or reduced via effective physical distancing measures), and those infected persons at destinations may be transported back to their origins within the incubation period.

Related to the above argument, Zhang et al. (2020b) and Yoshida et al. (2020) first empirically confirmed that infection cases in Japan were strongly associated with transport accessibility, by estimating a gravity model based on prefectural-level data. Then, simulation analysis results indicate that increases in infections obviously result from increases in human mobility. This implies that under the current situation, any policy measures encouraging active human mobility will worsen the COVID-19 pandemic, at least in Japan. On 22 July 2020, a “Go To Travel” campaign started, and another campaign “Go To Eat” started on 1 October 2020. It is true that these two campaigns resulted in more active human mobility, as expected by the campaigns. The above analysis results obviously suggest that these two campaigns were not irrelevant to the peaks.

Without transport, face-to-face contact between persons at different physical locations would not be possible. In other words, the best way
to control the pandemic is to cut the connections between persons at different locations. Thus, transport policy measures should not be ignored as a core part of general pandemic measures.

Actually, the risks in transport are diverse, from international to urban transport and logistics, and from infrastructure to economy and daily life, as shown below.

1. Airline flights can transport infected passengers from one side of the world to the other, within half a day.
2. Passengers in crowded public transport are more at risk of infection than automobile users.
3. It may be recommended for citizens to temporarily shift from public transit to cars to avoid the risk of infection. However, this may become a permanent change in transport behavior even after COVID-19 has been eradicated.
4. When gathering for events, people may be cautious about crowd density in the event venue but may not recognize the high risk of infection during travel to the gathering.
5. Reduction of passengers may bankrupt the transport and tourism industries, thus worsening the regional and national economy.
6. Infections among operational staff and reduction of transport services will lead to the collapse of supply chains and consequently lower the productivity of industries.
7. Lockdowns have increased pressures on the supply chains of vital goods for medical care and for citizens’ daily life.
8. There is increasing evidence of health risks to staff providing essential transport services.
9. In developing countries, paratransit and other informal transport services (e.g., tuk-tuk, jeepney, rickshaw) are very popular because of their low fares and flexibility, but both passengers and drivers face high risks of infection because drivers are poorly equipped and operate in close proximity to passengers.

2.4 Risks of Using Public Transport

Motivated by the review by Corazza et al. (2020), we further reviewed the existing literature on the risks of using public transport and summarized the evidence below.

1. Focusing on bus travel in the People’s Republic of China (PRC) between 21 January and 6 March 2020, Chen et al. (2020) found that among 2,147 persons with close contact with infected persons, 6.15% (132 persons) were infected, among
which 11.91% (15 persons: 0.7% of 2,147 persons) used the same transport vehicles.

(2) Concerning railway transport, Hu et al. (2020) revealed that the attack rate in train passengers on seats within a distance of three rows and five columns of the index patient varied from 0% to 10.3% (95% confidence interval [CI], 5.3%–19.0%), with a mean of 0.32% (95% CI, 0.29%–0.37%).

(3) In France, among 2,830 clusters, 33 clusters (1.2%) were transport (plane, boat, train) (Hebergementwebs 2020).

(4) According to the European Centre for Disease Prevention and Control (ECDC 2020), in Sweden, taxi drivers are at the highest risk among all occupations, with a relative risk of being diagnosed with COVID-19 that was 4.8 times higher than in all other professions (95% confidence interval 3.9–6.0) followed by bus and tram drivers (RR 4.3, 95% CI 3.6–5.1).

(5) In the United Kingdom, male taxi drivers and chauffeurs and bus and coach drivers were found to have statistically significantly higher mortality rates from COVID-19 than the general male population (65.3 deaths per 100,000 males vs 39.7 per 100,000 men for the general male population).

(6) In New York, being older was a risk factor for COVID-19 mortality in transit workers, with those 60–69 years old working in the transport sector having higher mortality rates than adults of a similar age working in other sectors.

Thus, there are serious infections related to transport, especially at the early stages of the pandemic, even though cases are very limited. Caution must be taken when using public transport. At the same time, evidence should be further accumulated for rebuilding the confidence of using public transport post-COVID-19.

2.5 Air Transport and Logistics

Adrienne et al. (2020) made an initial attempt to examine the impacts of COVID-19 on aviation by revealing massive groundings of aircraft (more than 5,000) in Europe between February and April 2020. It is argued that the integrity of the airframe and engines should be protected by technical and physical interventions such as cycling air-conditioning; ground engine runs; switching on electrical systems; turning the tires to prevent flat spots; covering probes, engines, and hatches to prevent foreign object damage ingress, under careful coordination between airlines and airports.
Focusing on Spain, ranked second in the world in terms of international tourism earnings and international tourism arrivals, Gundelfinger, Fernández, and Millán (2020) revealed a statistically significant negative relationship between airline ticket prices and the infection cases per 100,000 inhabitants in destination region in economy classes of direct flights from international origins to the top five Spanish tourist destinations in June 2020 when daily infections were 326 on average. Gundelfinger, Fernández, and Millán emphasized the importance of rebuilding confidence in the safety of tourist destinations for recovery of the tourism development and also argued the necessity of examining how COVID-19 alters perceptions of particular destinations suffering from high infection cases.

The airline sector, and aviation in general, is possibly the sector that has suffered most from the COVID-19 pandemic. According to Cifuentes-Faura and Faura-Martinez (2020), more than 130 countries have introduced measures of travel restrictions since the outbreak of COVID-19 began. Airlines have stopped operations of many flights because of government restrictions and quarantine requirements. The International Air Transport Association (IATA) estimated that 25 million jobs serving air travel are at risk. At the height of the pandemic, in April 2020, global air transport was approximately 95% below the previous year’s levels. With the relaxation of restrictions, passengers have gradually begun to travel and to discover that flying is a very different experience from what it was previously. Load factors were estimated to be 62.7% and as a result, worldwide air passenger revenue was estimated to drop to $241 billion in 2020. The total amount of cargo transported was estimated to decrease by 10.3 million tons compared to 51 million tons in 2019. After the peak of the pandemic in Europe in April 2020, air traffic was closed to contain it. However, it seems that low-cost carriers, despite the large drop in occupancy, continue to lead in terms of the number of flights operated and ticket sales. On 13 May 2020, the European Commission proposed to restore freedom of movement in a gradual and coordinated way within the European Union. The economic recovery of the airline industry after the COVID-19 pandemic is a complex task. The restrictions imposed by governments in different countries are disparate, and have not contributed to a lower incidence of coronavirus cases either. Several airlines have gone bankrupt and closed down permanently as a result of the crisis. To curb this situation and to be able to revive some airlines, governments are offering aid packages. Companies should take an active role in tasks such as helping to produce or transport the medical supplies needed to deal with the pandemic, or proactively demonstrate the safety procedures they have put in place to ensure the safety of passengers and employees. Companies,
suppliers, manufacturers, and lessors should also work closely together to anticipate potential recovery scenarios and ensure they have the flexibility to expand fleets when necessary. This may include resolving payment disputes quickly and without recourse to the courts.

In the ICPT2020, there were only a few presentations about freight transport and logistics. The study by Vanelslander (2020) was one of them. He revealed various immediate impacts in terms of significant declines in global and regional trade and port calls (based on external data sources), freight transport, ship calls, and port traffic as well as countermeasures in different countries (based on the author’s own survey). The countermeasures include the extension of payment deadlines of port dues, exemption from payment of port dues, extension of payment deadlines of concession fees, exemption from payment of concession fees, extension of payment deadlines of general taxes, exemption from payment of general taxes, cheap loans, and additional subsidies. Vanelslander (2020) further summarized major ship crew measures by international agencies and especially emphasized the issues of seafarers, because many seafarers have remained onboard even though their contracts have expired, and a similar number of seafarers urgently need to join ships to replace them. International agencies called on governments in May and June 2020 to recognize and/or designate seafarers as key workers and facilitate crew changes. Especially, the International Maritime Organization (IMO) issued a 12-step plan (six steps for joining a ship and six for leaving a ship) and the corresponding health protocols to 174 member states, about how to free seafarers from the COVID-19 lockdown.\footnote{https://wwwcdn.imo.org/localresources/en/MediaCentre/HotTopics/Documents/MSC%201636%20protocols/MSC.1-Circ.1636%20-%20Industry%20Recommended%20Framework%20Of%20Protocols%20For%20Ensuring%20Safe%20Ship%20Crew%20Changes%20And%20Travel.pdf (accessed 3 January 2021).}

The 12 steps are taken with respect to the place of ordinary residence, airport, aircraft, seaport, and ship. Vanelslander concluded that impacts on port volumes were observed, but no port really had to shut down; recovery will take some time; seafarers were totally “forgotten”; and the pandemic should be taken as an opportunity for innovation and digitalization.

### 2.6 Public Transport

Corazza et al. (2020) presented an overview of the literature on infections and clusters in the transport sector and only found a limited number of scientific papers. Existing studies have mainly focused on coaches and
trains rather than buses. The available literature suggests that transport clusters are small, but not that small if compared to other crowded environments (for example, kindergartens and correctional facilities) where either community time is longer or contacts might be stricter than among passengers and drivers. They summarized three types of public transport measures: reduce (e.g., seats availability reduction, capacity reduced, supply decreased, and even ceased), arrange (increase of service volume, opening windows, wearing masks, sealed driving area), and avoid (fostering touchscreen operation, automatic operation of button-operated doors). They further found that public transport measures have not been well prepared, relevant investments are limited, there are more restrictions than incentives, and there was poor communication with the public.

By implementing a panel survey in the United States, Parker et al. (2020) found that from the start of the pandemic to October 2020, those affected by transit cuts (17%) made more purchases to improve their active transportation options and used walking as a mode of transport on more days per week than those unaffected by transit cuts. From the start of the pandemic to August 2020, those affected by transit cuts made more purchases to improve their motorized transportation options than those not affected by transit cuts. While some have made purchases to increase their active and motorized transport options, they have not recovered the number of trips in the way those unaffected by transit cuts have. Those affected by transit cuts are more likely to have no household vehicle access, to have decreased income since the pandemic, to be caring for an elderly or disabled person, to be people of color, and to be female. These equity issues should be paid sufficient attention in policy making. Looking at the impacts of transit cuts on travel activity, Parker et al. (2020) estimated a panel negative binomial regression model and showed that being significantly affected by transit cuts post-COVID-19 is associated with a 12.6% decrease in weekly trips. A panel Tobit model was further estimated and it is observed that being minorly or significantly affected by transit cuts post-COVID-19 is not associated with a change in total or average distance traveled per week.

Król and Taczanowski (2020) presented an important report on Central and Eastern European countries, which belong to middle-income economies and have relatively strong public transport systems. In Central and Eastern Europe, public transport operators have reacted to governments’ decisions on closures of schools, shops, and restaurants, etc., and lockdowns (nonessential travel restrictions) by stopping the operation of peak-time lines and school lines and reducing operation routes by adopting weekend timetables during the entire week and special timetables with limited routes. Public transport operators have
also been proactive by stopping ticket sales by drivers, closing front doors of vehicles, and opening all doors at stops (door opening buttons kept inactive). During the pandemic, Poland limited the number of public transport passengers to 50% of the number of seats, Romania reduced the number of trains by 43%, and Slovenia and Croatia stopped the operation of the entire public transport systems (rail, buses, and urban transport). Central and Eastern Europe in the second quarter of 2020 experienced a 40%–70% decline in railway ridership, while urban transport reduced to 10%–30%. Król and Taczanowski (2020) identified four factors causing a decline in the ridership of public transport in Central and Eastern Europe: restrictive actions of governments (lockdowns), fear and risk of infection aversion, not enough capacity (social distancing implies less crowded transport means), and not enough revenues in fare boxes (cutting down services for economic reasons). Król and Taczanowski (2020) argued that the wait-and-see approach is wrong, in order to stop “bad habits” (e.g., increasing dependency on cars), and it is necessary to accumulate more evidence and expert knowledge and inform the public that public transport is safe. It is also important to ensure the short-term viability of public transport.

Focusing on railway passenger transport in Belgium, Voes et al. (2020) collected data from 82,961 respondents in an online survey. They observed that train passengers mainly switched to cars, tram passengers mainly switched to active modes, and bus passengers switched to both the car and active modes. These changes are probably related to the fact that teleworking has risen during the pandemic, and train passengers are more prone to work from home, even though this was not analyzed.

Fukumoto, Ihara, and Isobe (2020) examined the impacts of COVID-19 on buses in local areas of Japan and confirmed that the decline in intercity buses was much larger than in intracity buses (about 50%). The largest decline was observed in April and May 2020 when a state of emergency was declared over the whole country: the decline was more than 80% for intercity buses and about 50% for intracity buses. They reported that more than 80% of people perceived that using public transport was risky. The share of bus trips in October 2020 recovered to 80% for intracity buses and 40% for intercity buses. As protection measures for bus transport, daily body temperature checks of bus drivers, disinfection of vehicles, provision of disinfection liquid, and ventilation were introduced. As measures by the central government, local buses were supported by direct subsidies to operating loss and infection protection measures and a special grant for regional revitalization. As for local governments, only 23% provided support to public transport, mainly for business continuity, where local buses and taxis are two main public transport modes.
Focusing on Wuhan, PRC, Dou et al. (2020) investigated changes in travel behavior before and after the pandemic in terms of travel time, number of daily trips, and peak hours, by using smart card data between March and June 2020. Wuhan was fully locked down on 23 January 2020 and the lockdown was lifted on 8 April 2020. Before the end of the lockdown, 177 bus lines resumed on 25 March and six metro lines on 28 March. After the lockdown, all public transport services have been re-opened since 22 April, 2 weeks after lifting the lockdown. Citywide COVID-19 testing started on 14 May and ended on 1 June. After these efforts, citizens’ lives have gradually returned to a new normal, as evidenced by the Dragon Boat Festival organized on 25–27 June 2020. Both aggregate analyses and modeling analyses indicate that the Wuhan public transit system is far from recovering from the influence of the COVID-19 pandemic (about 40% on weekdays and about 30% on weekends). This implies that it is not easy to rebuild people’s confidence in using public transport.

In India, the central government made a three-pronged post-COVID-19 strategy: short-term (within 6 months), medium-term (1 year), and long-term (1–3 years). In line with this strategy, to prevent further increase in car transport in the post-COVID-19 period, Advani, Senathipathi, and Seetharaman (2020) explored how to avoid adding unnecessary space to road networks by paying more attention to the roles of nonmotorized vehicles (NMV) and buses, where different population sectors are targeted. The authors empirically showed that NMV lanes should be prioritized as the most cost-effective measure, further supported by segregated bus lanes, on all major roads in the future.

Thailand is one of few countries which have well controlled the pandemic. Vichiensan and Hayashi (2020) summarized several key measures, including the temporary shutdown of portions of the public and private sectors, closures of the potential risk places, prohibiting activities in crowded places, requesting cooperation to stay at home, night curfew, travel restrictions, and public transport measures. Public transport measures include body temperature checks of users, disinfection of public transport facilities and vehicles, physical distancing at 1.5 meters, reducing capacity at the concourse and platform levels, reducing train capacity by more than 80%, and introducing the health code, “Thais Win” app, for check-in and check-out.

2.7 Active Transport

Targeting Tyne and Wear (with a population of about 1.0 million people) in the United Kingdom (UK), Burke, Bell, and Dissanayake (2020) revealed that during the pandemic, a larger increase in cycle flows was found mostly in coastal areas (mainly related to recreation) and a
smaller increase mostly at suburban locations, while city locations saw a decline in cycle flows (because of the closure of workplaces). The biggest reductions in cycling were on weekdays and during peak hours, while the biggest increases were on other days and periods. An increase in cycle flows took place several months before the UK announced an Emergency Active Travel Fund (EATF) of £250 million (or $335 million) on 9 May 2020. The EATF encourages local authorities to reallocate road space for significantly-increased numbers of cyclists and pedestrians and ensures that the increased levels of active travel (walking and cycling) can occur within social distancing guidance (2 meters). People’s early responses may reduce the effects of the EATF, and a lack of pre-consultation of the EATF has been criticized. In a coastal pop-up lane case study, it was found that reallocating road space to cyclists where they are already segregated from car traffic did not appear to have a substantial effect on the volume of cyclists.

By collecting data from 804 respondents from all over Bangladesh, Zafri et al. (2020) found that during the pandemic, 56% of respondents increased walking and 45% increased cycling, while about 60% reduced their use of public transport and 45% reduced shared transport. It is further revealed that the perception of risks about COVID-19 transmission in different travel modes plays an important role in the shift of modes. It is argued that the COVID-19 pandemic has presented a unique opportunity to increase the modal share of active transport, and policy measures should be targeted at removing the barriers to active transport use and encouraging its increased usage in the context of Bangladesh.

2.8 Behavioral Policies

2.8.1 Behavioral Observations

Forscher, Deakin, and Shaheen (2020) made preliminary analyses of the substitution and complementary effects of e-commerce orders on in-person trips based on a small-scale sample survey and revealed that e-commerce substituted trips for nonessential nonfood, and complemented trips for food (particularly for groceries). It is also observed that the resulting pick-up caused by e-commerce also increased.

Morita and Nakamura (2020) implemented a survey of behaviors and attitudes of 1,600 respondents living in the five largest cities in Japan and found that more than 10% of respondents’ income between March and November 2020 reduced to 70%–90% of the 2019 level, more than 5% reduced to 40%–60%, and more than 7% reduced to 30% or lower. Temporal differences in income changes are minor.
The largest percentage (more than 70%) of respondents reported that post-pandemic social changes made them anxious, while only about 10% of people thought that post-pandemic social changes would provide them hope. An obvious declining trend was found with respect to the sense of trust, mutual help, and solidarity in communities, governments, and society as a whole.

Supported by a testing–tracing–treatment (3T) strategy, the Republic of Korea had successfully controlled the outbreak of SARS-CoV-2 by May 2020 (Kim, Kim, and Kim 2020). Unfortunately, two more peaks were observed in August 2020 and late December 2020. Targeting the Daegu metropolitan area, showing the most severe infections at the beginning of the outbreak in the Republic of Korea, Kim, Kim, and Kim (2020) investigated the changes in the demand for urban public transport and confirmed a large reduction in comparison with that in the same period of 2019. They further investigated travel mode choices influenced by social distancing practices as well as attitudes toward safe urban transport by implementing a questionnaire survey. They revealed that more than 90% perceived that the virus SARS-CoV-2 is very dangerous and more than 70% reported that the virus is scary. Several key aspects of dysfunctional anxiety were further explored. Such concerns about safety during the use of transport systems led to an extremely high preference for passenger cars (mainly for commuting and shopping), a relatively high preference for bicycles, and a very low preference for public transport. The importance of rebuilding confidence in using public transport is emphasized via proper risk communication measures.

Li, Sun, and Tan (2020) built a conceptual model of infection spread by incorporating the influence of people’s social networks, where an infection model with social networks was treated as a control group. Such a modeling tool is useful to figure out what kinds of policy measures should be taken; however, it is necessary to collect evidence of infection risks related to different types of social networks by associating them with activity locations and transport routes to connect members in social networks.

### 2.8.2 Risk Communication and Behavioral Interventions

Based on a nationwide life-oriented retrospective panel survey implemented in Japan at the end of March 2020, Zhang, Alhakim, and Ding (2020) revealed the importance of designing risk communication differentiated to different population groups for encouraging behavioral changes through effective interventions. It is further shown that governmental policies are the main triggers to change people’s behavior,
among which school closures affected a large group of people more than any other policy. People were aware of the risks of travel, whether domestic or overseas travel, in transmitting viral infections. Masks, disinfectants, and emergency foods became an integral part of the daily necessities. While trying to reduce the use of public transport, people relied more on their private cars, bicycles, and walking. Many behavioral changes occurred simultaneously. Spending more time at home increased the housework time and amount, leading to more conversation between family members. Eating outside and shopping at stores were replaced with online shopping and online-telephone food ordering. Spending more time at home led to spending more time on household activities such as chores, social networking services (SNS), and hobbies, thus increasing sleep time. All these may affect people’s productivity. Staying at home decreased their physical exercise time and frequency, which increased household energy consumption. Staying at home not only resulted in people’s physical and mental tiredness, but also negatively affected their relationships with friends and relatives.

Using retrospective panel data (2,643 respondents residing in different parts of Japan) collected by the Mobilities and Urban Policy Lab of Hiroshima University in November 2020, Ding et al. (2020) built a dynamic Scobit model to represent behavioral changes in daily life activities and trip making between April and September 2020, in line with the life-oriented approach. Ding et al. quantified the roles of risk communications in containing and mitigating the impacts of COVID-19 by examining a large number of factors related to risk perception, reliability of information resources, and attitudes to policymaking and stakeholders. Their findings suggest that governments (especially local governments) should build an authoritative information management system for informing the public about how to contain and mitigate the spread of the virus, especially via SNS and the information channels of medical institutions. Governments should reinforce the reliability of information from experts. Local governments should make efforts to prevent the spread of fake news via SNS. Large-sized municipalities should promote flexible working arrangements such as staggered commuting and flexible working hours. Governments should support people with low education levels to telework and telestudy. Governments should allow people to timely access the up-to-date information of infections at various daily facilities for inducing people to reduce their daily trips.

Aimed at restoring the use of public transport, Kaplan (2020) developed a behavioral framework for capturing major barriers and motivators in returning to the post-COVID-19 new normal, by referring to the protection motivation theory. Using data with 850 users of public transport in Israel, collected 3 months after lockdown, Kaplan
estimated a structural equation model and found that fear of infection negatively affects the use of public transport, while organization trust shows a positive effect. Social distancing and mask-wearing measures induce higher fear of infection from the use of public transport. Denial (measured in terms of self-exemption beliefs) is positively associated with the use of public transport under the pandemic. It is concluded that encouraging transit use after the pandemic depends on organizational trust and decoupling self-protection from fear of using public transport.

Zhang and Pan (2020) examined work patterns and commuting travel during the pandemic in the PRC by using data from a questionnaire survey with 1,540 respondents in Shanghai. Teleworking could reduce the use of public transport, which is helpful to curb the spread of the virus and reduce road congestion during rush hours. It is found that compared with respondents working at home, respondents who have to commute are relatively older and essential workers, have a lower income, and live relatively far from the center area of Shanghai. These population groups may be socially and spatially excluded during the pandemic. During the lockdown, although the average daily passenger volume of metro users was reduced substantially, very few respondents reduced the use of the metro for commuting. People living in suburban areas have poor access to metro stations and many of them cannot afford a car, but they have to take the metro to commute for a long time (usually longer than 45 minutes). Thus, the metro plays an irreplaceable role in undertaking medium- and long-distance travel. In addition, people working in medical care, transportation, administrative institutions, and manufacturing industries need to commute the most. Their jobs are important to avoid the collapse of urban services operation during the lockdown. How to provide a safe and secure commuting environment should be given a higher priority in transport policy making. It is necessary to increase the frequency of public transport routes to and from hospitals, industrial parks, transportation junctions, logistics hubs, and other important places. Governments could also provide them with monetary support to let them commute by taxi, or provide some customized shuttle buses. Zhang and Pan further analyzed work efficiency and revealed that the length of commute time does not significantly affect work efficiency. For people who work entirely from home, living alone or living with family does not matter, but whether having an undisturbed space or not is the key for guaranteeing work efficiency. If a person has to take care of a baby, flexible working will reduce their work efficiency.

Wang et al. (2020) implemented a questionnaire survey and collected data from 3,721 households living in several major cities in Canada, by focusing on the period between the first and second waves of the pandemic in Canada. They found that the automobile gained extra
popularity, and the driving distance was long (from 6.4 kilometers to 11.6 kilometers). The transit modal share decreased from 17.3% to 7.7%, while the walk and cycle modal share increased from 9.4% to 15.0%. On a particular weekday, more than 60% of the respondents stay at home. They observed a diminishing morning peak period (6 am to 9 am); however, they also observed a spread afternoon peak period starting from 12 pm. People were spending more time shopping (from 84 minutes to 93 minutes) and also more time for other out-of-home discretionary activities (from 98 minutes to 141 minutes). Based on the above analyses, they made several policy recommendations to curb COVID-19, including (i) to increase the frequency of surface transit to allow appropriate social distancing on board; (ii) to maintain proper transit services for commuters working in industrial zones; (iii) to keep working from home until the end of the pandemic; (iv) to keep practicing virtual education for at least post-secondary institutions until the end of the pandemic; (v) instead of just closing all malls in a subregion (reduction in capacity and revenue), to manage the demand of shopping activities across all shopping facilities across the entire region evenly; and (vi) to pay attention to health and safety compliance at parks, conservation areas, forests, and golf clubs. As policy recommendations for a “new normal”, they suggest maintaining a positive image for transit services, preventing permanent demand loss, and calling for planning consideration in terms of extra momentum gained by auto-dependency during the pandemic.

Alhajyaseen (2020) focused on the case of Qatar with more than 140,000 infection cases and summarized COVID-19 measures into four phases: Phase 1 (maximum of 20% work from workplace, 30% shops inside mall), Phase 2 (maximum of 50% work from workplace, low capacity restaurants), Phase 3 (maximum of 80% work from workplaces, inbound flights from low risk countries), and Phase 4 (public transport with maximum 50% capacity, schools with a maximum of 30% attendance). Alhajyaseen implemented a questionnaire survey and collected valid data from 404 respondents. Empirical analyses suggest that policy makers may take this as an opportunity to promote flexible work and business for reducing overall traveling activities and congestion and indirect costs for businesses, and should learn lessons from the ongoing pandemic for smartly handling the next wave of the COVID-19 pandemic and future pandemics.

2.8.3 Importance of Social Inclusion Policy Making

The current pandemic has brought about various social equity issues. By referring to existing studies, Carrasco (2020) first showed that ratios of teleworking increase with income, that remarkable gaps in teleworking
exist between low-income groups and high-income groups, and that workers in a household with more members are more likely to work away from home. Then, a panel model was estimated to examine and confirm the effects of quarantine measures taken in different phases of the pandemic in some cities of Chile. It is concluded that equity issues have been acknowledged but overlooked; teleworking seems to be too skewed toward high income groups; current trips and modal split will involve important future challenges to preserve transit’s safety and attractiveness; and there is a worrisome trend that sanitary measures have a diminishing effect on mobility.

2.9 Tourism Policies

Targeting the tourism sector in the PRC, Zhang, L. et al. (2020) first summarized key policies made by the central government over time. On the same day when Wuhan was locked down (3 January 2020), the PRC suspended all tourism activities by following national policies on pandemic control. Financial support was provided to enterprises on 1 and 2 February 2020 when stricter national policies were issued, and a reduction or exemption of taxes to enterprises was added to policy menus on 6 February. After these efforts, the PRC first allowed 21 tourism destinations to reopen on 19 February and then permitted the reopening of museums on 26 February. After enforcing the training and management of tour guides on 27 February, the PRC further decided to orderly reopen other tourism destinations from 13 April and issued guidance on 30 April for tourism destinations to prepare for the golden week holidays in May. With these efforts and preparations, the first peak of tourism recovery for the whole country was observed during the golden week in May. Efforts continued. On 24 June, tourism demand control was implemented first by limiting the number of tourists, making reservations, and arranging visits in different periods, and on 14 July policies were made for enlarging the work resumption of tourism, developing new models of the tourism industry, encouraging the tourism market, and increasing job opportunities. Furthermore, policies of rural tourism recovery were issued on 17 July, policies about the work resumption of tourism agents on 20 July, and policies about the jobs and business of rural migrant workers on 11 August. For preparing for the double-holiday period (1–8 October) of the National Day and Moon Festival in October, a guidance for tourist destinations was announced on 18 September. As a result, the second peak of tourism recovery was observed during the double-holiday period. Among the top 10 provinces ranked by tourist arrivals and revenue in this period, three provinces (Henan, Jiangxi, and Fujian) showed larger numbers of tourists even than those in the same period of 2019.
Zhang, L. et al. (2020) further conducted a content analysis of tourism policy responses to COVID-19 and tourism recovery, from both the demand and supply perspectives.

Concerning the demand side, the number of keywords related to national tourism policies after 1 May (351 keywords) was three times higher than those before 1 May (112 keywords). Compared to before 1 May, the number of keywords related to policies of marketing orientation after 1 May increased 4.5 times, the number of keywords related to policies of tourism products increased 3.5 times, and the number of keywords related to tourist policies increased 2.9 times. The number of keywords related to policies of promotion only increased 1.1 times. However, the keywords related to pricing policies are barely mentioned over the whole period under study. Major examples of national policies include lifting the restrictions on the number of tourists at scenic spots, improving tourist satisfaction, enriching the tourist experience, promoting new forms of destinations (for example, night markets and rural markets), improving the quality of products and services, improving the safety standard of products, improving digital cultural products, extending the life cycle of smart products, branding of online products, arranging activities at different zones, home economy (online selling), no-booking-no-tourism policy (except elderly and children), and promoting responsible tourism. At the regional level (only the top 10 provinces ranked by tourist arrivals and revenue are selected), there were fewer keywords of tourism policies after 1 May (1,519 keywords) than before 1 May (2,067 keywords). An increase was only observed in the keywords related to policies of tourists. Compared to national policies, there were many more keywords related to pricing policies at the regional level. The keywords related to regional policies of marketing orientation and tourism products account for the largest share among all keywords over the whole period under study. The keywords related to pricing policies after 1 May dropped to half compared to before 1 May. Only Jiangxi and Fujian provinces showed an increasing number of keywords related to tourism policies. These two provinces are two of the three provinces (the third is Henan) having more tourist arrivals than in 2019, and the reduction rate of keywords in Henan was the lowest. At the level of cities or scenic spots, the keywords related to policies of marketing orientation almost doubled after 1 May, while other types of keywords decreased after 1 May. Unique policies at the level of cities or scenic spots include multiple entries with one ticket, free tickets to all during certain periods or for certain series of personal ID numbers, getting free tickets based on “likes” clicked on SNS, and the use of QR codes for promotion, among others.
Regarding the supply side, only keywords related to national policies increased after 1 May. Policy keywords of provinces, cities, and scenic spots all decreased. Examples of national policies include policies for tourism enterprises (safety assessment of tourism products and routes, controlling the number of tourists in each tour, promoting healthy tourism styles (e.g., individual dining and serving chopsticks), policies for industry (multi-industry and multi-field integration), policies for production and maintenance (work at any time and any place; optimizing online services, promoting contactless service), and financial policies (rent and tax reduction, increasing support for cultural and tourism, and entertainment industries; differentiated preferential services; cutting interest rates). Examples of regional policies include policies for tourism enterprises (stabilizing labor relationships, building smart tourism platforms, development of industrial tourism), policies for industry (promoting the integration of culture and tourism industries), policies for production and maintenance (night performance services, night tours consumer services, ticket booking services, free admission to tourist attractions for medical workers), and financial policies (setting up special culture and tourism development funds; supporting the construction of culture and tourism infrastructure; CNY1 billion [CNY1 = $0.15] special loans for cultural tourism). Regional policies are supplementary to national policies, and financial support to tourism enterprises gradually shifted from subsidies to entrepreneurial innovation after 1 May.

To combat the COVID-19 pandemic, most developing countries highly dependent on tourism have implemented policies restricting human-to-human interactions, isolating persons with exposure, stopping use of public transport, and restricting international transportation. However, these policies have various negative effects. Existing studies have investigated the relationships between political, economic, transportation, and epidemic factors. No study can be found to explore policies that can balance the control of the current pandemic via transport and tourism policies (at both international and domestic levels), and economic development via tourism. To fill this research gap, Ma, Li, and Zhang et al. (2020) first built a system dynamics model to represent relationships, feedback, and delays existing in a system with disease transmission, economy, international transportation, and tourists. They further evaluated the effects of several policies. The relationships are specified between COVID-19 and transportation, between transportation and tourism, and between tourism and COVID-19. Cambodia was selected as a case study country. Comparing policies one by one found that the quarantine policy is the most effective, followed by the policy of domestic travel bans. The policy
restricting immigration entry from a single country is not very effective to control the COVID-19 pandemic. Looking at the effects on the total income, the policy of domestic travel bans show a lower influence on increasing the total income than other policies, while other policies affect the income similarly. When considering both economic benefits and the control of the COVID-19 pandemic, the quarantine policy is the most effective. When making packaged policies, combining the tourist behavior policy and enterprise activity policy perform better than combining the immigration entry restriction policy, the policy of travel restrictions and the quarantine policy, for reducing infection cases. Policies encouraging tourism, including the quarantine policy, the tourist behavior policy, and the enterprise activity policy work better than policies of travel restrictions, including the immigration entry policy and the travel restriction policy. The performance of combining the immigration entry policy and the tourist behavior policy is worse than policies focusing on local stakeholders, the travel restriction policy, the quarantine policy, and the enterprise activity policy. For increasing the government’s income, combining the immigration entry policy, the travel restriction policy, and the quarantine policy are more effective. From a comprehensive viewpoint, policies of travel restrictions show the best performance. If efficiencies of policies and benefits of both tourism and control of the pandemic are considered, policies of travel restrictions show the best performance, followed by combining immigration entry, travel restriction, and quarantine policies with public support as supplements (efficiencies: 20% for the tourist behavior policy and 20% for the enterprise activity policy) and the immigration entry policy and the tourist behavior policy (both 80% of efficiencies) with local stakeholders as supplements (all 20% for the travel restriction policy, the quarantine policy, and the enterprise activity policy).

2.10 Evidence-based Policy Evaluation

Focusing on the initial stages of the pandemic in Japan, Kashima and Zhang (2020) made use of data from a nationwide retrospective panel survey implemented in March 2020 to compare the impacts of three major announcements of pandemic measures, including the Public Health Emergency of International Concern announced by the World Health Organization (WHO) on 31 January, temporary school closures by the Japanese government on 27 February, and the COVID-19 outbreak as a pandemic declared by the WHO on 11 March. Based on a cross-sectional analysis (using a logistic regression model) and a time-series analysis (using a Poisson regression model), it is shown that even though the declaration of school closures was not directly restricted to
activities for all Japanese individuals, the announcement had been an important trigger for initiating behavioral changes against the spread of COVID-19. It is also revealed that young individuals perceived the infection risks late than the elderly population, and an intensive alert for younger individuals seems important at the early stage of the outbreak.

Using a retrospective panel data (2,643 respondents residing in different parts of Japan) collected by the Mobilities and Urban Policy Lab of Hiroshima University in November 2020, Ding and Zhang (2020) estimated a dynamic structural equation model to evaluate the effects of COVID-19 policy measures by focusing on the roles of attitudinal factors. The LASTING approach argues that to prevent the further spread of the pandemic, people should take action by modifying the needs in their lives [L] and consequently adjusting activity participation [A] at proper space [S] and time/timing [TING]. The effects of the PASS (prepare–protect–provide [P]; avoid–adjust [A]; shift–share [S]; and substitute–stop [S]) and LASTING measures were found to be statistically significant and remarkably large. The findings derived from the modeling analysis imply that all PASS and LASTING measures should be taken to effectively control the spread of COVID-19 and governments should ensure the reliability of information provision via feedback from the public. Local governments should pay more attention to the public’s attitudes toward them. Inconsistent policy measures by the central government and local governments are not helpful to control the spread of COVID-19.

Lei and Ozbay (2020) estimated the impacts of the stay-at-home policy on taxi and Citi bike use in Manhattan of New York, by using large-scale open data between March and June 2019 and 2020. To estimate the immediate effects of the stay-at-home policy on the Citi bike use and yellow taxi demands, the regression discontinuity method is applied. The results show that the subscriber users of Citi bikes had a 75% decrease, whereas customer users had a decrease of 94% on the day when the policy became effective, while the impacts of the policy on taxi demand are statistically insignificant. For taxi pick-ups, the average monthly use fell by 96.0% in March, 94.5% in April, 98.5% in May, and 94.3% in June than the similar group where no stay-at-home policy was applied. For the total Citi bike use, the average month use first increased by 5% in March, and then decreased by 32.2% in April, 74.1% in May, and 19.6% in June, as estimated based on a propensity score model. The policy impacts on Manhattan is heterogeneous. The impacts on the lower Manhattan areas were more severe than those in the middle and upper Manhattan areas. Daily average estimation results show that spikes of Citi bikes for a surging demand occur on weekends. Policy makers should consider the surging demand for the Citi bikes on weekends and perform proper disinfection.
It has been a difficult task to estimate the effects of various COVID-19 policies. Zhang et al. (2020a) made an additional contribution by collecting 274 policy measures from Cambodia, the PRC, Japan, the Philippines, the Republic of Korea, and Viet Nam. Policy measures are classified based on the PASS approach. The 274 measures are treated as samples for several modeling analyses, where the corresponding dummy variable (1 or 0) of each measure and its implementation timing (from implementation to the coming peak of infection) are dependent variables. For each measure (sample), the corresponding infection data (cumulative deaths and new daily cases before implementation) are added as explanatory variables. Furthermore, to assess the effects of timing decisions of policy measures, infection data of the coming peak (new daily cases, cumulative deaths, and cumulative infection cases) are treated as additional dependent variables. Because the collected policy measures (samples) come from six countries in different months, statistical correlations may exist. To address such statistical issues, two types of multilevel models are built: Bayesian multilevel binary logit model and Bayesian multilevel generalized linear model.

- **Choice of policy:** Both expected and unexpected influences are observed. More daily cases and cumulative deaths are significantly associated with choices of prepare–protect–provide and avoid–adjust measures, respectively. Unexpectedly, more deaths lower the probability of choosing prepare–protect–provide and substitute–stop measures.

- **Timing decisions of policies:** All four types of the PASS measures were more likely to be made late in an almost equal way.

- **Timing decision by policy type:** Only in the case of avoid–adjust measures, new daily cases encouraged policy makers to make earlier decisions on choosing these measures. As for other types of measures, both infections and deaths are associated with late timing decisions.

- **Policy timing decisions and infections:** Three infection indicators (new daily cases, cumulative deaths, and cumulative cases) suggest that all the policy decision timings are positively associated with the peak infections. For example, the consequences of 30 days of delay for each type of PASS measure are: 1.5–1.8 new daily cases would be additionally observed, 1.9 cumulative deaths would be added, and 37–127 cumulative infection cases would be added.

Existing PASS measures (both transport and non-transport) may be made too late to flatten the growing curve of the spread. To effectively prevent the next wave of the pandemic, policy measures should be made
as early as possible. Policy makers should be more sensitive to deaths. All members of the global society should be more sensitive to the spread of the virus.

In the context of the United States, Tomás et al. (2020) demonstrated that promoting the use of carpooling in university campuses while under public health threats is able to enhance the environmental and road traffic performance of the campus transportation network. To implement carpooling under public health threats, it is necessary to set vehicle occupation limits for carpoolers. Vehicle occupants have to ensure that the distance to other occupants is maintained, use mouth and nose covering, and keep good ventilation in the vehicle. Carpoolers should have access to carpooling dedicated parking spaces.

Fazio et al. (2020) developed an agent-based simulation model to examine the impacts of mobility restrictions on controlling the COVID-19 pandemic, where infection risks are captured by considering the influences of winter temperature, air pollution, housing concentration, and density of health-care facilities. The model simulates different scenarios beyond the status quo one. By focusing on Italy, they made a simulation and showed that the epidemic may have begun before the official date. They finally proposed policy measures in a conceptual way, which include protection measures to reduce hazards and prevention measures to reduce vulnerability. As protection measures, dynamically providing the risk level of a region over time was proposed. As prevention measures, promoting no polluting transport modes (e.g., active modes) was recommended.

Clifton, Nelson, and Hensher (2020) summarized lessons from Australia in terms of short-term impacts, medium-term impacts, emerging themes, and policy directions. As short-term impacts, even without hard lockdowns, officer workers have rapidly switched to working from home and as a result, lower traffic volumes in inner-city and commuter zones have been observed. However, manual workers (especially in industries like manufacturing and construction) have not been affected by lockdowns as observed by the rapid growth in logistics and e-commerce, and road maintenance work done by manual workers. Hospitality and tourism activities have become dormant. Immediate loss in confidence in public transport and some reductions in public transport service levels have led to a large drop in public transport ridership and loss of cash fares. All door boarding in buses has become popular. Concerning active travel, walking and cycling to work and school have decreased, while walking and cycling for leisure have increased. There have been concerns over access to footpaths and bike lanes in denser residential areas, and as a result, pop-up footpaths and bike lanes have been instituted and are still
expanding. Looking at the medium-term impacts, the transition from lockdown was quicker than expected, and rapid transport demand management was required. Messaging already switched from “stay at home” to “stay safe”. More cooperation between governments, employers, and schools was observed by learning lessons from the 2000 Sydney Olympics. “No dot no seat” has been well practiced in public transport systems. The declining use of face masks has been observed as community infections ceased. Working from home and staggered start times have continued. As emerging themes, attention should be paid to the contestation of road space between car traffic, public transport, and active transport; working from home; maintaining core public transport networks (e.g., capacity was increased during the pandemic for maintaining physical distance); on-demand transport; and impacts on transport networking companies (e.g., Uber) and mobility as a service. It is concluded that flexible and adaptive regulations and better preparedness for the future should be made. To better understand the COVID-19-caused issues and take more effective countermeasures, there are still many modeling challenges, and more international cooperation should be prompted.

Takeshita et al. (2020) proposed a conceptual analysis framework for modeling the number of infection cases in association with policy measures, which consists of relationships between infection cases and the number of social contacts, between the number of social contacts and utility of participating events and/or activities, and between utility of participating events and/or activities and generalized travel costs (monetary cost, time cost, psychological cost, and legal cost). Within the generalized travel costs, psychological and legal costs are more likely to be significantly affected by the pandemic and its countermeasures. The utility of participating events and/or activities is further analyzed with respect to destination choice, travel mode choices, and technological interventions (e.g., for assisting in online activities). The conceptual framework is further extended to cover economic and social recovery measures and enhancement of environmental sustainability. Limited policy measures from a restrict–prohibit–arouse perspective are qualitatively compared with respect to Japan, the PRC, Thailand, India, the United Kingdom, Germany, and Austria.

2.11 Nationwide Policy Responses

Pagliara (2020) reported that the perception scores of safety in public transport are very low at only 3.1–3.5 points (the safest score is 10 and the least score is 1), while the score for cars is 8.7, and that for foot is 7.3. She analyzed data collected from about 14,000 public transport users in
the province of Naples. Probably because of such perceptions, 6% of public transport users would prefer not to use public transport in the future, shifting to private transport. This means that within 1 month, there would be an additional 54 million trips by private car, leading to more serious congestion and environmental pollution of the province. By referring to an existing study, Pagliara summarized sustainable public transport policy measures post-COVID-19, including measures with high sustainability and high effectiveness (fare differentiation in different time slots, seat reservations, access to stations and/or vehicles with reservation), measures with high effectiveness and low sustainability (use of masks and body temperature control, interpersonal distance onboard vehicles, increased public transport frequency, vehicle sanitization), and measures with low effectiveness and low sustainability (introduction of dedicated services meeting the demand). Pagliara further emphasized the roles of high-speed trains in the post-COVID-19 period and pointed out possible factors and key areas for future railway transport, such as lifestyle (e.g., fifth generation, Internet of Things), territories (e.g., home working, health teleconsultation, distance learning), economy, technologies (e.g., autonomous trains), energy and environment, and transport governance (e.g., strict emissions standards, disincentives to use the car).

Based on panel data and models with fixed and random effects, Diomo et al. (2020) examined the effects of statewide policies (nonpharmaceutical interventions [NPIs]) on travel reductions in the United States, by reflecting the influence of individual unobserved heterogeneity. Daily normalized seasonal vehicle miles traveled (NDVMT) and daily normalized seasonal vehicle trips (NDT) are used to represent travel activities. NPI policies under study include stay-at-home orders (43%); gathering bans (63%); school closures (83%); nonessential business closures (56%); and partial nonessential business closures (25%). It was found that during the first 3 months of the COVID-19 pandemic, full nonessential business closures had the biggest impact on reducing traffic (both NDVMT and NDT). School closures and partial nonessential business closures had similar impacts, but only on NDVMT for school closures (the impact on NDT is about half) and NDT for partial nonessential business closures (the impact on NDVMT is about half). The impacts of stay at home orders are about half of that of full nonessential business closures. Gathering bans were significant but resulted in a comparatively very low reduction in traffic. In the modeling analysis, COVID-19 related variables of new cases per capita and deaths per capita are added as explanatory variables, together with the above policy variables. It seems that further modeling efforts should be made for addressing the endogeneity issue.
India is the second-placed country in the world in terms of cumulative infection cases and the third-placed country in terms of deaths. According to Maitra et al. (2020), to control the pandemic the government of India implemented phase-by-phase policy interventions, including screening of international passengers on 4 February 2020; restrictions on mass gatherings on 5 March; an advisory on international travel on 6 March; work and study from home on 16 March; suspension of international flights and sports events on 19 March; 1-day curfew on 22 March; national lockdowns on 25 March, 15 April, 5 May, and 18 May; buses resumed on 5 May; domestic flights resumed on 25 March; and lifting of lockdowns on 1 June, 1 July, and 1 August. Maitra et al. (2020) examined the transport-related effects of policy interventions in India and found that the first lockdown on 25 March led to the largest decrease in out-of-home activities and trips and the largest increase in staying at home. Unfortunately, the other three lockdowns could not reduce activities and trips that were sources of infections, and the effects of the three lockdowns are even smaller than the countermeasure of advisories on work and/or study from home implemented on 16 March. The extended lockdowns helped to maintain low out-of-home activities and trips for a longer period. Significant effects of restrictions on mass gatherings cannot be identified, suggesting the absence of general awareness among the people during the early stages of the pandemic. The minimal impact of the advisory regarding the “restriction on mass gathering” highlights that such soft measures are unlikely to result in the desired impact in diverse countries like India unless accompanied with strict enforcement. It is further revealed that policy effects differ across cities. The pace of increase of activities varied across regions, which sometimes resulted in a rapid increase in COVID-19 cases and thus forced the government to implement localized lockdown measures. It is concluded that the transit system will require a longer recovery period compared to driving and walking. However, strategic interventions in terms of implementing adequate safety measures and awareness programs focusing on building confidence in public transit may help in drawing additional passengers to the public transit systems.

Senathipathi et al. (2020) also reported on the situations in India from a broader perspective. As for the impacts on the aviation sector, all domestic flights were suspended for 40 days from 25 March to 3 May 2020 and resumed gradually from 4 May 2020. All international flights were stopped for 19 days from 15 April to 3 May 2020 and resumed gradually from 1 June 2020. Railway operations were also suspended during the above periods. Different from the aviation sector, such suspension was also forced in August and September 2020. However, detailed economic impacts on the aviation and rail sectors remain
unknown. In the road transport sector, the largest decline (−89%) of road traffic on major roads in Delhi was observed from 25 March to 14 April 2020 and traffic gradually recovered when strict measures were relaxed step by step. By the end of October 2020, it recovered up to 80%. Because of the decline of road traffic, traffic accidents in major states decreased 8% to 17% in comparison with data in 2019. During lockdowns, daily freight flows reduced by one third. As a result, for example, in Delhi, NO₂ and CO₂ decreased as much as −45.99% and −21.43% in industrial locations, and as much as −50.61% and −36.84% in traffic dominated locations, respectively (Seetharaman et al. 2020). Velmurugan et al. (2020) further found that in the case of public transport, an 80%–90% reduction in ridership was observed when public transport operations resumed. Based on a questionnaire survey, about 30% of people wanted to buy a vehicle for safety reasons in the near future due to the COVID-19 pandemic. A majority of public transport operators are not confident about a full recovery within 1 to 2 years and beyond because of users’ fear of infection, even though about 70% of people stated that they would prefer to use public transport if it meets high quality standards for services. Furthermore, loss of jobs caused by lockdowns forced a massive reverse migration from large cities to small villages with many migrants walking and cycling for thousands of kilometers due to the suspension of vehicle and train movements. All the above observations are expected to keep changing. Immediate measures are proposed, including transport demand management strategies such as work-from-home and e-commerce (because of the impossibility to increase the fleet size of public transport), demand responsive transport services, management of demand volatility, and safeguarding customers and employees from the impact of the pandemic. As long-term strategies, it is proposed to support the revival of public transport systems (especially buses) via fiscal policies, to allocate more protected lanes to buses and more protected footpaths and cycle lanes with flexible barriers, and to reduce unnecessary travel trips by teleworking and move short trips to walking and cycling as much as possible.

Based on documentary research and an expert survey in the context of Turkey, Ozaydin and Ulengin (2020) proposed several measures that should be taken by the Turkish authorities. For example, Habur Border Gate, which is Turkey’s gate to Iraq, was closed to passenger entry and exit as of 1 March 2020, and commercial passages started to be operated under strict control. At the entry point to Iraq, only Turkish drivers were allowed entry subject to quarantine requirements, while foreign drivers were not allowed to enter Turkey. Vehicles coming from Iraq were disinfected in the buffer zone and a driver change was made. Turkish and foreign drivers arriving at the Turkish border at Kapikule as well as
other border gates are expected to be allowed to continue their journey after a rapid diagnostic test has been administered, instead of 14-day quarantine. For export transportation, after applying rapid diagnostic tests to the drivers and provided that their test results are negative, border crossings of vehicles to European countries could be allowed and the Schengen visas of Turkish drivers could be extended until a specified date. The quota and transit permit system applied by the European Union to Turkish transport vehicles should be amended. Transport corridors should be kept open for freight. In maritime transportation, there has been a decrease in imports from East Asia, where the unloaded export loads resulted in space problems on vessels because the vessels coming from banned countries are not accepted at ports due to the requirements of a 14-day quarantine. On the other hand, in transportation conducted with the combination of railway and seaway, high demurrage and warehouse fees occur due to delays in railways. Railways have been least affected by the coronavirus pandemic, becoming the preferred mode of passenger transport, due to lower physical contact. In fact, in all countries including Turkey, the negative impact of the measures is relatively low and there has been a considerable increase in demand for railway transport. Due to these facts it can be seen that more efficient railway transportation and an increase in frequency and the supply of additional wagons should be realized.

As the first country hit by the COVID-19 pandemic, the PRC responded rapidly and recovered quickly from the pandemic, because of lessons learnt from the severe acute respiratory syndrome (SARS) experience in 2003. Zhu, Wang, and Huscroft (2020) introduced the PRC’s successful measures of lockdowns, mandatory mask wearing, health code, timely information dissemination, epidemic traffic monitoring and early warning platform, travel by reservation, temporary transport demand management, customized bus routes, intelligent logistics, telecommuting, among others. Zhu, Wang, and Huscroft took the resurgence of COVID-19 in Xinfadi, Beijing as a case study. The case of Xinfadi was similar to that of Wuhan in the early stage and it was quickly controlled by a rapid response system based on the experience of Wuhan. The first case was confirmed on 11 June 2020 and the peak of new daily cases was on 13 and 15 June. The outbreak was controlled on 6 July when no new cases were observed since then. This happened just within 1 month. Xinfadi is located in south Beijing, which is Asia’s largest agricultural products wholesale market and responsible for 90% of Beijing’s supply of agricultural products. The size and influence is 21 times higher than that of the Wuhan seafood market. The virus source was found from the packaging of foreign seafoods. For dealing with the COVID-19 pandemic, the PRC built a four-level hierarchical emergency
response system at the early stage of the pandemic. The Xinfadi case was judged to be Level 2 (Level 1: particularly important event, Level 2: important event, Level 3: major event, Level 4: normal event). During the so-called Golden 48 hours, the movement of the first patient was tracked, mainly relying on personal memory and mobile phone records for the past 14 days. After locating the Xinfadi market, everyone who had passed by the Xinfadi market in the past 14 days was located using signaling data and/or transaction data analysis. The located persons came from 12 districts out of 16 districts in Beijing. Those who received the isolation message had to stay at home for self-isolation and wait for the arranged free nucleic acid test. Their health codes turned to red (i.e., serious). For those who live in the high-risk area, working at home and strict protective measures were recommended to protect themselves and their families. By using a set of time-series analysis techniques, compared to the traffic reduction of 50% caused by locking down the whole city, the Xinfadi’s hierarchical response control countermeasures resulted in a maximum of 15% traffic reduction. Zhu, Wang, and Huscroft (2020) summarized the key experiences as follows: (i) at the very early stage, speed is life, fast responses are the key to success; (ii) artificial intelligence and big data technologies make precise anti-epidemic policy possible; (ii) hierarchical emergency response systems helped prepare for the sudden strike of COVID-19; (ii) the countermeasures lead to big success with less cost (less reduction of traffic volume and human mobility but complete control of the pandemic); (v) it will not be an isolated case and similar cases may occur in the future due to cold-chain logistics, contaminated water, and contacts with animals, etc. They further emphasized lessons learned: (i) comprehensive information dissemination policy is the key to mitigating the spread of the pandemic; (ii) information technologies have become a powerful weapon in the battle against COVID-19; and (iii) policies and related measures have been implemented in a hierarchical system to address the social distancing needs in the transition period.

Zhang, Z. (2020) conducted a resilience analysis of the PRC’s national highway transport system. Zhang demonstrated that the big decline of highway traffic volume will result in a much bigger rise in highway traffic volume in the recovery and bounce stage. It is also discovered that the heterogeneous linear relationship between highway traffic volume and the COVID-19 effective spreading rate in the response and recovery stage of the PRC. He further built two control policies based on a susceptible–infectious–recovered (SIR) COVID-19 spreading model and concluded that shortening the length of the COVID-19 outbreak period is more effective than just lower the effective spreading rate. The quantification effects of the two policies are calculated that the
maximum active infected population is reduced to 35,809 and 19,450; highway traffic volumes are reduced by 12 million and raised by 56 million; while the gross domestic product (GDP) is reduced by CNY173 billion and increased by CNY761 billion. It is finally recommended that government administrators should implement strict traffic control policies in the outbreak stages of COVID-19 based on monitoring the evolution process of this pandemic and accurately calculating the virus spreading rate, recovery rate, and effective spreading rate dynamically.

Zhang and Tong (2020) built a transportation computable general equilibrium (CGE) model and used it to simulate the impacts of traffic consumption on the economy under the COVID-19 epidemic. The model includes the following parts: production, international trade, household, enterprise, government, market closure, and clearing conditions. Sectors included are agriculture, forestry, animal husbandry and fishery, mining and dressing, manufacturing, electricity, heat, gas and water production and supply industry, building industry, service industry, railway transport, urban public traffic, road transport, and air transport. Four scenarios are examined: (i) the marginal propensity to consume falls by 16% and the proportion of consumption in railway, air, urban public traffic, and road transport falls by 60%; (ii) the marginal propensity to consume falls by 8% and the proportion of consumption in railway, air, urban public traffic, and road transport falls by 50%; (iii) the marginal propensity to consume falls by 3% and the proportion of consumption in railway, air, urban public traffic, and road transport falls by 40%; and (iv) the marginal propensity to consume falls by 2%; the proportion of consumption in railway, air, urban public traffic, and road transport falls by 30%. It is concluded that during the pandemic, cutting off nonessential travel becomes the best and most effective way to stop the spread of the virus by minimizing the flow of people, but it has negative impacts on the PRC’s economy. The pandemic reveals the shortcomings and defects in public transport, namely governance capabilities and technological levels. It is necessary to accelerate the intelligent construction of transportation and promote coordinated development of different transportation modes. It is also important to build a favorable investment environment, because investment in railways plays a more positive role in economy recovery.

In Singapore, several key intervention measures were taken, including travel advisory and entry restrictions announced in late January 2020, stay-home notices and contact tracing work in early February, social distancing and work shift arrangements on 13 March, stricter safe distancing measures and restrictions on short-term visitors on 20 March, and a national circuit breaker (also known as partial lockdown) from 7 April to 1 June. To investigate the potential impacts
of these measures, Liu et al. (2020) made a Flux correlation analysis and found that in the early stage of the pandemic in Singapore, the number of infection cases immediately resulted in the announcement and enforcement of intervention measures, implying a relatively quick response to COVID-19 situations and intervention measures. However, during reopening in June–August 2020, reopening did not immediately cause a recovery in economy, and travel demand was less sensitive to the number of new infection cases. It seems worth exploring whether other measures are truly not effective or other better approaches should be adopted or developed.

By interviewing a small number of experts at national, regional, and local governments; public transport operators; nongovernment organizations; and consultants in the United Kingdom via an in-depth survey, Marsden, Docherty, and Anable (2020) found that transport has been a “taker” not a “shaper” in COVID-19 policy making. Despite a pandemic being the number one risk on the national risk register, the importance and implications of this had not filtered down to the transport sector. It was only practice in “operational resilience” from matters like terrorism and flooding that meant operators were able to adapt so quickly. It is further revealed that the whole policy system is so large that the communication of messages ignores the understanding of behavior change in the transport sector. Transport experts are not present in the pandemic expert advisory team of the central government. The mechanisms to deliver policies are those which pre-exist, tending to lock-in past-dependent paths rather than challenge them. This is a reality of taking decisions under time and resource pressure. While the immediate policy changes have been limited, it is concluded that it is still too early to say what the long-term policy change from the pandemic will be. The pandemic could yet have a massive impact on where people live and work and how often and when people travel. Even if this happens for just the significant minority of people who can work from home, this could fundamentally alter the financing of public transport and the necessity for new road and rail infrastructure. The ability to conduct business activities remotely will not be the death of business travel but it requires policy makers to pay more attention to the role of travel time savings in future business cases. Promoting active transport may become a mainstream prioritization in government policy making with the recognition of the importance of better public health and the need for more space for people to reduce future pandemic risks. Finally, this has been a period of unprecedented government support to keep public transport services running. However, an economic recession will follow and how governments’ treat the massive rise in public debt will be central to how long and in what form such subsidies persist. This in
turn will shape how well the public transport sector can return from this difficult period. There are important months and years ahead which will determine whether the transport sector has been able to shape the pandemic outcomes as an opportunity for change towards a more sustainable future.

2.12 Social Distancing Measures and Design in Association with the Built Environment: A Cross-sectoral Perspective

Social distancing has been a key measure to control the COVID-19 pandemic. But it has not been well defined. Hayashi and Zhang (2020) revisited such definitions. They first defined that social distance is appropriate intervals between the subjective body and the objective body, which can share the other’s good values and do not share bad values. Then, social distancing is defined as an action to keep social distance. Quality of life can be maximized by optimal social distancing. A system of “Cities of Social Distancing” is cities that are globally decentralized and locally compact, equipped with community design assuring comfortable human contacts, and necessary material services based on social distancing. Social distancing practices need to instruct people what is proper physical distance. For this, the WHO recommends that a distance of 1 meter or more is safe, which is applied in the PRC, Denmark, France, Lithuania, Singapore, and the United Kingdom. Differently, the Republic of Korea recommends a 1.4 meter distance; Australia, Belgium, Germany, Greece, Italy, Netherlands, Portugal, and Spain adopt a 1.5 meter distance. The United States and Japan apply a 1.8 meter distance, while Canada recommends the largest distance of 2 meters. Examples of social distancing measures include avoiding physical contact, school closures, workplace closures, canceling mass gatherings, travel restrictions, cordon sanitaire (a cordon that quarantines an area during the pandemic), isolating ill persons, contact tracing, and quarantine of exposed persons. Zhang (2020a) proposed more social distancing measures. Hayashi and Zhang (2020) proposed a three-step conceptual framework for estimating the number of infections including steps from generalized transport costs (monetary cost, time cost, physical distance cost, mental cost, etc.) to magnitude of events and/or activities, from magnitude of events and/or activities to the number of contacts, and from the number of contacts and the number of infections. They further conceptually discussed how different types of social distancing measures are associated with the relationships captured at each step. By reviewing the existing studies, they also pointed
out negative impacts of social distancing measures, such as anxiety and depression, emotion dysregulation, social isolation, increase in domestic violence, rise of vehicle crime, and decline in economic activities.

Li, Ma, and Zhang (2020) conducted the first study in literature on the whole PRC by associating the built environment attributes with the spread of COIVD-19. Second, they examined more intracity and/or intercity-built environment attributes than all of the existing studies by focusing on the spread of COVID-19 in its initial stage. Third, they conducted a joint analysis of both the global and local effects of the built environment attributes by estimating a mixed geographically weighted regression model. It is found that restricting intercity connections via railways is likely to prevent the further spread of COVID-19 in most cities of all levels. For sub-provincial cities and country-level cities, control of the population flow is probably effective to suppress the spread of COVID-19. Lowering the betweenness centrality could slow down the spread of future pandemics in more than 70% of prefectural-level cities. Reducing the population densities of built-up areas could be effective to prevent the spread of future pandemics in about 70% of the provincial capitals. Effective countermeasures seem not to be the same across locations, showing geographical differences. Reducing the travel time by public transport from residences to nearby activity centers could be significantly effective to control the spread of COVID-19. The findings of this study have long-term urban planning and policy-making implications. For example the built environment could be improved to mitigate the impacts of future public health pandemics, such as planning a more flexible transport network and city schedules, and rethinking about the location of landmarks and urban activity centers, as well as integrating the telecommuting work plans.

Uniquely, Nakamura and Morita (2020) focused on the roles of urban rivers and water use in creating social distancing-sensitive communities under COVID-19 in Japan. They observed an increasing use of rivers and green spaces by children and their families during the pandemic and pointed out the importance of rivers and green spaces in cities. For example, in Tokyo, about 80% of rivers were lost for building roads, sewage systems, and other public and private facilities. Thus, the values of rivers as well as green spaces were (have been) ignored in the urban planning developments in Japan, and consequently should be re-evaluated.

According to Murayama (2020), cumulative infection cases in Tokyo account for 27% of total cases in the whole country. The over-concentration of population in the Tokyo metropolis has been a serious social issue for decades. In Tokyo, there are 50.6% of listed company headquarters of the whole country, 50.6% of large companies with capital
of more than ¥1 billion, 52.1% of offices with more than 1,000 employees, 19.6% of GDP, 15.8% of employees, 11.0% of the population, and many universities. Housing rent in Tokyo is twice as high as the national average. Murayama discussed several key factors causing such a concentration: many companies’ unrecognized higher risks of natural disasters (earthquake, typhoon, flood, etc.) in Tokyo, inactive use of teleworking, a young generation of 15–29 years old (accounting for more than 90% of excessive migration to Tokyo: less attachment to local cities, a concentration of many universities, limited job opportunities outside large cities (especially for females); companies hire more people in Tokyo), and vague longing for Tokyo. He revealed that a large share of infection cases were concentrated in the high-density central wards of Tokyo. As a matter of fact, excessive migration to the Tokyo megaregion has dramatically decreased since April 2020, where the reduced excessive migration to Tokyo is almost the same as the increased inflow to local cities. But at the same time, Murayama also pointed out that high residential density does not directly lead to high COVID-19 case rates, referring to a case study of New York City. He argued that it is necessary to revisit the concept of density by paying more attention to residential population density, internal residential density, institutional settings density, public spaces, and workplace density. Related to distancing measures in high-density urban areas, Murayama argued that it is necessary to carefully plan and design open spaces and commercial and office buildings in walkable neighborhoods as well as urban centers, and to increase the diversity in mobility to mitigate congested commuter trains. He further suggested that declining suburban residential areas could be sustainably regenerated with the spread of teleworking and people’s preferences toward spacious homes and urban environment. Whether the over-concentration of population in Tokyo will stop or not may depend on the movement of young generation, and regeneration of local cities through good planning and job creation.

2.13 New Normal and Long-term Impacts as well as Post-pandemic Responses

Rothengatter et al. (2020) first discussed the dual role that the transport sector unintentionally played in the pandemic with spreading the virus worldwide and being hit most heavily by its impacts. They analyzed the actions taken for controlling the pandemic and the state efforts for compensating economically negative impacts. They addressed the risks of a massive second wave which most seriously hit particular segments of the transport sector such as air transport, rail and bus long-
distance transport, as well as urban public transit. Two scenarios were constructed for describing the range of possible developments after COVID-19. The first scenario relates to the development 100 years ago after the First World War and the Spanish flu pandemic, when rapidly upcoming economic optimism initiated a decade of the “golden” or “roaring” twenties. The second scenario presumes that people have learned from the 2008 and 2020 crises and will pay more emphasis to stable, resilient, and sustainable development of the economy. This would have particular consequences for a change of trends in the transport sector, substituting physical transport with electronic communications, strengthening public and nonmotorized transport, and developing only on those segments of motorized individual and air transport, which promise to achieve a zero carbon footprint.

Daily travel patterns and mobility behavior of commuters have been significantly affected by the pandemic. COVID-19 has affected all forms of transport, including cars, public transport, and planes across the world. A key question for researchers is whether changes to transport behavior during COVID-19 may result in a permanent change in behavior. COVID-19 induced changes to our long-term travel and household decisions will have significant implications on the global energy sector if these changes become permanent in the post COVID-19 world. Policy makers need to have a clearer understanding of how peoples’ long-term choices will change due to the COVID-19 crisis. This knowledge will assist city administrators in determining what sort of policy options are available for governments to incentivize certain behaviors and discourage others. Anik and Habib (2020) used an integrated transport, land use, and energy model to predict changes in households’ long-term decision making in the context of COVID-19. They simulated households’ residential location choice, travel tool ownership and vehicle transaction decisions, as well as vehicle type choice and decisions of 20,233 households in Nova Scotia, Canada, between 2020 and 2030 under two scenarios associated with COVID-19. They designed two scenarios: a baseline scenario (business-as-usual scenario of land use and transportation) and a COVID-19 scenario (the changes caused by the crisis on people's travel behavior, perception of risk, and decision making will persist from 2020 to 2030). In the COVID-19 scenario, it is assumed that only 6% of households will change their residential location in 2020; peoples’ vehicle transaction behavior will change, and they will prefer to buy more private vehicles after the first 2 years of COVID-19; transit pass sales will decrease for 2020; and for 2020, transit is considered to be limited and school trips are restricted, but shared travel is allowed; however, starting from 2021, these three restrictions are lifted. It is discussed, based on the modeling results, that, first, urban
sprawl may occur gradually. Having the opportunity of “working from home”, “virtual school”, “e-shopping”, and online medical services, people are not as inclined to live downtown and would prefer to live in the surrounding suburban areas. This issue finally leads to major problems in cities, like traffic congestion, long travel times, increase in infrastructure costs, reduction of environment quality, and social interactions. Strategies such as creating urban boundaries, betterment of low income households' living conditions, supporting smart growth, creative and efficient management strategies can be utilized based on the characteristics of the region. Second, there will be an increase in the number of private vehicle purchased. The model prediction results show that under the COVID-19 scenario, vehicle purchases will double in 2022. This shows signs of getting back to previous auto-oriented travel behavior. Decision makers need to make plans to improve sustainable travel mode infrastructure and formulate strategies to attract new users to those modes. Efforts should be made by the transport policy makers for attracting high-income households to walking, biking, and public transport so that they are less dependent on their private vehicles for trip planning. Third, sports utility vehicles (SUVs) will become more popular. Model results show that when more people are intending to purchase new vehicles, they are likely to prefer an SUV. As urban sprawl increases so do SUV sales. From 2010 to 2018, SUVs were the second-largest contributor to rising carbon emissions. Governments and private organizations should consider taking initiatives for promoting environment-friendly cars (e.g., electric vehicles). Fourth, an uncertain future for transit systems will be expected. The transit pass ownership results show that under the pandemic scenario, people will be buying more (slightly) transit passes than under the baseline scenario. Transit planners should formulate plans to reconfigure and improve public transport, with an aim to keep the existing riders as well as to attract new passengers. From the vehicle ownership level results, it can be presumed that people aged greater than 60 tend to be more dependent on private vehicles than others age groups. Mass transit authorities may take necessary steps to attract these groups of people to public transport. Fifth, it is necessary to avoid a return to auto-oriented travel habits. Findings of this study indicate mostly a return to precrisis private car dependent travel behavior. Federal, provincial, and municipal governments, as well as private organizations, should work together to form policies and plans to incentivize sustainable travel behavior among households and avoid returning to an auto-oriented society.

The COVID-19 crisis has affected societies and economies around the globe and will thoroughly reshape our world as it continues to unfold. It is also likely to trigger permanent long-term impacts on the
transport sector in the post-COVID world and its “new normal”. While the post-COVID’s new normal would have negative interferences, it can be an opportunity to adapt for a more sustainable transport sector. To understand the role of the transport sector in achieving climate change targets with the arrival of the post-COVID’s new normal, the purpose of the study by Zhang and Zhang (2020) is to analyze transport dynamics with an energy focus when considering the unprecedented challenges and opportunities stemming from the post-COVID’s new normal. They developed an urban economic model in the tradition of urban spatial CGE model that represents the interplays among location choices, transport system, and energy to identify the decarbonization pathways for transport sector. Taking Changzhou, PRC, as an example, a set of scenarios are structured to project the long-term trends of transport demand, energy use, and emission profiles in the post-COVID world. These scenarios are defined under varying model assumptions regarding lifestyle changes and policy interventions, such as working from home, online shopping, bike-friendly design, bus service reduction, and carsharing service reduction. Scenario simulations present a low-carbon roadmap and decarbonization pathways for transport sector. Lifestyle changes such as working from home and online shopping would play the most important roles in contributing to the achievement of CO$_2$ emissions reduction. However, decreasing public transport and carsharing services due to lockdown and social distancing may counteract the positive effects on emission reduction of lifestyle changes. Thus, safe public transport during the pandemic is needed to achieve the maximum emission reduction. In addition, location choices and population distribution would change significantly with lifestyle changes and policy interventions, implying that impacts of the post-COVID’s new normal on urban structure and organization deserve more attention.

2.14 Packaged Policies

In April 2020, the WCTRS president released the following messages to the global society, derived from a series of urgent and intensive discussion among its key members. The messages include both immediate and long-term responses, as shown below.

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• **How to decide on the best timing to start and remove lockdowns**

There is a real trade-off between the timing (beginning and ending) of the lockdown and impacts on economic activities and health outcomes. If a nation (province, state, city) removes lockdown too early, there is a higher risk of the Corona Virus resurgence while society regains short-term business and social activities. Here are some useful guides to the decision makers of the lockdown periods:

(a) Pro-business decision-makers (President, Prime Minister, Governor or Mayor) will typically choose a shorter lockdown duration than is socially optimal because he/she may discount ‘external’ costs of spreading virus to other groups. Since spreading virus to others are ‘externalized’ costs, each of us impose to others (especially because we don’t know who carries the virus), the socially optimal lockdown period should be always longer than what the business community wants.

(b) This external cost (of spreading the virus) is more serious in larger cities where many people rely on mass transit and share crowded spaces, one virus carrier can easily spread it to many others. Therefore, in larger cities the socially optimal lockdown period is far greater (longer) than is likely to the case in outlying areas and in smaller cities.

(c) Where access can be controlled between areas, it is possible to set different lockdown periods instead of setting a uniform lockdown period for a whole country or state (province).

• **Government leaders need to worry about increased private vehicle dependence being sustained after lockdown periods end**

It is important for governments to prepare transit firms/authorities to deal with this issue in the following ways:

(a) Transit services need to be improved to allow physical distancing during pandemic and ability to return to normal service post pandemic;

(b) On-going promotion of telecommuting (working from home) even as restrictions are eased so that only necessary travel occurs;

(c) Programmes of staggered commuting times (e.g. not all organizations start their work at 9:00 am) are considered to lower peak hour demands;

(d) Resist pressure for reduced parking fees. Where necessary raise charges to manage demand and keep
public space safe for walking and cycling with safe social distancing; and
(e) Support public transport with subsidy to recognise the health and climate benefits it provides and the critical social service it provides for key workers.

- **Increased role of active transportation**
  Active transportation improves public health, supports transit, and reduces GHG emissions. Several cities are re-appropriating road space to cycling and pedestrians on surface streets to provide sufficient safe space for recreational and utilitarian travel.
  (a) Reallocate road space to accommodate active transportation and support safe social distancing
  (b) Support e-bikes to enable longer distance traveling
  (c) Demonstrate ongoing health and GHG reduction benefits of increased accommodation of bikes and pedestrians post-pandemic

- **Role of the government in the transport firms in which they invest**
  This COVID-19 crisis demonstrates vividly that governments are the powers of last resort to make sure that the private sector markets function when facing the scale of natural/economic disasters that no insurance firms can deal with. As a result, necessarily the decision makers in governments have enormous power to exercise to the extent that they can decide which firms survive, and which firms should go bankrupt or be liquidated. After the initial crisis is over, the politicians/bureaucrats are likely to develop temptation to exercise their power over the private sector firms in which the government owns significant portions of their shares and/or bonds. Such government power may lead to inefficiency and/or corruptive practices. We make the following suggestions:
  (a) Governments should purchase ‘non-voting’ shares rather than purchasing bonds. Non-voting shares make it difficult for the government to take over the firm or change the Chief Executive Officer. Critically, the government can recover some returns to taxpayers’ money by selling those shares at higher price later.7

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7 For example, Delta Airlines and the US Treasury recently agreed on a $1.6 billion 10-year low interest loan in exchange for the warrants that allows the government to acquire about 1% of Delta’s non-voting stock at $24.39 over five years so that the taxpayers may get profits from this risk taking. The airline bailout package in the wake of the 9/11 terrorist attacks resulted in the U.S. government making $130 million profit for the taxpayers after airlines recovered their profitability. Non-voting share bailout package deals appear to be a good practice to follow.
• **Priority on resource allocations to the transport sector**
As discussed in Recommendation 2 above, governments need to prepare for transit systems to satisfy the social distancing needs in the transition period and in the post-pandemic period so that not too many people turn to automobile driving:

(a) Since transport is an enabler of all economic activities including travel, tourism and trade, it is important that the transport firms and organizations need to get ready to initiate services as soon as the current pandemic is over by retaining their key employees on their payroll and government support schemes should enable this.

(b) Numerous studies show how increased transport connectivity (air, rail, land, sea) generates positive economic benefits to the society/country including essential services to remote communities. Careful understanding of how best to allocate fiscal and monetary stimulus funds is required to ensure transport services remain viable. In this sense, the U.S. Federal Reserve’s current practice of buying municipal bonds may leave pressures off from the city budget crunch. However, a lot more input from the new infrastructure budget may need to be allocated to improve urban transit services suitable to the post-pandemic service requirements.

• **An important longer-term issue**
The lockdown and social distancing requirements made us do far less automobile driving, which has had unprecedentedly high environmental side benefits. We expect that the new normal in the post-COVID-19 will be significantly different from before. There are those who argue that it could be more car dependent and those who suggest it is a major opportunity for more local living and virtual communications to replace longer trips. The outcomes we see will be the result, in significant part, of the policy choices we make over the coming months and years. This is clearly a unique and rare opportunity for policy makers and transport researchers to work together and seize the momentum to devise new policies in order to change our everyday living and choices toward more environmentally sustainable life and work.

The WCTRS Task Force further released the following measures and actions for consideration, after the above messages.

(a) To allocate enough resources to allow airlines to immediately reduce flights, which will help prevent the spread of COVID-19 and enable a responsible and safe transition in the recovery process.

(b) To financially support the deficit facing the transport and logistics industries, which are lifelines for regional economies and citizens’ daily life and health.

(c) To take immediate measures to sanitize public transport vehicles/facilities and maintain safe loading factors for different vehicles at different levels of virus management.

(d) To financially support public transport service providers and their employees, as well as service users, by subsidizing services during the transition from lockdown restrictions.

(e) To urgently develop knowledge on how best to communicate with the public about risks and safe use of public transport and movement in crowded places.

(f) To promote collaboration between public health, transport and supply chain experts to inform policy-makers’ decisions about lockdowns.

(g) To make use of the “new normal” after COVID-19 to encourage changes toward more environmentally sustainable life and work choices after the crisis.

(h) To prevent increased car dependence due to adverse reactions to public transport services after the pandemic.

(i) To share the learning of successes and failures in responding to COVID-19 across countries all over the world.

(j) To provide urgent international aid to compensate operators/drivers of paratransit and other informal transport services in developing countries for their economic losses due to social distancing and other operational restrictions.

Even though the above messages about packaged policies were formulated within a short period, they still have long-lasting values. Since then, many studies on packaged policies have been done worldwide.

Zhang (2020b) presented his published work (Zhang 2020a) in the conference about a comprehensive and seamless COVID-19 policy-making methodology: the PASS approach. This approach can be applied to not only the transport sector but also other sectors, in theory. The public health sector emphasizes containment, mitigation and support measures, while the PASS approach emphasizes how to contain, mitigate, and support. Zhang (2020a) proposed more than 100 policy measures that should be taken by governments, transport operators and
users, and identified key policy-making gaps and cultural differences of policy making. The approach emphasizes that transport policy measures must be a key part of general COVID-19 policies, supported by effective cross-sectoral collaboration. The approach can better support COVID-19 policies by further targeting different types of policy instruments, such as laws and (de-)regulations, economic measures, technologies and enlightenment, in response to different stages of the pandemic: during the pandemic, the transition and recovery stage, and the post-pandemic stage.

Taking the current pandemic as an opportunity to reconfigure future transport policy, Budd and Ison (2020) proposed the concept of responsible transport by arguing the importance of individuals as a responsible autonomous actor in delivering socially desired transport outcomes in response to COVID-19, in addition to environmental consideration. This concept claims that individuals should reconsider their needs of trip making, especially related to work, and carefully choose travel modes by considering environmental and social impacts. In the transition to responsible transport, the roles of employers and transport service operators are also emphasized, via proper incentives.

Leather (2020) summarized a three-phase set of bounce-back strategies by transport mode to assist countries exiting lockdowns, proposed by the Asian Development Bank. The three phases are a short-term response phase (up to 3 months: emphasizing protective measures), a medium-term recovery phase (up to 1 year: emphasizing care-oriented measures), and a long-term rejuvenation phase (after 1 year: emphasizing pandemic-resilient adaptations), before vaccines become widely available. Protective measures include restricting nonessential travel; providing adequate protective equipment; protecting transport staff, passengers, and consumers; protecting infrastructure; institute contact tracing; and institute health monitoring. Care-oriented measures include introducing demand management measures; introducing contactless technologies; enhancing safety; restructuring concession and service agreements; providing financial subsidies; relaxing or restricting nonessential travel in phases; monitoring, reviewing, and evaluating effectiveness of the response and recovery plan; exploring alternative physical reconfigurations to mitigate the impact of safe distancing; controlling transmission; and flexibly redeploying assets in a constrained environment. Pandemic-resilient adaptations indicate the enhancement of long-term sustainability of services and assets, and mainstream measures as part of overall pandemic-resilient response and operations plan.

According to Ito and Hanaoka (2020), the cruise population in 2018 was 28.5 million, which increased by 43.9% from 2010 and by
70.2% from 2000. Thus, the expansion of the cruise market had been very rapid. The largest share in 2018 was observed in the United States (43%), which was more than five times higher than the share in the second-place countries, including the PRC (8%), Germany (7%), and the United Kingdom (7%). However, the 43% share was 20 points lower than that in 2010. This means that cruising travel had become popular in more and more countries. However, due to the pandemic, for example, the revenue of the world’s three largest cruise line operators decreased to 65% to 75% in the first 9 months of 2020, and it is estimated that suspending cruise operations for 1 day will lead to the loss of about 2,500 jobs and every 1% decline in global cruising leads to 9,100 jobs lost. Internationally, health protocols have been implemented to control the pandemic, with the following key mandatory core elements: testing, mask-wearing, physical distancing, ventilation, medical capability, and shore excursions. Ito and Hanaoka (2020) summarized major safety guidelines for resuming cruise ships by international agencies. Ito and Hanaoka (2020) discussed five lessons and consequently recommended five types of policies.

(a) Different regions, countries, and ports have different safety acceptance standards for cruise ships. This is unhelpful to effectively control the pandemic but also inconvenient to implement the measures required in a cost-effective way. Thus, it is necessary and important to unify different standards.

(b) During the pandemic, many ports in the world refused cruise ships, forcing many ships to wander the sea for a long time. In response to such a pandemic, it is necessary to designate evacuation ports in different parts of the world.

(c) There are usually many passengers on a cruise ship. If infections occur, it is necessary to implement testing as soon as possible. Currently, this is not possible. Thus, it is necessary to make use of advanced technologies.

(d) Too many passengers in cruise ships are more likely to transmit viruses to local communities at nearby ports.

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For reducing infection risks, it is necessary to regulate vessel size, considering the carrying capacity of each local community.

(e) The cruise industry had grown rapidly by 2019. If cruise ships continue to stop all over the world, the entire cruise industry will collapse. To avoid this, de-regulations and economic measures become important, such as reduction and exemption of port-related fees (port entry fee, berth usage fee, facility usage fee, etc.), permission for cruise itinerary without port of call, and temporary relaxation of cabotage regulations.

To implement the above policies, better governance is required. In this regard, Hirschhorn and Veeneman (2020) summarized the main events related to the pandemic and the policy responses in the Netherlands. In March to April 2020, the first lockdown began and avoiding use of public transport was recommended, leading to an immediate and sharp decline (–80% to –90%) in ridership (in reference to 2019) and in fare dodging (especially buses); initially, public transport services were reduced to 50%–60% of normal schedule, but soon were upscaled again because of the national government’s requests on operators to keep “regular timetables” (as an essential service); and later, the National Public Transport Council (NOV-B) started discussions on financial consequences of the crisis. In June, public transport no longer needed to be avoided; availability fees were agreed by NOV-B and approved by the government; the national government and public transport authorities maintained subsidy payments, and the national government promised to pay availability payments to ensure that 93%–95% of operational costs were covered (in total, about €1.5 billion); and operators bore the remaining costs (“bail-in” of 5% to 7%), and waived bonuses and dividends. In September, the public transport demand was on average around 50%–60%, and the national government announced that a new financial package would be available for 2021 (until July). In October–November, a new lockdown started. As a result, avoiding use of public transport was recommended again, but public transport operators were required to keep regular timetables. Because of new falls in public transport demand, operators had to reduce supply again, but ensuring services were available. Stakeholders in NOV-B reached agreement on operationalization of availability payment. The European Commission approved state aid and availability fee was paid by the national government. Under such circumstances, based on the multilevel governance theory, Hirschhorn and Veeneman
(2020) analyzed the decision-making process for a policy response to the COVID-19 pandemic as a critical case of policy making to address the problem, and attempted to explain why and how an agreement has been made to address the financial crisis in public transport and to define a nationally-funded availability payment to operators. The analyses were done by interviewing 14 key actors involved in the negotiation of financial aid (including politicians, officers in public transport authorities and operators, officers in the national government, key members in organized interest groups), and desk research of policy documents, correspondences, and news pieces. They identified key governance factors driving the formulation of this policy response to the crisis across three analytical levels: policy (the decision-making arrangements and instruments), politics (actor constellation and their patterns of political mobilization), and polity (formal governance structures). In the first dimension, policy, the authors highlight the use of informal cooperation platforms as main decision fora—this is the case of NOV-B mainly—a practice that follows the usual Dutch approach of governance via consultation and concertation. This way, informal practices and interactions that are commonly accepted despite not being formally codified are spun around formal procedures to ensure coordination. Concerning the second dimension, politics, the authors highlight the role taken by specific key actors that show leadership and act strategically to advance their interests during negotiations. These individuals activate resources, promote diverse coalitions, take multiple roles, and use their skills and social acuity, travelling across different jurisdictional levels of decision making to drive the policy outcome. Finally, in relation to the polity dimension, the authors show how some formal governance elements were relevant in the decision process. The Ministry of Infrastructure and Waterways, formally responsible for transport policy and transport funding, was enabled by these responsibilities and eventually took the role of coordinating the decision-making process (meta-governor role). The formal separation between the responsibilities for funding and planning public transport in the Netherlands, between national and regional authorities respectively, also drives important differences in the way players in these different government levels see the crisis and search for solutions. The small size of the public transport market, involving few operators and authorities, was also an important factor to make negotiations more fluid—players know each other and trust each other. On the other hand, the allocation of revenue risks in concession contracts (net cost and gross cost), which the authors had assumed would be influential for discussions on the state-aid scheme, did not play a significant role.
2.15 Conclusions and Further Challenges

The COVID-19 pandemic has not been controlled. Infection indicators change every day. A limited number of countries have started vaccination, but at a very slow pace, while it is still uncertain in many other countries when vaccination will start. According to the WHO (2020), it is unknown how large the percentage of the population must be vaccinated against COVID-19 to begin inducing herd immunity. It is further unclear when and how many of the population will be vaccinated. Thus, nonmedical countermeasures are still required. Countries all over the world have to confront various uncertainties ahead, and it is important to promote more research with sound scientific evidence for supporting COVID-19 policy making. In the transport sector, even though it is unfortunately not positioned as the main troops of the battle, a huge amount of money has been invested and numerous research and practice efforts have been made by researchers and all relevant stakeholders. This chapter summarized the state-of-the-art and the state-of-the-practice of such efforts, by making an overview of the presentations made in the ICPT2020, which is the first full-scale international conference on pandemics in the field of transportation.

Effective policy measures are required urgently. From this conference, a variety of new evidence has been revealed and more than 100 measures have been proposed. Some key findings are summarized below.

(1) Risk levels of the transport sector: The infection risk level in the transport sector, especially public transport, was high in the initial stages of the pandemic. Even though transport clusters of infections are limited, they should not be ignored. The risk level in the transport sector has declined largely; however, caution is still required for safe use of transport systems via effective physical distancing measures. Probably because of higher infections in the initial stages and many unknowns related to the infection mechanisms, it is still difficult to rebuild confidence in using public transport within cities and intercity transport modes, such as airlines and railways. To prevent infections, some countries have practiced limiting the number of passengers. However, there is no scientific evidence on how much public transport demand should be limited, due to a serious lack of collaboration between the transport sector and public health sector.

(2) Understanding the impacts: The various impacts caused by the COVID-19 pandemic have been extensively investigated worldwide, by making clever use of Big Data and Open Data and through the implementation of surveys to the general
public, experts, policy makers, and a variety of stakeholders. Unfortunately, there are still many inconsistent observations, suggesting the necessity of conducting more international comparisons based on large-scale data with richer information about various causalities.

(3) **Association between transport and the pandemic:** Transport systems are a part of the drivers of the virus spread. It is observed that active human mobility and the resulting person-to-person contacts are strongly associated with the spread of the virus. Probably because of such associations, many countries have experienced a resurgence of infections after resuming economic activities. The pandemic should be controlled by reflecting such phenomena. After the highest peak was observed during early January 2021, global infection cases have dropped largely. On the other hand, vaccinations has been deployed at a very slow pace globally, and there are still many countries waiting for vaccines. Under such a situation, economic activities should not be resumed carelessly without adequate protection measures. In other words, it is worth exploring how to resume economic activities in a well-controlled way, where the transport sector should play a key role in controlling the resurgence of widespread infections, via smart mobility management and under close collaboration of other sectors.

(4) **Aviation:** Impacts of COVID-19 on the aviation sector are serious, where bankruptcy and unemployment are widely observed, even though various policy measures have been taken, including those prepared before the current pandemic. This suggests that existing measures are not sufficiently effective to address the impacts of COVID-19. Worldwide resumption of airline operations will be a symbol of the victory against the current pandemic; however, it is still unclear when this victory will come. Individual airline companies, the whole aviation industry, governments, and international organizations, as other stakeholders, should continue to work together to solve how to recover from the pandemic and rebuild the whole aviation industry after the pandemic. Considering there are some regions and countries that are highly dependent on international tourism, it might be worth exploring how to welcome tourists in a well-controlled way, with close collaboration with the aviation industry.

(5) **Measures of logistics and supply chains:** While the economic damage to logistics and supply chains has been significant,
serious social and business operation issues have been revealed. For example, many seafarers whose contracts have expired still remained onboard, while many other seafarers are waiting to replace them. Urgent humanitarian and employment measures to protect and support seafarers are required. Meanwhile, the current pandemic has presented an opportunity to promote smart logistics and supply chains via digital development.

(6) **Active transport:** The COVID-19 pandemic also provides an opportunity for extensively promoting active transport in both developed and developing countries. The reallocation of road space has been a major instrument; however, it is still a big challenge how to sustain this policy measure. Obviously, there are some people who have become new users of active transport due to fear of infection risks of using other transport modes. It is therefore important to take effective measures encouraging these new users to continue the use of active transport, even after the pandemic.

(7) **Behavioral policy making:** Life-oriented policy making should be strongly promoted from the following perspectives. First, impacts on people’s lives (especially, those impacts threatening essential needs in life) should be better addressed in COVID-19 policy making. How to rebuild people’s confidence in life is crucial, considering the long-lasting uncertainties. Second, people’s voluntary behavioral changes should be better promoted for both control of the current pandemic and better future sustainable development. Behavioral interventions should be better designed to encouraging co-changes in different life domains by properly identify key behaviors. In this regard, cross-sectoral interventions are crucial. Third, risk communication should be better designed, where both risk information and intervention messages and their targets should be carefully reflected. For this, smart technologies should be better used.

(8) **Timing and intensity of evidence-based policy making:** Scientific evidence for supporting policy making is still limited, requiring urgent and broad international collaboration. Necessary policy measures should be taken as early as possible. Even though voluntary behavioral changes are important and indispensable, stricter measures should be strongly recommended for controlling the pandemic as quickly as possible. Early and intensive policy measures are more likely to lead to social exclusion issues, which should be properly addressed.
(9) *Policy-making methodologies:* Countless measures (including those in the transport sector) have been taken globally. Unfortunately, effects of these policy measures have mostly remained unclear. Viruses causing pandemics are not visible. This suggests the necessity of making policies in a seamless and comprehensive way. In this regard, a PASS approach has been proposed, which argues that COVID-19 policy measures should be taken from nine aspects: i.e., prepare–protect–provide, avoid–adjust, shift–share, and substitute–stop. Different roles of various stakeholders are further emphasized.

(10) *Forward looking:* First, early preparedness is required to prevent the potential growth of car dependence and rebuild the confidence of using public transport. Active transport should be strongly promoted. Second, the current pandemic should be taken as an opportunity for encouraging better changes and discouraging bad changes. Third, roadmaps toward a distancing-sensitive future should be drawn based on careful scenario design by paying attention to the changing economic, institutional, social, technological, and behavioral contexts. It is important to revisit distancing between people, between people and nature, between countries, between regions, between cities, between communities, and between buildings, etc.

**More Research Efforts Needed in the Future**

Examples of future research include more interdisciplinary research between transport experts and public health experts, more evidence-based research on policy making, more lessons learned from history, mutual learning of lessons across countries, more research on emergent capacity building, and more research on how to prepare for future pandemics via broad international collaboration. Research on developing countries is very limited and should be promoted, to which international cooperation is the key. The current pandemic makes direct observations of the various COVID-19 impacts and effects of policy measures in developing countries difficult. For both immediate and long-term responses, it is crucial to quickly establish a data-sharing platform of policy making in all countries of the whole world, in order to derive more scientifically sound evidence-based policy measures for controlling the pandemic and addressing the various issues caused by the pandemic. Data sharing between the fields of transport and public health as well as other related sectors must be promoted.
References


3


Nicholas Johnson, Jai Malik, and Giovanni Circella

3.1 Introduction

The novel coronavirus disease (COVID-19) pandemic has caused significant disruptions to nearly every aspect of society since its emergence in early 2020. On 31 January, the United States (US) Centers for Disease Control and Prevention (CDC) confirmed the first US COVID-19 case in Washington State. By 11 March, COVID-19 was widespread enough to be declared a pandemic. Due to a growing fear of COVID-19, the US public began to travel less and take precautionary measures. During those early stages of the pandemic, many countries and some US states issued stay-at-home orders and travel restrictions to contain the deadly virus. The lockdown policies enacted during that time and the fear of contagion among the public created major disruptions for the US economy and society. Falk et al. (2021) showed how unemployment levels in the US rose to the highest levels since 1948, at 14.8%, in April 2020. By December 2020, the situation had improved, as unemployment rates fell to a still-elevated level (for the US economy) of 6.7%. Especially during the early stages of the pandemic, businesses and schools began having their employees and students telecommute

¹ The authors would like to thank the 3 Revolutions Future Mobility (3RFM) program at the University of California, Davis for partially supporting this research.
if possible, while nonessential stores either shut down or moved to curbside pickup. As of early April 2021, over 30 million people in the US had contracted COVID-19, with 555,638 recorded deaths. The hardest-hit counties have been Los Angeles, Maricopa, Cook, Miami-Dade, and Harris (Johns Hopkins 2021).

Brodeur et al. (2020) summarized the four main indicators of COVID-19 transmission rates. These indicators are (i) the total number of tests, (ii) the number of confirmed COVID-19 cases, (iii) the number of COVID-19 related deaths, and (iv) the number of patients in intensive care and hospitals. These numbers have been monitored through the Center for Systems Science and Engineering at John Hopkins University, which is a good source of data for researchers and policy makers. Using these metrics, and under guidance from the CDC, federal, state, and city governments in the US have been making decisions about which response strategies to enact to mitigate the spread of COVID-19.

As discussed by Cheng et al. (2020), to date, the most prevalent response strategies worldwide have been external border restrictions, health measures (increased testing, resources for hospitals, etc.), quarantine, lockdowns, and restrictions of mass gatherings. Unfortunately, in the case of the United States, it seems that the delay in taking action against the pandemic, a general lack of strong federal policies, and the patchwork of heterogenous responses at the state level have caused an inefficient ability to contain the pandemic contributing to the high death toll in the country. The most visible policy effort in the country was the introduction of social distancing guidelines. Federal guidelines have asked United States residents for many months to limit face-to-face contact with non-household members to reduce the spread of the virus. These guidelines called for maintaining “social distancing” of at least 6 feet from those not in your household, wearing masks, and frequently washing hands. In combination with these efforts, many state governments enacted mandates ordering the closure of nonessential activities, as well as mask mandates and other local regulations, although the response to the pandemic considerably varied by US state (and sometimes even at the county or city level). To meet these mandates, businesses, schools, community centers, and more were required to close their operations or meet the standards necessary to mitigate the spread of COVID-19. The main motivation behind implementing social distancing policies was to “flatten the curve” or prevent the exponential growth in the number of positive cases who contracted the virus and thus limit the burden on medical services.

Both the COVID-19 pandemic and the US government response strategies have impacted the economy, mobility, equity, and society’s well-being. There is already a great wealth of research that is being carried
out, seeking to understand travel behavior changes, the effectiveness of lockdowns, changes in congestion, and greenhouse gas reductions associated with the impacts of the pandemic. While this field of research is continuously evolving, to the extent possible this chapter tries to serve as a synthesis of this body of research for the United States. The studies include various research methodologies, including stated preference and revealed preference surveys, the analysis of geolocated cellphone data, use of travel demand models, scenario planning algorithms, time-series models, among others. These studies have highlighted the significant temporary reductions in travel that have been observed in the United States with some of them trying to assess the expected long-term changes caused by the pandemic.

3.2 The COVID-19 Pandemic in the United States

The response of the United States federal government to the emergence of the COVID-19 pandemic was alarmingly slow. The lack of clear and consistent communication in the early days of the pandemic caused confusion about the severity of the virus and the protocol necessary to address it. Many states took the lead in developing their public health measures, which resulted in a variety of response strategies, and a lack of unifying messages to communicate relevant information to the public. States varied widely in their response measures, with some taking immediate action and others being far more hesitant to issue stay-at-home orders or mask mandates. The patchwork nature of these responses and lack of interjurisdictional coordination contributed to the failure of the United States to contain the virus. Haffajee and Mello (2020) wrote that by 27 March, 56 days after the first US case, all 50 states and the federal government had declared emergencies for COVID-19. But it was not until 1 April, 72 days after the first US case, that 33 states and many localities had issued stay-at-home orders. Further, the efficacy of these orders varied, and many jurisdictions lacked effective enforcement mechanisms, leading to a widespread disregard of CDC guidelines. Haffajee and Mello (2020) attribute the United States response’s primary failure to be the use of localized action to combat a threat that was far beyond local capacity to mitigate. Figure 3.1 and Figure 3.2 summarize the distribution by month of the number of cases and number of deaths attributed to the COVID-19 pandemic in the United States, respectively.

As shown in Figure 3.1, case counts steadily grew through the early months of the pandemic until an initial peak in July 2020. From August
Figure 3.1: Number of COVID-19 Cases in the United States (January 2020 to March 2021)

Source: Created by the authors using data provided by John Hopkins COVID-19 Case Tracker and compiled into a dataset by the Associated Press (John Hopkins 2021).

Figure 3.2: Number of COVID-19 Related Deaths in the United States (January 2020 to March 2021)

Source: Created by the authors using data provided by John Hopkins COVID-19 Case Tracker and compiled into a dataset by the Associated Press (John Hopkins 2021).
to September 2020, case counts began to level off, although the United States saw a rebound with the massive growth in case counts through the fall and winter months. COVID-19 related deaths shown in Figure 3.2 differ somewhat from the spread of COVID-19. In the initial months of the pandemic death counts were much higher relative to the overall case counts. This is likely due to the health-care sector being unprepared to handle a pandemic and the influx of patients that followed. Beyond those initial few months, COVID-19 related deaths followed the relative case counts quite closely, with a few weeks of delay between the peak in the number of new COVID-19 cases and the peak in the number of COVID-19 related deaths. The spread of COVID-19 showed an interesting pattern in terms of the geography and the demographics affected. Wang et al. (2021) sought to identify the spatiotemporal characteristics of COVID-19 spread in the United States. They used county-based case counts to detect weekly hotspots of confirmed cases using spatial and space-time scan statistical analyses to understand the spread from 22 January to 13 May 2020. For the first 6 weeks of the pandemic, cases were documented sporadically throughout the west coast and northeastern states. A rapid spread of COVID-19 occurred until the 11th week where a slight decline in overall confirmed case counts occurred. From this point through the conclusion of their analysis on the 16th week, the authors observed a steady spread throughout the regions in the Midwest, South, and West. Their findings also showed higher rates of COVID-19 clustering in metropolitan counties when compared with rural counties. Higher rates of clustering were also observed in counties with larger populations near large airports (Wang et al. 2021). Past the 11th week of the pandemic, confirmed case counts in metropolitan counties steadily decreased as incidence in rural areas increased. This trend was particularly concerning as rural residents tend to have more limited health-care access and older demographics.

The spread of COVID-19 cases also varied by demographics. Throughout the summer of 2020, the highest incidence of cases had started to shift toward younger adults, with persons aged 20–29 accounting for more than 20% of confirmed cases (Wang et al. 2021). They also observed higher clustering in counties with more black, indigenous, and people of color (BIPOC) residents. Along with this finding there is substantial evidence that COVID-19 has had a disproportionate impact on the health of BIPOC communities across the United States. As of June 2020, the CDC reported that 21.8% of COVID-19 cases in the US were black and 33.8% were LatinX, while these groups only account for 13% and 18% of the US population, respectively (Tai et al. 2021). These groups have had less financial ability to make health conscious decisions throughout the pandemic and often had far greater levels of exposure.
These disproportionate impacts can be traced back, in part, to the history of structural racism in the United States (Tai et al. 2021). Achieving health equity and mobility justice in future pandemic scenarios will require the deconstruction of the legacy of structural racism in the United States. Understanding how this pandemic has disproportionately impacted these demographic groups offers insight into strategies for targeting resources to mitigate the spread in these communities.

The spread of COVID-19 had remained steady through late summer and early fall, although as the winter months approached case counts began to grow significantly. By 3 January 2021, the CDC COVID-19 response team had reported 20,346,372 confirmed US cases and 349,246 COVID-19 related deaths, showing a dramatic increase from a few months prior (CDC 2021). Just a few weeks earlier, on 11 December 2020, the Food and Drug Administration approved the emergency use of the Pfizer–BioNTech COVID-19 vaccine. The Pfizer vaccine’s approval and later the approval for the Moderna vaccine, both approved for emergency use in a relatively short time compared to the usual times required for the development and approval of a vaccine, became a symbol of hope as COVID-19 cases continued to spike. On 27 February 2021, a third vaccine developed by Johnson & Johnson was approved for emergency use. This vaccine offered full protection with a single dose compared to Pfizer and Moderna’s two-dose administration. At the time of writing, a massive effort is underway to vaccinate the population as quickly as possible. As of 6 April 2021, 30,787,596 US cases have been confirmed, with 555,638 COVID-19 related deaths (Johns Hopkins 2021). In the meantime, the federal government has stated an objective of vaccinating most Americans by the beginning of summer 2021.

### 3.3 National Policies in the United States

The US federal government enacted many policies to try to control the spread of COVID-19. These policies included public awareness measures, the configuration of new task forces or bureaus, declaration of emergencies, mobilizing health resources, scaling up of COVID testing, and guidance around hygiene (e.g., face covering). While these policies may have indirectly affected travel behavior and the transport sector, the implemented policies with most impact on transportation include restriction of borders, restrictions on government services, restrictions on mass gatherings, and social distancing guidelines. Table 3.1 summarizes the timeline and details of some of the key national policies that impacted the transport sector in the United States.
Table 3.1: Selected Major National Level Policies with a Potential Direct Impact on the Transport Sector

<table>
<thead>
<tr>
<th>Name of the Policy</th>
<th>First Date of Announcement</th>
<th>Description</th>
<th>Recent updates (as of 15 April 2021)</th>
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</table>
| External Border Restrictions              | 31 January 2020           | The United States (US) first restricted entry of foreign nationals who had traveled to the People’s Republic of China within the past 14 days. This restriction was later extended to foreign nationals who had recently visited other regions including the European Union, Brazil, South Africa, and India. | 1. The US requires all international travelers to provide documentation of a negative COVID-19 test.  
2. The US suspends entry of noncitizens who have been in the Schengen Area, the United Kingdom (excluding overseas territories outside Europe), the Republic of Ireland, Brazil, and South Africa into the US starting 30 January 2021. A similar policy was enacted to suspend the entry of noncitizens who have been in India starting 4 May 2021. |
| Restriction and Regulation of Government Services | 12 March 2020             | Many national level offices temporarily paused some activities. Some of these included pausing of international exchange programs by the Bureau of Educational Affairs and pausing of bringing new recruits to the US Army. | All on-duty or on-site federal employees or contractors are required to wear face masks, maintain physical distance, and adhere to other measures defined by the CDC. |
| Restriction on Mass Gatherings            | 16 March 2020             | The US government launched recommendations at the national level. These encouraged citizens and resident aliens to avoid visiting nursing homes, retirement homes, or long-term facilities; avoid discretionary travel; avoid social gathering of more than 10 people; work from home (except essential workers); take advantage of drive-through, pickup, and delivery options. |                                                                                                                                 |
| Restriction on Cruise Ships               | 17 March 2020             | The CDC issued a No Sail Order (Warning – Level 3, avoid nonessential travel, widespread ongoing transmission) on travel with cruise ships (Allen 2020).                                                          | On 2 April 2021, the CDC released a new phase of the Framework for Conditional Sailing Order for cruise ships operating or seeking to operate in US waters. The CDC issued new technical guidelines for this purpose. |
| Social Distancing                         | 21 January 2021           | The US President issued social distancing guidelines and mask requirements.                                                                                                                                 | 1. The US requires individuals to wear masks at airports, ferries, and all forms of public transport, effective 2 February 2021.  
2. The CDC recommends all individual to wear double-layered masks. |

CDC = Centers for Disease Control and Prevention.  
Source: Created by the authors using information from Cheng et al. (2020).
Table 3.1 indicates that the federal government issued general guidance on responding to the COVID-19 pandemic, with guidelines and executive orders that were also modified over time, as an effect of the change in the federal administration following the November 2020 elections. However, some of the mandatory policies and measures were determined using the discretion of the state, city, and county-level governments. Some of the measures that may have a bigger impact on the transport sector included the closure of schools, closure and/or restriction of restaurants, local lockdowns, and curfews.

While the federal government has provided economic support to the businesses and citizens most affected by the economic crisis caused by the pandemic, there has been no unified response among federal officials and institutions. In light of this, individual states have become largely responsible for managing the impacts of the pandemic. Hale et al. (2020) found that common measures across states were school and workplace closures, travel restrictions, public gathering bans, stay-at-home orders, emergency investments in health-care operations, financial support, and contact tracing. While many states did undertake these measures, they varied significantly in how rapidly they undertook them, how long they used these strategies, and how well they coordinated across government agencies.

The United States Federal Government has released a variety of economic stimulus and financial aid legislation over the course of the pandemic. To better understand these policies Probasco (2021) organized the legislation into five distinct phases. Phase 1 was introduced with the Coronavirus Preparedness and Response Supplemental Appropriations Act that was enacted on 6 March 2020. This initial phase provided $8.3 billion in emergency funds for vaccine development, small business loans, and aid to federal agencies. This act also provided $14 billion to support public transportation agencies as ridership revenues began to fall sharply (EBP 2021). Phase 2 began with the Families First Coronavirus Act that was signed on 18 March 2020 and has an expected long-term cost of $192 billion. The funds in this package were allocated to offer free coronavirus testing, expand food assistance, and provide protections for workers such as paid sick leave. On 27 March 2020, Phase 3 began with the Coronavirus Aid, Relief, and Economic Security (CARES) Act. This legislation provided $2.2 trillion to fund direct payments to taxpayers, additional funds for unemployment insurance, and massive aid to various businesses and organizations. Notably this act allocated $50 billion in aid to passenger airlines and $8 billion for cargo air carriers (Hotle and Mumbower 2021). Another $25 billion was provided for transit agencies across the United States (EBP 2021). Phase 3 also included the Paycheck
Protection Program and Health Care Enhancement Act that was signed on 24 April 2020 and primarily served as interim funding for elements of the CARES Act. The $484 billion introduced with this act funded hospitals, health-care providers, and continued coronavirus testing, while also reestablishing many loan programs. Phase 4 began with the Consolidated Appropriations Act enacted on 27 December 2020 that provided $900 billion in stimulus relief. The act funded a second round of direct payments, aid to government agencies, and economic support for businesses and the health-care sector. Phase 5 began with the American Rescue Plan Act signed on 11 March 2021, which allocated $1.9 trillion for a third round of direct payments, additional emergency funding for government agencies, economic support for businesses, and much more.

3.4 Impacts of the COVID-19 Pandemic on Travel

The COVID-19 pandemic has had a strong impact on activity participation and trip generation of all communities across the United States. As stay-at-home orders were issued across the majority of US states, many had to completely restructure their work, social activities, and daily needs to meet the public health guidelines set by the CDC. Among other impacts, there was an immediate reduction in economic activities as many switched to remote working and online shopping, or simply postponed or canceled many of their activities (and travel). During the pandemic, activities became increasingly centered around the household. Trip purposes, mode choice, the distance traveled, and the frequency of trips were all significantly disrupted during the pandemic. Abdullah et al. (2020) observed that in the absence of trips for work or study, shopping trips became the primary purpose for traveling during the pandemic. Travel distances also tended to be shorter than in pre-pandemic times as individuals began moving more within their immediate communities. People generally began to give pandemic-related factors a greater priority when making travel decisions (Abdullah et al. 2020). This led to a preference for safer means of transportation (in terms of the perceived risk of contracting COVID-19) throughout the pandemic, in addition to many other changes in trip patterns and destination choices. In the following sections we will discuss the impacts on the use of various modes of travel over the course of the pandemic and the likely long-term impacts that each of these modes might experience.
3.4.1 Air Travel

A spatiotemporal analysis conducted by Wang et al. (2021) found a strong correlation between distance to airports and COVID-19 clustering. This suggests that air travel played a significant role in the initial spread of COVID-19. Airlines have used improved cleaning practices, reduced in-flight services, and limited seating on flights to reduce the spread of COVID-19. Despite these efforts, there is clear evidence that airports contributed substantially to the region-to-region spread of COVID-19. Similar to public transport and shared mobility, air travel has seen significant reductions in passenger numbers and air flights throughout the pandemic. As shown in Figures 3.3 and 3.4, by mid-March 2020 the demand for domestic and international flights plummeted as fear of COVID-19 grew among the public and countries began enacting travel restrictions. Hotle and Mumbower (2021) reported that in April 2020 international flights had decreased by approximately 90% when compared with April 2019. Unsurprisingly, the airline industry began seeing massive revenue losses and potential bankruptcy. In the first quarter of 2020, airlines had seen a net loss of $5.2 billion (BTS 2020). The United States quickly intervened with the CARES Act that provided...
$50 billion in loans and payroll support for passenger air carriers and $8 billion for cargo carriers (Hotle and Mumbower 2021). Conditions of this financial assistance included airlines maintaining a minimum level of service to domestic cities, prohibiting pay reductions for airline employees, and prevented the involuntary furloughing of airline workers.

From March to May 2020 airlines saw the largest drop in passenger traffic on record (BTS, 2020). In March 2020 passenger traffic had fallen by an average of 51%, in April 2020 it fell by 95.7%, and for May 2020 it had fallen by 88.4% (Hotle and Mumbower 2021). Hotle and Mumbower (2021) found that the impacts of these drastic reductions were not uniform across all commercial airports. Smaller airports saw smaller reductions in departure operations and passenger traffic than larger hub airports. This trend is attributed to the minimum level of service requirements set by the CARES Act that required a higher proportion of flights at smaller airports. After the first several months of the pandemic, air travel in the United States started to steadily rebound. While at the time of writing big-city airports in San Francisco, Portland, and Seattle are still serving far fewer travelers, many smaller airports have seen increases in passenger volume when compared to
the February 2020 average (Bui and Kliff 2021). As millions are being vaccinated daily (as of spring 2021) and many states are beginning to remove pandemic restrictions, Americans are becoming increasingly willing to travel for leisure. Particularly smaller airports located near outdoor vacation destinations have seen an increase in passenger travel during spring 2021, while international travel remains substantially below pre-pandemic levels. Early speculation suggests that many Americans may begin engaging in “binge” travel behavior, meaning as travel restrictions are removed people tend to over compensate for their perceived loss of travel opportunities during the pandemic (Miao et al. 2021). This theory is supported by the tourism sector seeing a dramatic increase in bookings and demand after positive results from early vaccine trials. For many who feel a strong urge to regain their lost experiences, the benefits may begin to outweigh the risks associated with tourism.

The COVID-19 pandemic created a sudden and dramatic disruption to the airline industry. Through the CARES Act, airlines were able to survive and maintain a minimum level of service for domestic flights. The future of air travel is uncertain as air travel behavior change among many Americans still remains somewhat unclear. However, the pandemic has also provided an opportunity to airlines to reorganize, and many suggest the US airline sector might emerge from the pandemic with a more efficient cost structure, a younger and more efficient fleet, and streamlined services. Revenues might remain lower than pre-pandemic levels for a while, though, as higher-paying business travelers in particular have not returned yet to flying. That will likely particularly affect larger hub-and-spoke traditional network carriers, whose business model more directly depends on business travel, while the current rebound in air travel is mainly associated with an increase in domestic leisure trips.

3.4.2 Activity Patterns and Travel Choices

Figure 3.5 summarizes the mobility trends for walking, driving, and public transport in the United States over the course of the pandemic. As evidenced by the graph, travel with each of these modes fell significantly in mid-March to early May 2020 due to the widespread fear of contagion and the implementation of stay-at-home orders. Both driving and walking rebounded quickly over the following several months, while public transport saw a much smaller proportion of its ridership returning. A small dip in the use of all modes was observed after the winter holidays as a new wave of the pandemic caused the number of positive cases (and deaths) to spike significantly throughout the US,
although the decline in the number of trips during this time was much more limited than in the first phase of the pandemic in 2020. As vaccines began to be distributed, many Americans started to increase their travel and socialization leading to much higher rates of walking and driving while the use of public transport continued to lag behind. Each of these modes will be examined in more detail and in their unique contexts in the following sections.

Figure 3.5: Mobility Trends in the United States (January 2020 to March 2021)

Immediately prior to the announcement of a national emergency, median travel distance was increasing across most counties throughout the United States. Not surprisingly, using an interactive web-based mapping platform developed by the GeoDS Lab at the University of Wisconsin-Madison, Gao et al. (2020) showed that in the immediate aftermath of the declaration of a national emergency most states saw a sweeping reduction in daily mobility. Despite the general trend toward reduced mobility, adherence to stay-at-home orders varied from state to state. Despite warnings from health experts, people in Florida, Arizona, New Mexico, Colorado, Utah, and Wyoming continued to
increase their daily mobility (Gao et al. 2020). By late March 2020, however, most states had enacted stay-at-home orders that broadly reduced mobility in most locations, with only a few exceptions in small counties. In early May 2020, several states began lifting their stay-at-home restrictions. Predictably, median travel distance began to grow in these locations.

Lower-income and less-educated residents showed a less dramatic change in mobility during the stay-at-home restrictions, primarily due to a limited ability to work remotely. Matson et al. (2021) used a longitudinal dataset of travel survey responses to understand this relationship better. They found that most survey respondents in their dataset reported a change from traveling to work 5 days a week to 0 days. However, when these findings were separated by income bracket, they observed that the lower the household income of a respondent, the higher the likelihood that the respondent continued to physically commute to work on a larger number of days also during the pandemic. In other words, lower-income workers had less opportunity to transition to work-from-home during the pandemic.

Agarwal et al. (2020) found that a slight decrease in mobility is correlated with a decrease in the number of COVID-19 related deaths. However, more than a 40% drop in mobility is not associated with a proportional decrease in deaths. Beyond a 40% decrease in mobility the benefits of these restrictions on mortality rates begin to diminish. While other factors might be at play to explain these trends, this could be an important hint that broad, long-term stay-at-home orders limiting mobility may be just as effective as stricter, more strategically timed lockdown procedures. This would be an important finding because the United States bears the costs associated with lockdowns and have been seeking to minimize these costs while ensuring the safety of Americans. Coibion, Gorodnichenko, and Weber (2020) suggested that, in the United States, it was mainly the lockdowns, rather than COVID-19 infections per se, that led to drops in consumption and employment, lower inflationary expectations, and economic uncertainty. Acemoglu et al. (2020) and Brodeur et al. (2020) discussed how various combinations of general or targeted lockdown policies and other COVID-19 related interventions could lead to various results in terms of fatality rate and economic loss. In retrospect, it seems evident that the inconsistent policies and inability of the US authorities during most of 2020 to organize an effective response to control the COVID-19 pandemic led to both significant economic losses coupled with the highest COVID-19 death toll, to date, worldwide. However, the experience from the first
months of 2021, during the vaccination campaign in particular, seems to suggest that the United States’ response to COVID-19 greatly benefited from the massive investments in the development and distribution of the first COVID-19 vaccines. That appeared to be an effective strategy allowing the US to reopen many economic activities at a time in which other countries—that seemed more able to control the virus during the early stages of the pandemic—are still struggling to organize an effective vaccination campaign and reopening plan.

### 3.4.3 Public Transport

The emergence of COVID-19 and the subsequent stay-at-home orders have led to an unprecedented decline in public transport ridership. The degree of decline of public transport ridership varied by system and mode, reflecting different degrees of transit dependence across communities (Liu, Miller, and Schef 2020). For example, Liu, Miller, and Schef (2020) reported that by the end of March 2020 the Washington DC, Metro experienced a ridership decline of 90%, while bus ridership fell by 75%. In contrast to this, VIA Metropolitan Transit in San Antonio, Texas only declined by 30% during the same time period. As of 2 April 2021, across the United States, the use of transit stations was still 27% lower than the average use prior to the emergence of COVID-19 (Google 2021). Ridership reports released by the American Public Transportation Association (APTA) offer some insights into the national trends in public transport ridership by month. Quarter 1 in 2020 saw an average decline in ridership of 9.94% from the previous year’s ridership, mainly because of the normal ridership still experienced during the first two months of the quarter. However, Quarter 2 of the same year saw an average decline of 76.01%, compared with the same quarter in the prior year. Quarter 3 recorded a decline of 62.24%, while Quarter 4 had a 62.16% decline (APTA 2021). This information shows that public transport is having difficulty recovering ridership. In particular, heavy rail, light rail, and commuter rail have seen greater reductions in ridership than buses as downtown office commuters extensively switched to remote work. The smaller reductions in ridership on bus lines likely depend on the fact that riders of the bus network tend to be more dependent on public transport and less able to work remotely than users of rail. In support of these findings, Figure 3.6 uses mobility data gathered by Apple to graph the changes in all public transport ridership over the course of the pandemic.
Figure 3.6: Transit Use Trends in the United States (January 2020 to March 2021)

Source: Created by the authors using Apple Mobility Data (Apple Inc. 2021).

Figure 3.7: Transit Use Trends in Selected States (January 2020 to March 2021)

Source: Created by the authors using Apple Mobility Data (Apple Inc. 2021).
As shown in Figure 3.6 and Figure 3.7, across these different states the trendlines of public transport remain similar overall. Generally, public transportation agencies across the United States experienced a rapid decline in ridership that has very slowly started to recover in the later phases of the pandemic. Transit use in Texas stands out as different from the other US states, with a slightly lower decline in overall ridership. Regardless, the significant declines in transit use throughout the United States created compounding challenges for transit agencies. As revenues from transit fares fell, costs increased from improved sanitation practices (e.g., fogging, regular cleaning of high-touch surfaces), and fear of public transport use grew, transit agencies were forced to scale back their service. Hu and Chen (2021) commented how transit agencies, which often had little ability to determine which communities were most transit dependent and where to cut service, often felt forced to uniformly cut service across all their services. This unintentionally led to increased crowding on select routes, preventing riders from properly distancing and exacerbating COVID-19 spread in their community. In future pandemic scenarios, if transit agencies need to reduce their bus operations, it is recommended that they should try to concentrate operations in low-income neighborhoods where demand is the greatest, and where services continued to be used also during the pandemic by transit-dependent riders who had fewer alternative travel options.

An analysis of King County in Washington State by Brough et al. (2020) showed that between February and April 2020, total trips made to non-home census block groups declined by 57%, while public transit use declined by 74%. However, the decline in the total number of trips from February to July was only 36%. During the same period, demand for transit remained low, at 68% below the pre-pandemic levels. This finding means that transit use did not recover as quickly as total travel during the time King County began reopening. These findings are consistent with national trends. By controlling differences in these trends by socioeconomic group, Brough et al. (2020) revealed a diverse range of travel behavior changes. Not surprisingly, more highly-educated and higher-income transit users had higher capacity to shift modes at the start of the pandemic, while less-educated lower-income transit users had a greater dependence on transit. In support of these findings, Liu et al. (2020) found through their analysis of national public transportation statistics that cities with higher proportions of vulnerable populations and essential workers tend to have significantly greater dependence on public transport. By analyzing the transit ridership in Chicago using a Bayesian structural time-series model, Hu and Chen (2021) found that a similar relationship is seen among racial groups, as transit ridership
declined far more considerably for white transit users than for BIPOC riders. The main causes of this relationship are the lower rates of vehicle ownership among low-income communities and the evidence that “essential” workers are largely non-white and lower-wage workers. Hu and Chen (2021) point to further research, which suggests that the greater dependence on transit seen in these groups contributes to the higher COVID-19 transmission rates in BIPOC, uneducated, and low-income communities. Meaning that some degree of the disparity of COVID-19 related deaths among these groups can be attributed to transit dependence.

3.4.4 Car Travel

Similar to public transport, car travel saw a significant decline in the first few months of the pandemic. Many cities across the United States had significantly fewer cars on the road after stay-at-home orders were implemented. From early March 2020 to the end of April 2020 nationwide vehicle miles traveled (VMT) had fallen by an average of 39% (Lindquist and Jiao 2020). In New York City, Wang et al. (2020) observed that trips by personal vehicles initially fell by 58%. Similar major declines in car travel were seen in several other cities across the country. As the pandemic progressed, private vehicle use began to rebound quickly as many considered personal vehicles the safest way to travel. This mode preference in combination with Americans returning to some degree to physically travel to work while at the same time engaging in more discretionary travel (and disregarding health recommendation) likely led to this increase in driving. Figures 3.8 and 3.9 detail the trends in private vehicle use from January 2020 to March 2021. Throughout each of these figures there is a consistent story of a rapid decline in driving in the early months of the pandemic followed by a significant rebound. The most evident examples are Washington and Texas where the amount of driving in 2021 was significantly higher than pre-pandemic levels.

With fewer vehicles on the road, cities began to see declines in both air pollution and the number of vehicle collisions. Across the United States, Brodeur et al. (2021) observed a 25% reduction of PM2.5 in populous counties. Their studies also indicate that counties with younger populations and a greater share of remote-work capable jobs saw a greater reduction in air pollution. As average vehicle trip duration and frequency fell, many states saw a significant reduction in traffic collisions. Using data from Alabama, Connecticut, Kentucky, Missouri, and Vermont, Brodeur et al. (2021) computed a 50% reduction in traffic collisions after stay-at-home orders were enacted.
Figure 3.8: Driving Trends in the United States (January 2020 to March 2021)

Source: Created by the authors using Apple Mobility Data (Apple Inc. 2021).

Figure 3.9: Driving Trends in Selected US States (January 2020 to March 2021)

Source: Created by the authors using Apple Mobility Data (Apple Inc. 2021).
Another aspect of the car role in this pandemic was its use for long-distance travel. Fatmi (2020) reported that at many stages during the pandemic the majority of completed long-distance travel was done by private car, as personal vehicles were increasingly used for long-distance regional travel as a safer alternative to flying. Approximately 27% of the regional travel by car was done by management professionals, suggesting that private cars also were used for a significant portion of business trips.

In the more recent phases of the pandemic, car traffic has rebounded significantly. For example, Wang et al. (2020) observed how in July 2020 VMT in New York surpassed 100% of the typical normalized VMT for the month of July. In more recent months, the evidence of personal vehicle use making a dramatic comeback has been ubiquitous across the United States. To reduce the negative externalities caused by a massive increase in personal vehicle use investment in sustainable transportation will be more necessary than ever.

### 3.4.5 Shared Mobility

The COVID-19 pandemic has deeply impacted the use of shared mobility including ridehailing services such as those provided by Uber and Lyft in the United States. These ridehailing services had grown rapidly in the past several years and had begun to cement themselves as an integral element of the transportation network by the time the pandemic hit the country. Matson et al. (2021) observed that from 2019 to spring 2020 the use of ridehailing among their survey respondents had fallen from 18.7% to 7%. In an attempt to improve rider safety while using ridehailing, Uber and Lyft set new rules requiring mandatory use of masks, increased cleaning practices, allowing only backseat seating, and encouraging open windows while riding (Uber 2021). Uber and Lyft also suspended their pooled services as social distancing would not be possible when allowing multiple passengers to be matched by the companies to share a ride (Lyft 2021). Despite these safety efforts undertaken by Uber and Lyft, and also as a result of the reduction in the number of trips for many travel purposes, many chose to forego using ridehailing during the pandemic due to fear of exposure to COVID-19. Paul (2020) wrote that in August 2020, Uber reported that demand for its ridehailing services had fallen by 73% compared to August 2019. For this same period, Lyft saw a 60% decrease in revenue. These numbers represented a huge blow to these companies’ goals of becoming profitable and posed a challenge to their long-term viability. Shamshiripour et al. (2020) speculate that
this shift away from ridehailing services is accompanied by an increase in the use of private vehicles and active modes.

Carsharing services such as GIG Share and Zipcar also had to rapidly adjust their business model to ensure their user base’s safety and health. Carsharing companies made some initial changes to their business model, e.g., promoting monthly and weekly rentals of their vehicles as a safe mobility solution for customers who do not own a car, and improving sanitation practices (Zipcar 2021). Later on, these companies started to experience a growth in demand. Paul (2020) reported how according to a Zipcar spokesperson the company added hundreds of cars back to their fleet to meet the growing demand for their services as stay-at-home orders were lifted. This trend is attributed to few Americans being able to afford a new car and an increased interest in personal vehicles stemming from COVID-19 also among zero-vehicle or low-vehicle owning households. Shared-mobility companies have suffered from the COVID-19 pandemic but their business is expected to rebound solidly as we move out of the pandemic (Shokouhyar et al. 2021). Bike and e-scooter sharing also saw large declines in usage in the initial months of the pandemic, and in some cases even citywide bans on their services. In New York City, Teixeira and Lopes (2020) observed a 71% decrease in the use of the city’s bikesharing service. Lopes (2020) also observed how bikesharing in New York was more resilient to ridership declines than public transport. Bikesharing even saw a significant growth in the average trip duration, leading to speculation that a modal transfer occurred from public transport to bikesharing. Many cities have been trying to capitalize on these modal shifts and the increase in active modes of travel. To ensure that there is not a disproportionate increase in private vehicle use in the post-pandemic society, cities should enact robust policies and invest in infrastructure to accommodate the use of active modes, as well as bikesharing and e-scooter sharing.

3.4.6 Active Travel

As cities across the United States went into varying degrees of lockdown, people seemed to take greater notice of, and enjoy to a greater extent, the built environment surrounding their homes. Americans began to walk, bike, jog, and engage in other leisure travel far more frequently, also as a reaction to the stay-at-home policies and reductions in other forms of travel, and the temporary closure of many gyms and other sport facilities. Public outdoor recreational space began to be used more as nearby residents sought safe ways to get out of their homes and engage
in physical activities. According to the mobility trends reported by Google, trips to public parks, green spaces, and national parks increased by 11% nationally (Google 2021). Recreational bicycling in particular has seen a massive resurgence throughout the pandemic. Nurse and Dunning (2020) reported that bike shop owners they spoke with had reported selling out of entry-level bikes as demand grew substantially. While all these people began taking to the streets, it became quickly apparent that the current pedestrian and bicycle infrastructure in most American cities was woefully inadequate. Pedestrian space was unfit for meaningful physical distancing as sidewalks and pedestrian paths are rarely wide enough for safe passing (Nurse and Dunning 2020). While many cities have started to make relevant efforts to convert car space to pedestrian and bicycling facilities in order to capitalize on the resurgence of active modes and facilitate the use of these modes, additional efforts should be made to not only improve infrastructure for recreational active travel but also to invest in utilitarian pedestrian and bicycle infrastructure.

As shown in Figures 3.10 and 3.11, national walking trends seem to follow rather closely with personal vehicle use. As Americans became more relaxed in their fears of COVID-19, walking and driving steadily
increased. After the initial few months of the pandemic, the amount of people getting out of their homes and walking for recreational or utilitarian purposes has stayed mostly above pre-pandemic levels. To meet this growing demand, several US cities, including Oakland, New York, and many others, began reclaiming space for pedestrians along their streets, in what Nurse and Dunning (2020) describes as the “taking back” of road space. This typically involved reclaiming parking spaces for outdoor dining, creating temporary cycle lanes, or closing off streets for temporary conversion into pedestrian-only spaces.

The COVID-19 pandemic has created an enormous opportunity for cities to test pedestrian-oriented infrastructure in their cities. Oakland’s Slow Street program implemented a temporary plan which closed 74 miles of the city’s streets to through traffic, which is equivalent to 10% of their streetscape (Bereitschaft and Scheller 2020). Along with this, 21 miles of streets were designated as slow streets with temporary barriers and signage to alert drivers of the reduced speeds. Time will tell whether these temporary redesigns of urban streets will remain, though there are signs that at least some roadways in US cities will be...
permanently altered. Bereitschaft and Scheller (2020) highlighted that in Seattle 20 miles of the local street network has been permanently closed to vehicle through traffic. Through the analysis of their nationwide survey, Conway et al. (2020) observed that many respondents expected to increase their walking and bicycling even in the post-pandemic time. As more Americans begin to engage with the built environment around them, we are presented with an enormous opportunity to reimagine active travel in our cities.

3.5 Changes in Lifestyles and Business Operations

The COVID-19 pandemic created a massive shift in American lifestyles. People have been finding new ways to work, learn, interact with others, shop, travel, and entertain themselves. The most evident changes have been a significant increase in the time Americans spend at home and an increased dependence on information and communication technology for work, socialization, and leisure activities. As work-from-home became ubiquitous and stay-at-home orders were enacted, Zhang and Hayashi (2020) observed that residential energy use increased by 20% compared to previous years. Grashuis, Skevas, and Segovia (2020) reported that consumer expenditure on groceries and grocery services has been on the rise throughout the pandemic as many eating establishments closed temporarily. Google's mobility reports have found that trips to grocery stores and pharmacies increased by 3% nationally throughout the pandemic (Google 2021). Online retail has seen robust growth, with its market share growing from 3%–4% to 10%–15% as more Americans chose to do their shopping from home. Grashuis, Skevas, and Segovia (2020) conducted a national survey to understand changes in grocery purchasing methods, time windows, and online grocery shopping constraints. Their findings show an increase in grocery delivery preference and curbside pickups, with grocery deliveries being significantly preferred to curbside pickup. Similar trends are seen in retail, with Americans finding e-shopping and deliveries preferable to in-store shopping.

Stay-at-home orders and social distancing guidelines had devastating impacts on small businesses across the United States. Fairlie (2020) found that by April 2020, 22% of small business owners were inactive with disproportionate impacts on BIPOC, immigrant, and female business owners. Small businesses made a slight rebound during
summer, with May 2020 seeing 15% of small business owners inactive. Donthu and Gustafsson (2020) commented how large companies such as Sears, JCPenney, Hertz, and J. Crew have come under immense financial pressure, with many of them turning to bankruptcy protection and restructuring plans to survive. The travel and entertainment industries saw significant workforce layoffs and considerable declines in demand for their services. While these sectors have been struggling, a few others have been thriving throughout even the most intense peak of the pandemic. Particularly, internet-based companies specializing in online shopping, deliveries, telecommunications, and services for remote work have seen enormous financial success.

From the initial shock of the emergence of COVID-19 and stay-at-home orders, unemployment rates spiked dramatically across the United States. Acs and Karpman (2020) found that 43.4% of respondents to their national survey reported their families suffered a job or income loss because of COVID-19. Adding to these findings, Felipe et al. (2020) found that low-income households’ unemployment rates were four times higher than those in high-income households, highlighting how the likelihood of an individual’s unemployment status during the pandemic was negatively correlated with their socioeconomic status. At the national level, the unemployment rates in the US were substantially connected with stay-at-home orders. For every 10 days of lockdown, employment rates fall by 1.7% (Felipe et al. 2020). With these falling employment rates, the United States saw a very sudden spike in unemployment insurance (UI) claims. Felipe et al. (2020) analyzed the increase in UI claims due to the pandemic in states with high-infection rates and low-infection rates. They found that by 21 March 2020, UI claims had grown by 1,281% in high-infection states and 1,095% in low-infection states. This dramatic spike created a significant strain on unemployment services and led to delays in the distribution of unemployment benefits. In the national survey conducted by Acs and Karpman (2020), 36.3% of adults who had experienced a job loss reported that they had received UI benefits in the last month. About 17% had applied for UI benefits but had not received them in the past month, with 54.6% of this group that had applied and not received any UI benefits. Many of the adults in this last group reported that the process was complex and cumbersome. In the Chicago metropolitan area, Shamshiripour et al. (2020) sought to understand the financial impacts of the pandemic on Chicago workers. In the analysis of the data they collected with an online opinion panel in the Chicago metropolitan area, they found that 50% of part-time
workers and 19% of full-time workers lost their jobs either temporarily or permanently.

Acs and Karpman (2020) found that households with family incomes below 250% of the federal poverty level reported experiencing unemployment or income-related losses at an 8.8% higher rate than families with higher incomes. Unemployment rates for immigrant communities have also been disproportionately higher than US born groups. In the first several months of the pandemic, unemployment among immigrant women rose from 4.3% to 18.0%, while immigrant men saw an increase from 3.0% to 15.3% (Clark et al. 2020). It is important to note how these numbers are likely even worse for undocumented immigrants who were ineligible for CARES Act benefits. Hispanic respondents reported a 14% higher share of losses than non-Hispanic white and non-Hispanic Black adults. Among these Hispanic adults, families with noncitizens were more likely to report higher losses than families where all members are citizens. Throughout the United States, the sectors most impacted by temporary closures have been the hospitality, travel, and nonessential retail sectors. Employees in these sectors typically work for lower-than-average wages. Therefore, the adults most likely to face economic losses due to COVID-19 often already had lower-than-average incomes. These findings support the understanding that the impacts of COVID-19 are associated with disproportionately higher economic losses for blue-collar workers and low-income households.

With Americans spending far more time in their home, many have begun to reconsider where they would like to live. Bereitschaft and Scheller (2020) speculate that the COVID-19 pandemic will have a dramatic impact on where people choose to live. While there has been an evident growth in demand for more urbanized living over the past several decades, the risks posed by contagious diseases may stall this trend. Before the pandemic, the US American Community Survey showed that older adults, specifically those in the 55–74 age range, much preferred suburban, exurban, and rural areas to more centrally-located urban neighborhoods (Bereitschaft and Scheller 2020). A much less predictable group comprises those aged 18–34 who are equally likely to choose to live in urbanized areas or suburban communities. Many of those who live in urban neighborhoods are more likely to forgo lawns, gardens, and private patio space when shared public amenities are available. As these spaces have become less accessible due to the possibility of contracting COVID-19, many have been left with inadequate public space to meet their physiological and psychological needs.
One of the most prominent responses to the COVID-19 pandemic was a dramatic increase in telecommuting among the American workforce. Workers in office jobs, including many government or academic positions, were more likely to switch to remote work than workers in industries that required their physical presence. Thus, many employees in these positions started to telework as states enacted stay-at-home orders. Guyot and Sawhill (2020) suggest that as of 6 April 2020 about half of the employed adults in the country were working from home. Since then, the number of Americans who report working entirely from home has been steadily declining throughout the later stages of the pandemic. The Gallup poll used by Guyot and Sawhill (2020) shows that, by September 2020, 33% of respondents reported working entirely from home. This is a decrease of 18 percentage points from April 2020 (Brenan 2020).

Attitudes toward continued teleworking tend to vary across US workers: according to Brenan (2020), approximately 35% of workers report a preference for continuing to work from home in the future, 30% prefer to work from home primarily out of concern about COVID-19 (and therefore only on a temporary basis), and the remaining 35% would prefer to return to in-person work. Many studies suggest that teleworking will likely continue to play a prominent role in the American workforce for many years to come, with increased percentages of workers telecommuting compared to before the pandemic, even if the daily average number of remote workers in the post-pandemic will likely be way below the pandemic peaks.

The pandemic has had a severe impact on people’s preferred travel modes and will impact travel behavior for many years to come. About 43% of respondents in a survey by Shamshiripour et al. reported that they would reduce air travel in the future. Similarly, Conway et al. (2020) commented that we are unlikely to return to our pre-pandemic way of life, suggesting that an important proportion of Americans will likely have longer-term shifts toward online work, e-shopping, and the use of active modes of travel. This is substantially consistent with the findings from the analysis of survey data conducted by the authors of this chapter, who found that 60% of their survey respondents reported that they will likely continue to travel more by car in the future. In contrast, more than 70% of the respondents reported continued discomfort with the use of public transit and ridehailing, which might

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2 For additional information, see https://postcovid19mobility.ucdavis.edu/.
point to more depressed demand for these services in the near future. It seems evident that, as we move forward from the COVID-19 pandemic, it will be important to increase investments in bike and pedestrian transportation infrastructure, support carsharing, discourage the use of private vehicles also through road pricing and other strategies, and promote online work and other remote activities to prevent an increase in automobile dependence.

3.6 Lessons Learned from the Pandemic-related Policies

A wide range of response strategies to mitigate the impacts of COVID-19 were implemented worldwide and across US states. Perhaps the most significant contributor to the early spread of COVID-19 was the delay in response to its emergence. Khanna et al. (2020) found that if the People’s Republic of China had implemented control measures just a week earlier, 67% of total cases would have been prevented. Similarly, if the United States had implemented response strategies at an earlier stage, the spread of COVID-19 cases could have been slowed considerably. The countries that succeeded at mitigating the pandemic’s impacts during the early stages of the infection all did so through continuous testing, isolation of infected persons, and immediate quarantining of all known contacts (Khanna et al. 2020). Countries such as Singapore implemented immediate travel restrictions, encouraged working from home, offered people compensation for isolation, and encouraged respiratory and hand hygiene rigorously.

In contrast, the United States was slow to implement containment measures and showed an apparent lack of coordination. Khanna et al. (2020) attributes one of the most significant initial failures in the United States response to COVID-19 to be the unclear and conflicting messaging between the US President and national health organizations. With no consistent national policy, a chaotic pattern of response strategies emerged across the 50 states. An absence of widely available testing kits and accurate tracking of the positive cases left hospitals and policy makers unprepared for the rapid proliferation of COVID-19. Since the inauguration of the Biden administration, the US Federal Government has become more consistent in its messaging and policy decisions. However, the authority on preventative measures against COVID-19 has remained at the state level, where actions have continued to vary significantly across states. In the future, it will be important
for the United States to react far more quickly to potential pandemic threats and quickly implement clear national policy while coordinating between different levels of government.

The national and state level management of the coronavirus pandemic was rife with slow decision making, inconsistent information, and ineffective interjurisdictional communication. Forman et al. (2020) identify and discuss many key lessons learned from the handling of the coronavirus pandemic. The first is that transparency of information is vital. Many who tried to warn the global community about the emergence of a novel illness were silenced out of fears of economic and political repercussions. Paradoxically, attempts to prevent panic and maintain economic prosperity by downplaying the severity of this virus allowed COVID-19 to spread rapidly. This caused more harm over the longer term to economic activities. Any successful response to a global crisis can only be successful through decisive leadership and unified responses across governments (Forman et al. 2020). Despite COVID-19 being a global pandemic, there has been little evidence of international coordination as most countries turned their focus inwards. The World Health Organization has urged countries to implement coordinated response strategies. Yet, the speed and intensity of responses have varied significantly from country to country (Forman et al. 2020). While consistent responses are largely the most effective at combating pandemics, “one size fits all” strategies should be avoided as domestic cultures and contexts may warrant unique action.

Forman et al. (2020) also commented how the development of vaccines and treatments has been commendable, but the existing distribution channels for the products of these technological developments are woefully inadequate. Accountability of governments is also a critical factor in building community trust and inclusive decision making. Data, models, and decision-making processes should be presented to the public clearly, as a lack of clarity leads to confusion and mistrust (Forman et al. 2020). Mistrust of government institutions throughout the coronavirus pandemic has been a major challenge for getting communities on board with public health measures. This is evidenced by rampant rejection of mask wearing policies and concern over the safety of current vaccines seen throughout many American subcultures. Finally, technologies such as robots and artificial intelligence can be harnessed to play a vital role in combating contagion. Generally, this pandemic has highlighted the degree to which we have underinvested in health systems, human resources, and health technologies in recent years. We must continue to learn from
the successes and failures of COVID-19 management to better prepare ourselves for future health and environmental crises.

In the transport sector, many lessons have been learned on potential ways to respond to the pandemic to try to harvest some of the potential societal benefits and limit negative externalities of behavioral changes. At the local level, tactical urbanism measures and the repurposing of street space highlight that large scale shocks such as COVID-19 can be harnessed to create positive changes in urban communities. With largely positive feedback from community members near slow streets initiatives, some cities are beginning to reevaluate the role of neighborhood-level traffic calming and people-oriented street design. While these interventions have generally served to improve accessibility and safety, some lower-income communities feel that current programs are not meeting their needs and sometimes conflict with public health messaging (City of Oakland 2020). Reimagining our streets to best serve walking and bicycling post-pandemic will be necessary for creating safe and sustainable areas for all users.

Regarding public transport, reduced ridership and uniform cuts to service across cities created enormous operational challenges and overcrowding on select routes. Hasselwander et al. (2021) suggest several options for prioritizing and making public transport more viable even in pandemic scenarios. One method is to implement pop-up bus lanes and corridors in communities with greater rates of transit dependence. When these measures were implemented in other countries travel times fell sharply while providing high-quality bus service (Hasselwander et al. 2021). Strategically placed pop-up bus lanes could alleviate eventual on-board crowding on select routes. One crucial action for future pandemic scenarios and phasing out of the COVID-19 pandemic will be to leverage big data and mobility as a service (MaaS) for sustainable and resilient transportation systems. MaaS can allow for multimodal travel opportunities which enable the planning of multimodal journeys. COVID-19 may accelerate the uptake of MaaS as it can offer safe, phased reopening strategies for transportation networks throughout the United States (Hasselwander et al. 2021), and help to reduce the eventual increase in car dependence of the post-pandemic society. MaaS provides enormous potential to utilize data for time-sensitive decision-making and long-term transportation strategies. The use of these policies to build a more resilient and dynamic transportation system will help to reduce equity concerns and other negative externalities borne from future health or environmental disasters.
3.7 Conclusions, Policy Recommendations, and Future Research

The COVID-19 pandemic has demonstrated plainly that the United States was unprepared to confront a global pandemic effectively. As the initial spread of the virus began, government agencies at all levels were slow to respond as conflicting information emerged surrounding the severity of COVID-19. The absence of a rapid and uniform response to the initial cases in the United States led to the early spread, which eventually prompted many states to implement stay-at-home orders. Mobility trends across all modes and nearly every geographic location plummeted mid-March 2020 as many switched to remote work and learning, or were temporarily furloughed from work. Gradually, the use of active modes of travel and driving began to rebound while public transport only recovered a small portion of its ridership. A spike in case counts began in July and August of 2020 as several states had begun to prematurely lift some of their more severe COVID-19 restrictions. This modest spike appeared insignificant compared to the massive proliferation of COVID-19 cases over the winter 2020–2021 holidays. Despite warnings from public health officials and many state governments, Americans had gathered to spend time with their families and socialize throughout the months of October, November, and December, leading to the dramatic spread of the virus. This dramatic increase in COVID-19 cases created additional strain on an already overburdened health-care sector leading to a spike in COVID-19 related deaths. More recently, the emergency authorization of three highly effective COVID-19 vaccines has offered some hope for an eventual end to the pandemic and a gradual return to a “new normal.”

This unprecedented global crisis has led to tremendous tragedy and uncertainty, although, through this shock, the country has also been presented with an opportunity to improve many aspects of society. Particularly the transport sector has seen some radical changes throughout the pandemic. Public transport, ridehailing, and shared mobility services have experienced massive declines in ridership as many Americans developed a strong fear of contagion when traveling in close proximity to non-household members. In contrast, active travel, the use of private vehicles (and, to a certain extent, of carsharing), and telecommuting have all seen incredible success as Americans have begun to incorporate these modes into their lives.
Overall, the most concerning transportation trend which has emerged from this pandemic is the quick and substantial rebound of personal vehicle use throughout the United States. Daily VMT has even surpassed pre-pandemic levels in several cities, despite over one-third of workers continuing to work from home. Aside from these general observations, there are many elements of the COVID-19 impacts on transport that need to be better understood. Future research should seek to gain a more holistic understanding of the short-term and long-term impacts of the pandemic on the use of private vehicles, public transportation, active travel, shared mobility, and air travel. The increased demand for certain forms of shared mobility (including bikesharing) and active travel provides enormous opportunities to develop policies and infrastructure that support these modes. Understanding how to get more Americans to embrace sustainable transportation modes will be critical for developing more equitable and resilient transportation systems.

Understanding more comprehensively the pandemic impacts on transportation equity and mobility justice will be vital to centering the voices of those most negatively impacted by COVID-19 in future transportation decision making. Much work is to be done to guide the trends and impacts towards making the United States a more sustainable and equitable country. We must take advantage of the limited positive news that have emerged from the pandemic, such as increased active travel, greater acceptance of working-from-home, and reduced air travel, to potentially expand environmental beneficial changes into longer-term travel patterns.

The US governments’ response strategies and inability to effectively control the COVID-19 pandemic have caused significant damage to and disruption of the nation’s economic activity. Some industries were able to adapt rapidly to the pandemic. In contrast, others were ill-prepared or unable to adjust their business models to suit pandemic conditions. This shock to the economy will be evident for many years to come, as many Americans either lost their job, had difficulty paying their bills, got seriously sick or died, or had increased financial burden throughout the COVID-19 pandemic. While the US Federal Government has made a serious effort to provide financial assistance and economic support throughout the pandemic, these efforts will likely not be enough to protect the most vulnerable members of the society from long-term financial crises. In future pandemic scenarios, there must be a swift and consistent reaction to the threat of viral spread to avoid the massive death toll and economic burden which was associated with the COVID-19 pandemic. Our economy must be better prepared to adjust to massive disruptions
such as a future pandemics and other disruptive scenarios. In particular, we must work to improve institutional support for small businesses and the unemployed during times of economic shock as significant as a global pandemic, and better coordinate responses and preparedness across all levels of government. With a better understanding of how to address a global pandemic, we can move forward with the knowledge necessary to mitigate the hardships caused by these disasters.
References


4

A Transport Policy Model for COVID-19 Response: A Mosquito/Malarial Analogy

Yoshitsugu Hayashi and Hiroyuki Takeshita

4.1 Introduction

The coronavirus disease (COVID-19) pandemic, which began to expand from late 2019 to early 2020, wreaked havoc on the world. People’s activities were forcibly or voluntarily curtailed, which resulted in an economic disaster. In particular, this curbing of activity has caused significant damage to the transport, tourism, and food and beverage industries, among others. Figure 4.1 shows the national statistics of the number of overnight stays by visitors by month in 2019 and 2020 (Japan National Tourism Agency n.d.). The significant drop in 2020 compared to 2019 illustrates the impact of the pandemic on the transport and tourism industries. Some hope emerged with the successful development of an effective vaccine in 2020, but the pandemic still shows no signs of abating in 2021.

Figure 4.1 shows a recovery trend from July to December 2020. This can be attributed to the “Go to Travel Campaign,” a policy launched on 22 July 2020 (Tokyo Prefecture to start on 1 October) to encourage tourist travel in order to support the tourism industry. Financial support to the tourism and transport industries have been seen not only in Japan but also in Thailand and the People’s Republic of China.

As the number of new infections started to increase again in parallel with the campaign, the campaign was criticized for being premature in stimulating tourism. The campaign was temporarily suspended on 28 December 2020, just before the New Year’s holiday, a time when Japan normally sees a significant increase in travel demand.

Did such a campaign really contribute to the spread of the COVID-19 pandemic? Is it possible that the kind of activities people did in the tourist area, rather than traveling to the tourist area itself, may have
affected the expansion? For example, in the United Kingdom (UK), the “Eat Out Help Out” campaign was launched to subsidize eating out in order to support the restaurant industry, which was also hit hard by the COVID-19 pandemic. According to a study by the University of Warwick, this campaign increased the demand for eating out, which was a factor in the second wave of the pandemic in the UK (Fetzer 2020). In Japan, a similar policy was launched on 1 October 2020—Japan’s was called the “Go to Eat Campaign”—but this too was suspended on 28 December 2020 due to the increase in the number of new infections.

In this chapter, we propose the “mosquito hypothesis,” which considers the spread of the COVID-19 pandemic in three factors: travel, activity, and protection. This hypothesis can evaluate the measures to control the spread and to promote the economy in each stage. Case studies using this hypothesis are presented.

4.2 How Has the Spread of Infection Been Predicted by Models of Infectious Diseases So Far?

In the field of infectious disease epidemiology, mathematical models of infectious diseases have been used to predict pandemics. Particularly in the early stages of an epidemic, the results of predictions made by such models have often been used to examine policies.
For example, in Japan, based on the results of analysis using such a model, Nishiura (2020) proposed that activity should have been reduced by 80% with the aim of reducing contact with others in order to manage the COVID-19 pandemic at an early stage.

Based on these recommendations by the infectious disease epidemiology experts, a state of emergency was declared for the Tokyo and Osaka metropolitan areas on 7 April 2020 (later extended to cover the whole country on 16 April), and citizens were requested to refrain from going out for various activities. Stores and facilities were required to close or shorten their business hours for 1 1/2 to 2 months. Since there is a major holiday period in Japan in early May, a state of emergency was declared just before. This is thought to have been highly effective in preventing the spread of infectious diseases, but also to have had a significant impact on the economy.

Now, what is the mathematical model of infectious diseases used in infectious disease epidemiology? The first mathematical model of infectious diseases is the SIR model, which was developed by Kermack and McKendrick in 1927 in the UK as a model for describing infectious disease epidemics. The model classifies the target population as susceptible (S, in other words, uninfected), infected (I), or recovered or removed (R) and expresses the dynamics at each point in time as an ordinary differential equation. The SIR model is shown below.

\[
\begin{align*}
\frac{dS(t)}{dt} &= -\beta S(t)I(t) & (1) \\
\frac{dI(t)}{dt} &= \beta S(t)I(t) - \gamma I(t) & (2) \\
\frac{dR(t)}{dt} &= \gamma I(t) & (3) \\
S(t) + I(t) + R(t) &= \text{Const.} & (4)
\end{align*}
\]

In other words, in equation 1, an uninfected person \(S(t)\) at time \(t\) will become an infected person \(I(t+1)\) at time \(t+1\) with a certain probability \(\beta\) through contact with an infected person \(I(t)\) at time \(t\). In equation 2, the infected person \(I\) at time \(t\) becomes the recovered (or removed, if they have died) person \(R\) with a certain probability \(\gamma\). Equation 3 shows that the recovering (or dead) person \(R\) becomes immune (or dies) at time \(t\) and does not become infected again after that.

In addition to the SIR model, there are many other variations, such as the SEIR model, which considers the incubation period \(E\) (exposed) of the virus; the SIS model in the case that immunity cannot be obtained; and the model that considers vaccine administration. The basic idea
these models have in common is to represent the movement at each point in time as ordinary differential equations.

These models are capable of predicting pandemics with little data, especially in the early stages, and are useful in considering policies to control the spread of a pandemic. They are also useful in considering policies to control the spread of the disease and countermeasures against infectious diseases during normal times.

However, because behavior may change in a prolonged pandemic and because people's behavior is complex (i.e., the parameters are diversified according to individual attributes and social conditions), parameters that represent infection and recovery as constant may not be suitable to consider and recommend policies under a prolonged pandemic.

In addition, the basic SIR model assumes that the number of uninfected people (S(t)), infected people (I(t)), and recovered or removed people (R(t)) is constant, which may not be suitable for considering policy recommendations that take into account the movement of people. For this reason, it is considered difficult to make specific policy recommendations, such as whether to stimulate movement and activity as an economic measure, as mentioned in the previous section, and if so, when to do so. Therefore, we need a framework to describe the spread of infectious diseases that takes into account movement and activity.

Even the predictions using artificial intelligence currently provided by Google are based on the SEIR model, and the parameters are estimated using machine learning from past data. In this way, in the field of epidemiology, researchers are trying to improve the model in order to address the issues mentioned above; this is cutting-edge research.

4.3 The Mosquito Hypothesis, a Framework for Verifying the Spread of Infection That Considers Movement and Activity

In this section, we discuss the mosquito hypothesis. This hypothesis attempts to describe the spread of the COVID-19 pandemic as an analogy for the spread of mosquito-borne infectious diseases such as malaria. This section will attempt to understand the spread of the COVID-19 pandemic, taking into account the impact of people's movement and activities, and lead to policy recommendations to prevent the spread of infection.
4.3.1 What Is the Mosquito Hypothesis?

Hayashi proposes that the process of COVID-19 transmission is similar to the transmission of diseases such as malaria by mosquitoes (Hayashi and Zhang 2020; Takeshita et al. 2020; Hayashi and Zhang 2021). A mosquito flies in, comes into the room, and finally bites you. And if you are unlucky, you will be infected.

What can we do to avoid mosquito bites? Mosquitoes carry infectious diseases such as malaria and dengue fever, especially in the tropics. Therefore, mosquitoes are the deadliest animal in the world (although the second is humans ourselves) (Gates 2014). In order to avoid infection by such diseases, we must avoid mosquito bites.

In order to prevent mosquito bites, one can take measures such as getting rid of mosquitoes in the first place. However, it is difficult to get rid of all mosquitoes, and we have to live with a certain amount of them. Secondly, you should not go to places where there are a lot of mosquitoes if you do not want to get bitten. Still, there will be times when you must go to places where mosquitoes are present. In this case, you should wear long-sleeved clothes, use insect repellent to prevent bites, and light mosquito coils to keep mosquitoes away from you.

Using the mosquito example as an analogy, the mosquito hypothesis proposed here is a framework to trace the workings of COVID-19. In other words, uninfected people and COVID-19 infected people (especially asymptomatic people) move freely, just like humans and mosquitoes do. The act of movement itself does not spread the infection; it is when they encounter each other that the infection spreads. Therefore, it is necessary to prevent infection by wearing masks and keeping a certain distance between people. In addition, activities in enclosed spaces with a high density of people, which are said to have a high risk of infection, should be avoided as much as possible, and organizers of events and other activities should create spaces that avoid such situations.

Table 4.1 shows the relationship between humans and mosquitoes and between uninfected and infected people. In this way, we can divide the process of infection (up to the point of a mosquito bite) into several stages and model the relationship between each stage, which will make it easier to study specific policies and compare and analyze policies in different countries and municipalities. In this section, we will divide them into three stages: travel, activity, and protection. We refer to these as “stages of strategy.” Table 4.1 also includes “remove,” which eliminates the pathogen (carrier), but because of the various problems involved in doing so for humans, we have not included this as a step in the process. However, if an infectious disease with a COVID-19 or higher level of contagiousness appears, we may need to consider it.
4.3.2 The Relationship between Travel and Activity

Figure 4.2 shows the relationship between the activity and travel stages. The graph represents the generalized costs of transport on the horizontal axis and the utilities from participating in activities on the vertical axis. Here, we consider that the generalized costs include the easily measurable ones, such as fares/costs and time, as well as the psychological or mental costs such as avoidance of travel due to the spread of COVID-19, which would be hard to measure. And suppose that the utility gained decreases with the increase of generalized costs. In other words, as the generalized costs increase, the utility gained decreases. In accordance with the decrease of utility, the number of people participating in activities is also expected to decrease.

Furthermore, when the generalized costs increase to some extent, shifting from going out to doing activities at home would be expected. The increase in activities at home would be explained by the fact that the generalized cost of shifting to home activities is smaller because the same activities can be done at home due to technology improvements.

Table 4.1: Comparison between Mosquito Bites and Infections

<table>
<thead>
<tr>
<th></th>
<th>How to Prevent Mosquito Bites</th>
<th>How to Avoid COVID-19 Infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel</td>
<td>Mosquitoes flying around does not in itself lead to the spread of infectious diseases.</td>
<td>Moving itself is not an infectious act.</td>
</tr>
<tr>
<td>Activity</td>
<td>Avoid going to places where there are many mosquitoes.</td>
<td>Avoid going to places where the risk of infection is high.</td>
</tr>
<tr>
<td></td>
<td>Create a space where mosquitoes cannot enter (mosquito net, screen door, etc.).</td>
<td>Avoid creating an enclosed, high-density space.</td>
</tr>
<tr>
<td>Protect</td>
<td>Use insect repellent.</td>
<td>Wear a mask.</td>
</tr>
<tr>
<td></td>
<td>Use mosquito coils.</td>
<td>Keep social distance from others.</td>
</tr>
<tr>
<td></td>
<td>Wear long-sleeved clothes.</td>
<td></td>
</tr>
<tr>
<td>Remove</td>
<td>Exterminate mosquitoes.</td>
<td>Forcibly quarantine all infected persons (and suspected infected persons).</td>
</tr>
</tbody>
</table>

Source: Authors.
4.3.3 The Relationship between Activity, Protection, and Infection

Figure 4.3 shows the relationship between activity and protection. Figure 4.3 shows the utility gained from participating in an event or activity on the horizontal axis and the number of people in contact while participating in the event or activity on the vertical axis. Then, as utility increases, the number of people who participate in the activity increases, and thus the number of people who encounter the activity also increases.

However, we expect the number of people in contact to vary depending on whether the environment in which they participate is high or low risk. As mentioned earlier, the risk of infection is greatly increased if the space is enclosed or if there is a high density of people in the space. In outdoor activities, for example, the risk of infection is lower because it is an open space and people are in a low-density situation. Therefore, it is possible to take measures to keep the risk of infection as low as possible in the same activity, or to avoid activities with a high risk of infection and substitute activities with a low risk of infection.
Figure 4.4 shows the number of contacts on the horizontal axis and the number of new cases on the vertical axis. The higher the number of people who encounter the infected people, the higher the number of new cases. However, if we take protective measures, such as wearing
masks and washing hands, even if you have direct contact with an infected person, the risk of infection is somewhat reduced.

### 4.3.4 How to Predict the Number of New Cases Using the Mosquito Hypothesis?

Figure 4.5 shows a matrix illustrating how the relationships among the stages (activity, travel, and protection) can be used to estimate the number of people infected. For example, the generalized cost of transport before the pandemic is point A. The utility of an activity would be around point A’, and then it would result in the number of encountered people A”, and we could get the number of COVID-19 cases (Point A’’’). The following two cases show how the matrix works.

**Case 1:** As a countermeasure to the COVID-19 pandemic, such as recommending the wearing of masks or restricting entry to a venue, the curves will each change from the red one to the green one. In addition, generalized costs become higher due to avoidance of going out, etc., so the number of cases would decrease to point B’’’.

**Case 2:** As an economic measure, encouraging people to go out or travel when the infections have not yet subsided sufficiently will cause infections to increase again (Point C’’’), even if the venue of the activity is low density and even if participants are wearing masks and/or washing their hands well.

---

**Figure 4.5: Matrix for Estimating the Number of Cases**

Source: Authors.
4.4 Case Study

In order to demonstrate the mosquito hypothesis, the Go to Travel campaign in Japan is discussed as a case study. It should be noted, however, that the data and information related to the COVID-19 pandemic are still insufficient and many assumptions have been made in this case study, so the figures do not necessarily guarantee accuracy.

The target area is Prefecture A, which has a population of 1.5 million and is a well-known tourist destination in Japan. Although no new infections were observed in June 2020, the number of infections has been increasing since July, and it is suspected that the infections were spread by tourists who came to Prefecture A. In this report, we use the statistics of number of overnight stays (Japan National Tourism Agency n.d.) from other prefectures as the number of tourists.

4.4.1 The Relationship between “Travel” and “Activity”

First, we need to determine the extent to which the Go to Travel campaign induced tourism. Here, the year-over-year ratio in June 2020 is multiplied by the number of overnight stays in each month of 2019 to obtain the number of tourists from the scenario without the campaign. June 2020 was selected because it is the only month during the pandemic in which a state of emergency was not declared and no kind of

![Figure 4.6: Number of Overnight Stays With and Without the “Go to Travel” Campaign](source: Authors.)
campaign was launched. Therefore, the people who stay in Prefecture A during this period are considered to be people who have to go there (e.g., business travelers) or who do not care about the pandemic.

Figure 4.6 shows the actual number of guests for the scenario with the campaign and the estimated number of guests for the scenario without the campaign. With the campaign, the number of tourists doubled from July to September and tripled from October to November, when the campaign was launched in Tokyo Prefecture.

In the case of Figure 4.2, it can be explained that because the generalized cost was lowered by the assistance of the campaign, Prefecture A’s attractiveness as a tourism site compared to other prefectures was 2–3 times higher. This means that the increase in the number of visitors was induced by the campaign.

4.4.2 The Relationship between Activity, Protection, and Infection

To what extent is the infection considered to have been spread by the tourists induced to travel in the above scenario? This needs to be verified, but the only readily available data are the statistics of the number of new cases and the number of guests mentioned above. On the other hand, although the behavior of residents and tourists under the COVID-19 pandemic is thought to have changed significantly, there are still insufficient data and statistics to show this. Therefore, the following assumptions are set for estimation.

- Tourists are divided into two groups: those who take part in high-risk activities and those who take part in low-risk activities. Tourists are often forced to engage in high-risk activities such as eating out, so the number in the group engaging in high-risk activities is assumed to be large.
- In the same way, residents are divided into two groups: those who take part in high-risk activities and those who take part in low-risk activities. However, it is assumed that the percentage of residents who engage in high-risk activities is not as high as that of tourists who do so, because many residents are considered to have shifted to low-risk activities.

Then, the following equation is used to estimate the number of newly infected people in month $t$.

\[
I_i = \frac{[a_i S_i(t) \beta_i(t-1) + a_j \sum_j T_j \beta_j(t-1)]}{p_i} S_i(t) Y_H + \frac{[(1-a_i) S_i(t) \beta_i(t-1) + (1-a_j) \sum_j T_j \beta_j(t-1)]}{p_i} S_i(t) Y_L
\]

(5)
where

\( P_i \) = Population of zone i (Prefecture A);
\( I_i(t) \) = Number of cases in zone i (Prefecture A) in month t;
\( S_i(t) \) = Number of uninfected people in zone i (Prefecture A) in month t;
\( T_j(t) \) = Number of visitors from zone j (other prefectures) in month t;
\( \alpha_i, \alpha_j \) = Percentage of people who engage in high-risk behaviors for infection;
\( \beta_i(t), \beta_j(t) \) = Proportion of infected people in zone i (Prefecture A) and zone j (other prefectures) in month t; and
\( \gamma_H, \gamma_L \) = Parameter to estimate the number of new cases from the number of contacts in high-risk and low-risk areas, respectively.

For the above assumptions, the parameters are set as shown in Table 4.2. The estimated value of \( \gamma_H \) is used to best match the actual and estimated values.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha_i )</td>
<td>0.1</td>
</tr>
<tr>
<td>( \alpha_j )</td>
<td>0.5</td>
</tr>
<tr>
<td>( \beta_i(t) )</td>
<td>Percentage of infected people in Prefecture A in month t</td>
</tr>
<tr>
<td>( \beta_j(t) )</td>
<td>Percentage of infected people in other prefectures in month t</td>
</tr>
<tr>
<td>( \gamma_H )</td>
<td>3.11</td>
</tr>
<tr>
<td>( \gamma_L )</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Authors.

The actual numbers of new cases and the numbers estimated by the model are shown in Figure 4.7. This figure shows that the discrepancy is large in August and December, indicating the need to incorporate factors other than tourists.

When the number of tourists under the scenario without the campaign estimated in section 4.4.1 is input into this model, the number of tourists is about 3,000 fewer than the actual number. This suggests that the Go to Travel campaign may have expanded the COVID-19 pandemic in Prefecture A.
Again, however, it should be noted that the figures in this case study are not necessarily accurate, as they are based on the statistical data available as of this writing (February 2021) and on several assumptions about the situation and parameters in order to verify the mosquito hypothesis.

### 4.5 Conclusion

In this chapter, we proposed the mosquito hypothesis, an analogy to the situation leading to mosquito bites, to explain how new infections can be estimated by considering the movement and activities of people. We also used this hypothesis to examine the extent to which the Go to Travel campaign, which was implemented to promote tourism in Japan at a time when the number of infected people was not yet sufficiently low, spread the disease.

However, detailed data and information on the COVID-19 pandemic are not yet fully available. As data on human behavior and infection status are gradually accumulating, it is expected that a model based on the mosquito hypothesis will be developed and its accuracy improved.

This will also enable us to examine the effectiveness of the policies implemented to counter the COVID-19 pandemic in each of the stages of strategies: travel, activity, and protection.
References


PART II
Wider Economic Impacts and Quality of Life Implications of Transport Infrastructure
The framework for understanding the many effects of transportation infrastructure development has been continuously advancing from the conventional (yet instrumental) cost-benefit analysis (CBA) approaches to the more recent approaches of capturing the wider economic impacts (WEI) for a network of transportation systems and quality of life (QoL) impacts for individuals in the society. Hayashi, Seetha Ram, and Bharule (2020) proposed the “pyramid of analytical hierarchy” to discuss the complexity of the impacts of transport infrastructure and categorized from bottom to top (of the proposed pyramid) the direct transport system impact, economic and financial impact, WEI, and QoL impact. While the bottom part of this pyramid constituting the direct transport system impact is historically well studied in the transport economics literature (through surplus theories-based CBA approaches and their extensions), conceptual and empirical works as we move to the top of this pyramid are only sparsely available in the literature. In particular, the stream of WEI and QoL implications, which go beyond project-related welfare effects captured through savings of generalized costs in CBA or the increase of willingness-to-pay captured by a project company, although rapidly advancing in the recent past, can also be argued as insufficiently studied and not well applied in the decision making of transport investments. The second part of this edited volume is hence dedicated to this developing body of transport economics literature and aims to illustrate the frontiers, best practices, and lessons from large transport investments, focusing on high-speed (HSR) rail development experiences from across the globe. Five chapters, comprising this second part, are refined from the presentations of the authors of the called-for papers and invited papers who participated in the ADBI-Chubu University conference (held virtually during 12–16 October 2020).

1 With contributions from Michael Wegener (Spiekermann & Wegener Urban and Regional Research, Germany). Partly drawn from the deliberations and discussions held at the sessions titled “Transportation Infrastructure and Its Wider Economic Impacts” and “Quantifying and Simulating Quality of Life” held on 13 October and 16 October 2020, respectively, during the ADBI-Chubu University Conference (virtual) on Transport Infrastructure Development, Spillover Effects, and Quality of Life. The authors also acknowledge the contributions from the participants of these sessions.
WEI are defined as the comprehensive economic effects of investments or action programs, including direct, indirect, and induced/second round effects over economic sectors, space, and time (Rothengatter 2017). The approaches that have been developed for measuring WEI can be broadly classified into welfare models (having neoclassical foundations in economic theory), endogenous growth models (those based on the growth of gross domestic product, or GDP), and integrated assessment models. They can be more precisely categorized as elasticity models, macroeconomic computable general equilibrium (CGE) models, system dynamics models, regional simulation and land-use transport interaction (LUTI) models, and input-output models. The first chapter in this part of the edited volume, Chapter 5 by Rothengatter, covers and summarizes these complex approaches encompassing the frontiers in the estimation of the WEI of transport infrastructure development. The chapter illustrates each of these conceptually along with a review of the humongous literature and concludes with a detailed discussion of the pertinent issues that are actively and widely debated during decision/policy making and are of keen interest to the research fraternity.

Chapter 6 by Truong and Derrible presents the WEI estimation for the case of the much-debated North–South High-Speed Railway Project in Viet Nam, which is proposed there for the second time. The ongoing debate for this first HSR project stretching over 1,545 kilometers (km) is due to its large capital investment requirement (estimated at $58.1 billion) and the unconvincing results of the socioeconomic CBA. Responding to the need for an enhanced understanding of the potential spillover effects of this huge investment, an elasticity approach is applied by the authors of this chapter to estimate the project’s impact on employment agglomerations through a measure of change in effective employment density. The analysis accounts for the phenomena of business enterprise development, effective employment density, and employment opportunities, thereby illustrating the capability of their methodology to identify a certain markup over the conventional transport user benefit. The time savings are very large, e.g., 5 hours or more on longer distances, such that the expected impacts from improved effective employment density are also large compared to values from the United Kingdom. Although one would expect these effects to dominate in densely populated areas, the study finds that the largest impacts are measured for peripheral and poorer regions, which raises several questions related to the equity/cohesion effects of HSR development for future research.

Chapter 7 by Pham, An, and Le empirically examines the impact of HSR in generating environmental benefits and mitigating the increasing share of the transport sector in causing climate hazards
under business-as-usual (BAU) conditions. The chapter analyzes the case of Viet Nam, where roads comprise a large share of interprovincial passenger traffic and are also the largest emitter of greenhouse gases among all transport subsectors. The planned North–South HSR link in Viet Nam, if developed, is expected to significantly shift the modal share of passenger transport from road and air to rail. By using the four-step modeling method and regression analyses, the authors examine this detailed modal shift from road and air to HSR. Indicators of economic growth, vehicle growth, modal shift, and vehicle kilometers traveled are studied in the analyses, and it is found that the presence of HSR has a significant and positive effect in reducing greenhouse gas emissions. The results of the estimations of these environmental benefits of developing HSR in Viet Nam are interestingly much higher than in the case of comparable projects in industrialized countries, and this could be because of the large expected modal shifts from road and air to rail.

Chapter 8 by Sugimori, Hayashi, and Takeshita extends the concept of WEI and its various dimensions, which were discussed rigorously in previous chapters, and discusses the improvement that HSR development brings to an individual’s QoL. The authors emphasize the need for bringing inclusiveness along the lines of the Sustainable Development Goals and their concept of “leave no one behind” to decision making in transportation planning. They clarify the mechanisms of QoL improvement along HSR corridors through their analysis in two steps of (i) shorter-term time saving effects for HSR users and (ii) longer-term industry interactions. An industrial location model is developed to focus on the latter mechanism and to empirically explain the number of employees in each industry. Such models are applied to Japan’s case and compared to the actual data along the Kyushu Shinkansen (bullet train) corridor as an example for HSR constructed in recent years.

Chapter 9 by Aparicio adopts a complementary approach based on a planning theory analysis and revisits the HSR policies in the European Union (EU), in particular the case of Spain, the highest HSR investor in the EU and the second highest in the world after the People’s Republic of China. In terms of HSR density (km/km²) or HSR km/capita, Spain is leading worldwide and followed the Spanish Strategic Plan on Transport Infrastructure and Services 2005–2020 as its political base. The plan was based on the guiding EU principles of reducing the contribution of transport to environmental degradation and concept of cohesion (both territorial and social). Its target was achieving polycentric regional development to improve the economic situation in lagging regions, in particular in the north of the country. The planning and
decision-making procedures in these projects are revisited systematically as the European and Spanish experiences continue to attract attention (both complimentary as well as critical), often from countries envisaging HSR infrastructure as leverage for regional development. The case of Spain deserves attention partially also because the EU cofinanced the HSR construction with €14 billion out of €56 billion (25%) until 2018. Aparicio aims to identify the key stakeholders; their interests, roles, and positions; and the constraints imposed on them by the prevailing economic and political paradigms during the HSR development. This approach provides an insight into the self-imposed limitations of EU transport policy and the difficulties in revising the HSR expansion paradigm. The chapter elucidates potential reasons European decision makers continue to favor HSR in their transport policies in spite of sustained criticisms. The public policy analysis is not intended to replace the valuable contributions from the geography and economics fields, but tries to expand the realm of the potential economic benefits, as suggested in studies carried out in previous chapters, and defines an important resource to understand the inertia involved in the stakeholder interactions and policy making processes of HSR development.

To summarize, the literature contains a large number of studies that present mixed evidence and discussions about the success or failure of HSR strategies and policies. (For instance, the case of HSR in Spain has witnessed confirmation of its positive regional equity impacts in a study by Ortega Perez, Lopez Suarez, and Monzon [2014]; in contrast, it was called a big overinvestment having a hidden centralization agenda by Albalate and Bel [2012].) However, these studies seem to contribute only partly to the wider understanding of projects and can be insufficient. While evidence for the argument that large cities like Madrid or Barcelona have benefited may be well accepted, other evidence that suggests positive effects for mid-sized cities is less apparent. The possibility that peripheral regions with longer distances to HSR stations have lost competitiveness still sees continued debate and is worth revisiting independently for each case. Therefore, it seems useful to consider alternative HSR network configurations and their construction scenarios and to apply WEI and QoL modeling for their assessment before deciding on a specific strategy. To do this would require combining different disciplines, such as geography, engineering, and economics, for determining the appropriate transportation system. It may be equally necessary to use integrated assessment methods, as applied in climate research, to bring different models investigating a wide range of impacts to a common platform for assessment in a comprehensive context. Further efforts in
this area may be required and are among the important agenda items for future research.

Other invited presentations and the related discussions that took place during the ADBI-Chubu University conference highlighted another insufficiently explored link between HSR development and the knowledge economy, as discussed by Bhatt and Kato (2021). The authors hypothesized about the potential enhancement in knowledge spillovers that arises through increased face-to-face knowledge interactions (of R&D firms and human capital) facilitated by HSR accessibility. This, in turn, is likely to contribute to longer-term productivity enhancements in the form of knowledge productivity, as was proxied through the patent applications/capita of 59 analyzed countries in the evidence presented by them. Such an enhancement plays a crucial role in defining the dynamics of economic growth as was also emphasized in endogenous growth theories (Solow 1956). Further research will be necessary to prepare better foundations for such evidence, to assess its applicability in heterogenous regional contexts, and to understand the underlying mechanisms, including the consideration as to whether this relationship is only mono-causal. Lastly, the HSR corridor’s impact on the formation of new places and its ability to integrate several metro regions into a megalopolis can also be an upcoming stream that needs to be further investigated. Pagliara (2020) applied an endogenous growth/GDP-based regression modeling approach to investigate this impact in Italy and discussed the development of new megacities along the MITO (MIlano–TORino, in the north of Italy) and ROSA (ROma–SAlerno, in the south of Italy) corridors. The impact on shrinking cities due to the witnessed change of mobility patterns and the reshaping of the studied regions explained potential ideas about the mechanisms. However, the findings suggested that the HSR link has not contributed to the MITO megalopolis formation, whereas it has served to shape the RONA (ROma and NApoli) megalopolis.
References


5

Frontiers in Wider Economic Impacts of Transport Infrastructure Development

Werner Rothengatter

5.1 Introduction

Since the 1950s, cost-benefit analysis (CBA) has been applied for assessing of infrastructure projects. Approaches for measuring benefits have been further developed and described in textbooks, guidelines, and handbooks. In many countries, they have been introduced into fiscal legacy. The standardized methodology that has evolved is based on welfare theory. It measures consumers’ and producers’ surpluses, or, even more simply, the generalized cost differentials on the transport market. Because a conventional CBA cannot capture all welfare-relevant impacts—a fact that became clear early on—the analysis came to include environmental and safety indicators.

However, important impacts remained unconsidered. Therefore, in parallel, extended methods have been developed for capturing impacts beyond the direct project-related benefits. For instance, methods can capture the expected changes of spatial development. Prominent examples are the land-use and transport interaction (LUTI) models (see, e.g., the MEPLAN model of Echénique et al. 1990) and the comprehensive simulation approaches addressing macro- and regional economic effects (e.g., the SASI model1 of Wegener and Bökemmann 1998). These approaches were applied to support decisions in more comprehensive transport investment plans, going beyond single projects. The approaches have not been standardized; rather, they were adjusted to suit the problems they were applied to.

1 SASI = spatial and socioeconomic impacts.
The development of wider economic impacts (WEIs) is following the extended branch of assessment methods. WEI is intended to include all relevant economic effects stemming from projects or investment plans over space and time. A first area of development is based on a general welfare approach, extending the partial welfare approach of CBA. It is differentiated by industrial sectors and regions. It assumes that most sectors are perfectly competitive, while some sectors, in particular the transport sector, show characteristics of monopolistic competition. Under such strong assumptions, the changes induced by transport investment can be modeled by spatial equilibrium approaches (Venables 2007; Bröcker and Mercenier 2011) or simplified elasticity models (Graham 2006).

A second area of development aims at measuring changed macroeconomic indicators like gross domestic product (GDP) or employment instead of abstract welfare measures. In many cases the impacts are classified into direct, indirect, and induced effects, following the framework of input-output analysis. Applied methods are often based on dynamic econometric or system dynamics models to study the long-term impacts, including productivity changes (see Rothengatter 2017a).

A third area of development is oriented to integrated approaches with simultaneous modeling of transport, economy, energy, and the environment. Such approaches are, in particular, supported by the European Commission for generating information on the impacts of a better connectivity among European Union (EU) countries, overcoming border distances, and a coherence of investment programs with ambitious policy programs like the “Green Deal,” published by the end of 2019 and aiming at a carbon-free EU in 2050 (European Commission 2019a).

In this chapter, we focus on the intended properties of the presented approaches as well as on the limitations (frontiers), which became evident when we applied them to practical cases. We start with the conventional CBA and its incremental extensions (section 5.2), present the general idea of WEI in section 5.3 and its extension to integrated assessment modeling in section 5.4. Section 5.5 illuminates the importance of WEI quantification for developing appropriate financing schemes, e.g., as suggested by Yoshino, Helble, and Abidhadjaev (2018). Section 5.6 starts from the existing frontiers of discussed approaches and analyzes the prospects for removing application boundaries by further development. Section 5.7 concludes the chapter.

5.2 Cost-Benefit Analysis

Early in its history, CBA showed the conflict between comprehensive and partial analysis. The founder of CBA, the French engineer-
economist Jules Dupuit, introduced the measurement of benefits through the area below the demand curve, which he called the “utilité relative” (relative utility; UR in Figure 5.1). This measurement according to Dupuit is not restricted to the transport sector. It includes the price/demand changes on the markets affected by the transport investment.²

Forty years later, Alfred Marshall published his famous book, *Principles of Economics* (1890). The book introduced the welfare measures of consumers’ and producers’ surpluses (CS, PS in Figure 5.1), measured partially on the market under analysis. If all markets except for the transport market are in equilibrium, then we can sufficiently measure the welfare impact by calculating the surpluses on the transport market and their changes by an investment activity. Under the conditions of perfect equilibrium, the supply curve equals the

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² This is explained by Dupuit presenting the example of a canal investment that opens the option to break the stone at a remote quarry with much lower production costs and carry it to the location of demand. While the cost of transport can increase, the total cost of the product supply (stone) decreases. The price change of stone at the location of demand—and not the pure change of transportation costs—is the relevant input for economic assessment (see Ekelund and Hébert 1999; Rothengatter 2017a).
marginal cost curve of the suppliers such that one can model the change induced by investments through the shift of the marginal cost curve. If the marginal cost is a constant, then the supply curve shifts downwards parallel to the horizontal axis and the only contribution to the welfare position is given by the consumer surplus.

In this case, the welfare measures of Dupuit and Marshall look identical (relative utility = consumer surplus), but this is a misinterpretation often found in the literature. The price/volume approach of Marshall is a partial approach for the transport sector while the Dupuit approach includes the product markets affected by the transport changes. Dupuit even gave warnings with respect to restricting the analysis purely to the transport cost differentials, because this can lead to wrong results if the investment induces structural technological (productivity) changes. However, in the following decades, the neoclassical equilibrium theory became the mainstream of economic modeling and, as a consequence, Marshall’s partial economic approach became the dominating paradigm for developing applied schemes of CBA. The change of generalized costs (time and operation costs) is propagated as the heart of the economic assessment in innumerable literature pieces, guidelines, handbooks, software packages of consultants, and components of many countries’ fiscal legacies. The underlying rigid assumptions of welfare theory and the Marshallian partial approaches are widely neglected and the uncertainties about applications, in particular the assumptions on the values of time or on the social rate of discount, are hidden behind conventions on their quantification, often using default or average values from other studies.

Alternative CBA approaches based on expected changes of macroeconomic indicators like GDP, consumption, or employment, which had been developed in United States (US) water resource management or investment in developing countries (e.g., Krutilla 1975; Eckstein 1959; Marglin 1969), were not followed. Input-output analysis, which had been developed as an efficient economic tool in many countries for quantifying interindustrial interactions, was applied for special studies but not as an integrated tool for the assessment of transport investments.

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3 This dates back to the (wrong) characterization of Dupuit’s theory as a “marginalist” approach, comparable to that of Marshall (Hotelling 1939).

4 The canal example makes this evident because the canal opens the option of increasing the productivity of stone production.
It was quickly recognized that focusing only on the surplus approach neglects important aspects of political decision making such that external effects on the environment and safety were added after monetizing expected impacts. The monetary quantification of externalities of transport was prepared by numerous studies that, in the first instance, intended to provide figures for charging (“internalization of externalities” through taxes and charges), and, in the second instance, served for extending the CBA for transportation projects (see INFRAS and IWW 2000; European Commission 2019b).

In several countries, these monetized externality estimations were supplemented by environmental/safety/spatial risk analyses that were treated outside of CBA, such that CBA was extended to a multicriteria analysis with a strong economic core part (e.g., German standardized evaluation method for federal transport investments, BMVI 2016; it consists of three parts: economic impacts, environmental risk, and spatial development).

Strengths of CBA:
• Non-economists can easily apply it due to its simple and transparent structure.
• It is formally widely standardized, generates comparable figures for projects, and supports choices of alternatives and priority setting of projects.
• The results look similar to private business performance criteria (net present values, internal rates of discount).
• Most stakeholders accept the results because it appears for nonexperts as project-neutral and consistent.
• Expert consultants like it because it is easy to design the core inputs in a way that fulfills clients’ expectations.

Limitations of CBA:
• CBA is a partial analysis, assuming the independence of projects and the validity of neoclassical assumptions (perfect market equilibrium).
• CBA neglects effects stemming from imperfect markets, like reduction of unemployment or growth effects through structural change.
• CBA neglects interactions and feedback between impact areas (economy, environment, energy, social).
• CBA tends to overvalue the generalized costs and to undervalue environment, climate, and risks for human life. In the recent EU Handbook on External Costs of Transport (European Commission 2019b), congestion costs count for almost double
of the overall cost share (27%) compared to climate change (14%).

- CBA encourages consultants to apply high values for time savings and to include small time savings per unit of activity, which cannot be used economically but make a substantial part of total benefits after multiplication with large traffic volumes.

The standardized applications using conventions for uncertain value settings have increased the confidence of nonexperts in objective and project-neutral evaluations of projects by CBA. But there are also numerous examples for manipulated CBA results. The evaluation of two maglev projects in Germany gives a striking example (see Box 5.1).

**Box 5.1: A Case of Manipulation with Cost-Benefit Analysis**

Originally, the German federal government had planned to build a maglev link between Berlin and Hamburg (280 kilometers) and had hypothecated the federal share of the calculated investment budget in the midterm fiscal planning, about 5 billion deutsche marks. This plan failed because the estimated investment costs increased while the forecasted passenger volumes decreased dramatically so that the foreseen operator, the Deutsche Bahn, withdrew from the consortium. The government then started a tender for smaller maglev projects in German states. The states of Bavaria and North Rhine-Westphalia expressed interest. The government felt that the best solution would be to split the investment budget 50/50 if both states would realize their projects. However, the fiscal law required that cost-benefit analyses (CBAs) be prepared for both projects. The consultancy in charge calculated the CBAs and came out with the surprising result that the benefit-cost ratios for both projects were identical at 1.5. The CBAs provoked headshaking and jokes when it became public that the consultancy had discovered a mistake in the calculations shortly before submitting the report. The mistake was hastily corrected by adding a benefit item that had not been considered before. The benefit item was applied only to one of the projects such that the result of 1.5 for both projects was left unchanged.


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5 In the 2019 update of the *Handbook*, the weight of climate costs has substantially increased. In the previous issue from 2014, the ratio “congestion/climate costs per vehicle-kilometer” was more than 10 for cars. (An exact comparison of the figures is not possible because of different units and currencies used by the consultants.) This indicates that, in past evaluations, climate change played only a marginal role.
People have other reasons to doubt the reliability of consultancies’ results, beyond the temptation of consultancies to please their client. Consultancies may have different experience evaluating large projects with uncertain outcomes and may interpret confidence intervals in different ways; these experiences may lead them to be more pessimistic or more optimistic. A solution can be to charge different consultancies for preparing essential data for feasibility studies. This was done, for instance, in the case of the high-speed rail Quebec–Windsor Corridor in Canada. In the feasibility study of 1995, three international consultancies presented traffic forecasts and the responsible public agencies selected the average of the highest and lowest estimation.6

These examples underline that CBA is an efficient tool for evaluating independent small and medium-sized projects while it neglects important impacts in the case of large projects or comprehensive investment plans. We should doubt CBA’s advantages in higher robustness and confidentiality of results compared with other methods, in particular if projects are large and complex or promoted by powerful stakeholders.

5.3 Wider Economic Impacts: Scoping and Measurement

WEI can be defined in different ways. In some of the literature, these impacts are characterized as effects on transport investments that are “wider than CBA,” i.e., not captured by conventional CBA. In this case it should be possible to strictly separate the impact areas of CBA and WEI, which is only possible for particular types of approaches like, for instance, welfare measurement using elasticity methods (see Graham [2005]; DfT of the UK [2006]; Legaspi, Hensher, and Wang [2015]). In general equilibrium and macroeconomic approaches cannot separate CBA and WEI. Therefore, the authors of WEI approaches usually define WEIs as the aggregate comprehensive impacts stemming from transport investments over sectors, space, and time (see Rothengatter 2019).

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5.3.1 Neoclassical or Behavioral Foundations

**Basics of neoclassical economics.** Since the work of Alfred Marshall (cited above), the neoclassical approaches have dominated economic literature and widely formed the foundation of economic assessments. Neoclassical theory is based on a set of assumptions the most important of which are:

- Rational, utility-maximizing behavior of egoistic consumers, and convex preferences resulting in convex demand and indifference curves.
- Rational, profit-maximizing behavior of egoistic producers, perfect foresight (or rational expectations), and convex technology, resulting in increasing supply and decreasing isoquant curves.
- Polypolistic markets with many participants on supply and demand sides, no market power of agents.
- Perfect information of all agents and perfectly/fast adjusting market prices and volumes.
- Perfect equilibrium for all markets, i.e., all markets clear for equilibrium prices.

Walras (1874) showed that a perfect market equilibrium can be derived for n markets from a set of (n−1) supply and demand equations.\(^7\) The richness of neoclassical theory is due to the various possibilities to assume partial imperfections in this system and to derive proven solutions by applying optimization and equilibrium methods. As this theory represented mainstream economic analysis for many decades, many Nobel Memorial Prizes have been given to general and special research outcomes. For instance, Debreu received one in 1982 for his mathematical formulation of the general economic equilibrium (Debreu 1959) and Becker received one in 1992 for his many applications of the neoclassical framework to study problems of daily life.\(^8\) Also, the neoclassical contributions to the theory of finance have been rewarded several times, the most quoted works in the literature were published by Modigliani (in 1985) or Merton and Scholes (in 1997). Neoclassical

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7 One price can be chosen as numéraire (Walras's law).

8 Examples include the economics of marriage, family life, crime, and discrimination; the rotten kid theorem; and organ markets. The Nobel Committee awarded the prize in the first instance for Becker's work on human capital investment, while he is better known worldwide for his use of neoclassical instruments for describing problems of daily life. Many “fun publications” such as the “economics of sleeping” and the “deep economics of sleeping” appeared after Becker's papers (El Hodiri 1973).
theory of finance lost favor after 1998 when the hedge fund Long-Term Capital Management (directed by M. S. Scholes) went bankrupt even though it had applied the optimal hedging Black–Scholes model. A further setback for the empirical relevance came with the financial crisis of 2008 when the developed neoclassical models had not indicated any probability of a financial crash stemming from a rapidly extending trade with subprime securities.

The appropriateness of the general equilibrium approach for explaining problems of the economy and finding the best solutions was always doubted in phases of economic crisis. This holds for the world economic crisis after 1929 as well as for the financial crisis of 2008 when it became obvious that neoclassical theory can neither explain the causes nor derive appropriate solutions for overcoming economic crises. In particular, the neoclassical theory of finance was heavily attacked by Keynes (1936) and later by Roubini and Mihm (2010).\footnote{Nouriel Roubini was teased by neoclassical economists who called him “Dr. Doom” after he published warnings of a probable financial crash in 2004.}

**Basics of behavioral economics.** John Maynard Keynes is known as the most prominent critic of neoclassical economics, partly from his publications *A Treatise on Money* (1930) and *The General Theory of Employment, Interest and Money* (1936), partly from his disputes with the most prominent neoclassical economist of that time, Arthur Cecil Pigou,\footnote{Pigou’s theory (Pigou 1932) can also be found in transport modeling for equilibrium assignment and optimal congestion charging (“Pigou pricing”). It was extended to other types of externality like safety and environment.} and partly from his role as an economic advisor to the government and chief negotiator of the United Kingdom (UK) in the Bretton Woods negotiations on monetary stabilization in 1944.\footnote{Keynes was not happy with the Bretton Woods system and instead suggested an International Clearing Union and the *bancor* as a basket currency. This idea has been revived after the economic crisis of 2008.}

The scope of behavioral economics is very wide, but some important characteristics are shared:

- There is no perfect foresight or rational expectations; agents decide under uncertainty about future events.
- People often decide based on observations and experiences made in the past, and social contacts or observations of other agents’ behavior play a big role.
- Prices may not be the drivers of economic decisions; quantities (unemployment for consumers, sales volumes for producers) may drive these decisions.
• Perfect equilibrium configurations of an economy may occur only “by accident or design” (Keynes 1936).
• The state plays a significant role in reducing uncertainty and resolving deadlock situations caused by economic pessimism.

These common features characterize the psychological situation of decision-making agents in a completely different way compared with neoclassics. In Keynesian economics, the consumers base their decision about consumption on the actual income received and the investors base their decisions on the sales observed in the past. In the financial market, the agents are partially led by herd behavior, which may result in crises that cannot be treated by monetary policy (“liquidity trap”). From these basic assumptions on the psychological drivers of human behavior, the famous theorems of multiplier and accelerator effects follow, as well as the conclusion that anticyclical behavior of the state (deficit spending in a phase of depression) is a promising instrument to stabilize the economy.

Economic theory based on the observation of actual human behavior and decision making has increasingly been honored by Nobel Memorial Prizes in the past 2 decades. Outstanding examples are Kahneman in 2002, Shiller in 2013, and Thaler in 2017. These authors present empirical findings that, though they appear not to be rational in the sense of neoclassical theory, can be explained by the uncertain situation, the social environment, and individual feelings (e.g., empathy, social care) of the agents. In general, observed human behavior follows a complex configuration of drivers such that it is difficult to describe it through mathematical optimization tools. But this does not mean that mathematical tools can be applied only in neoclassical and not in behavioral approaches. It was shown early that the Keynesian macroeconomic theory can be modeled by assuming microeconomic optimization behavior subject to psychological or “perceived” constraints (see, e.g., Malinvaud 1977). However, modeling the dynamics for behavioral models can turn out most complex (see Evans and Honkapohja 2001) such that simulation and system dynamics tools are usually applied for generating results. Because such models require numerical inputs, their results lack generality and mathematical proofs so that most economists prefer optimization models over behavioral ones.

5.3.2 Equilibrium Modeling of Wider Economic Impacts

Macroeconomic computable equilibrium modeling. The macroeconomic equilibrium approaches usually start from the assumption that the behavior of consumers and producers can
be modeled by “representative” agents. This allows for applying the microeconomic models of optimal consumer and producer decisions and their transformation to the macroeconomic markets for goods and labor in computable general equilibrium (CGE) modeling. For further description, we present some basic features of the GEM-E3 model developed by Capros et al. (2013) and applied for several assessment projects of the European Commission, in particular the TRIMODE project.\textsuperscript{12} The representative consumer maximizes utility subject to a budget constraint and the representative producer maximizes profits subject to a cost constraint. Markets clear through flexible prices and a perfect equilibrium is computed following Walras’s law. This also holds for the labor market for which the supply and demand curves are derived from the optimal behavior of consumers and producers. The government is treated as a final consumer and investor and influences the economy exogenously, i.e., there is no feedback between the actions of the government and those of other agents. Dynamics are modeled by the change of capital stock following investments of the producers.

Unlike other CGEs, the GEM-E3 model does not assume an increase of production capacity through infrastructure investments. Rather, the model assumes a cost reduction (welfare) effect through the time savings induced. The time savings are generated exogenously by a transportation submodel. The transport cost reduction leads to reduced costs of production, which result in lower prices and higher demand. As the model includes the capital market (applying the neoclassical rule investment = savings, both dependent on the interest rate), the additional funds needed for infrastructure investment must be raised on the capital market and cause a crowding out effect through increased interest rates on capital.

The above general structure is disaggregated by countries (modeling international trade) and sectors (using an input-output model). The transport sector is classified into eight subsectors so that a broad interface is constructed with the transport model. The dynamics of the economic system are modeled by the investment activity, which increases the capital stock of the next period.

As the model is used for integrated modeling of transport, the economy, and the energy/environmental sectors, it must also generate data on the regional level (here: NUTS-3,\textsuperscript{13} the geographical level of counties). This data generation is done by disaggregating the country

\textsuperscript{12} TRIMODE = Transport Integrated Model for Europe. http://www.trt.it/en/PROGETTI/trimode_project/

\textsuperscript{13} NUTS = nomenclature des unités territoriales statistiques (nomenclature of territorial units for statistics).
results on the base of assumptions of the new economic geography, in particular allowing for monopolistic competition in some sectors. These assumptions are reflected in indicators of attractiveness for every region, which influence the migration of factors (labor and capital). These indicators influence the regional utility and productivity levels and can lead to agglomeration effects induced by the transportation investment. The overall change of regional economic indicators is controlled by the aggregate general equilibrium results of the country models.

Strengths of CGE modeling:

- Full use of microeconomic and welfare theory developed in the economic literature.
- Minimization of estimations of behavioral parameters of agents because of assumptions on optimal behavior and price mechanisms.
- Formally consistent impact modeling with comparing equilibrium positions.
- Acceptance by the mainstream of economic theory.

Limitations of CGE modeling:

- Assumptions on “representative” agents. It appears simple, assuming that there is only one type of behavior of consumers and one type of technology for producers.
- Overly simple dynamics. Only investments change the production capacity over time. There is no structural change in the economy over time and no endogenous change of productivity.
- Unrealistic assumptions for the labor and financial markets. The labor market clears with flexible wages, i.e., involuntary unemployment cannot occur. The capital market clears with flexible interest rates, i.e., more public investment leads to increasing interest rates and causes crowding out of private investment and consumption.
- More realistic assumptions are included in the regional submodel of GEM-E3, in particular monopolistic market organization and agglomeration effects. But these effects can only lead to change the regional economic structures while the overall impacts on the country scale are determined by the aggregate master model.

Spatial computable general equilibrium modeling. While the GEM-E3 model uses a dual approach to constructing national and regional model families, the spatial computable general equilibrium (SCGE) modeling approach models these two layers simultaneously.
One of the first comprehensive approaches was developed by Anas and Liu (2007) with the RELUTRAN model. This was originally designed to study the effects of a menu of policies spanning capacity expansion, pricing, finance and investment in transportation, building and income taxation, and land-use planning and control in metropolitan regions. The model was reformulated by Jahn (2014) and applied to analyze regional climate change impacts and adaptation policies. Comparable to the CGEs, rationally behaving consumers maximize utility subject to a budget constraint to determine optimal levels of consumption, housing, and leisure. Firms minimize costs subject to a production function and optimize the levels of output and inputs of land, capital, and labor. The transportation sector is modeled for consumers (commuting, shopping, leisure trips) and firms (transportation costs for final and intermediate goods). Government activity (exogenous) and foreign trade (endogenous) are modeled, which is not described here. Prices are set equal to marginal costs and determine the equilibria on land, labor, and goods markets.

The CGEurope model (Bröcker et al. 2001; Bröcker, Kaevych, and Schürmann 2010; Bröcker and Mercenier 2011) is based on Krugman’s new economic geography (Krugman 1995; further developed by Venables 2007) and is until now the most ambitious attempt to bring the SCGE theory to practical application.14 It includes several hundred European NUTS-2 regions (province level) and their characteristics with respect to factor availability, production functions, and household consumer behavior. Up to six industrial sectors are modeled. Production factors (labor, capital) are assumed to be immobile. Freight transport flows are explained by interregional trade and associated flows of commodities. Besides the deviations from the abstract general equilibrium assumptions (monopolistic competition and increasing returns in one sector), the model is constructed in a neoclassical way assuming perfect competition and long-term equilibrium. This implies that consumers with convex preferences maximize utility functions and producers maximize profits and allocate production to the locations of highest factor productivity. The general equilibrium is then determined as the price vector (under consideration of transport costs), which equilibrates supply and demand on all markets. This requires the computation of the solution of a large system of equations (usually using the General Algebraic Modeling System, or GAMS, software).

CGEurope has been applied for several assessment studies on the Trans-European Networks for the European Commission. It

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14 Koike et al. (2015) give an overview on SCGEs developed in Japan; Republic of Korea; People’s Republic of China; Taipei, China; Norway; and the Netherlands.
was also integrated in the first version of the integrated transport/economic assessment model TRANSTOOLS, prepared for the European Commission and applied for a first assessment of the Trans-European Network concept of 2011. The task of CGEurope was to deliver the interregional trade flows in European NUTS-2 regions as a part of the freight transport modeling of TRANSTOOLS.

Strengths of SCGE modeling:

- Formally consistent multiregional multisectoral modeling of transport flows.
- Formally consistent impact modeling with measuring the change of equilibrium positions. Possibility to conclude the analysis with advanced welfare measures (price/income equivalent variations).
- Use of advanced micro and welfare economic modeling components and solution software for large optimization problems.
- Possibility to model partial deviations from perfect market conditions in some sectors to achieve more realistic outcomes (e.g., average instead of marginal cost pricing).

Limitations of SCGE modeling:

- Limited number of sectors (maximum 6 in CGEurope).
- Difficulties of calibration.
- Large deviations from observed flows in practical application.

As a consequence of the above limitations, CGEurope was no longer used in the last version, TRANSTOOLS III, and was replaced by a conventional gravity model for modeling the spatial freight flows.

**Elasticity approaches.** The discussion of SCGE in the previous paragraph showed that equilibrium approaches are much favored in economic theory but that the treatment of large dynamic problems with many sectors and regions turns out to be difficult. This was also discovered in the UK when the SACTRA Committee\(^{15}\) of the Department for Transport (DfT) was preparing an integrated approach for the assessment of large transport infrastructure projects. Anthony Venables was charged with developing an applied version of his Krugman-type equilibrium model, but he had to surrender after some time because of the high complexity when trying to combine his model with input-output analysis. The DfT then looked for a simplification of the method and found that the elasticity approach of Graham was appropriate.

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\(^{15}\) SACTRA = Standing Advisory Committee on Trunk Road Assessment.
(Graham 2006; DfT of the UK 2006, 2012). This approach was also used by Legaspi, Hensher, and Wang (2015) for applications in Australia.

The elasticity approach allows for separating the impacts into welfare economic benefits, GDP impacts, and overlapping welfare/GDP impacts. The most important welfare components are the agglomeration effects—a claim that is supported by the new economic geography. These effects are measured by

$$WB1 = \sum_{i,j} \left[ \left( \varepsilon_{i,j} \times \frac{\Delta ED_j}{ED_j} \right) \times GDP_{i,j} \times E_{i,j} \right],$$  \hspace{1cm} (1)

where

- $i =$ industries,
- $j =$ locations,
- $ED =$ effective employment density,
- $\varepsilon =$ elasticity of productivity with respect to effective employment density,
- $GDP =$ output per employed person,
- $E =$ number of jobs.

The data for GDP and employment density can be taken from regional statistics. The effective employment density is defined in DfT (2006) by

$$ED_j = \sum_{k \neq j} E_k \cdot T_{jk}^\alpha,$$  \hspace{1cm} (2)

where

- $T_{jk}^\alpha =$ travel time from region $j$ to region $k$,
- $\alpha < 0 =$ factor for travel resistance with respect to time.

Equation 2 characterizes the accessibility of all workplaces $E_k$ from region $j$, weighted with the time resistance factor $T_{jk}^\alpha$, $\alpha < 0$. In symmetrical networks this equals the accessibility of region $j$ from all workplaces $E_k$. The time resistance factor can be quantified in analogy to the distribution part of a transport model, for instance by a gravity approach.

A transport investment will improve the accessibilities of several regions and their workplaces and lead to improved relative effective employment densities $\Delta ED_j/ED_j$ in equation 1. The main quantification problem lies in the estimation of elasticities $\varepsilon_{ij}$, i.e., the elasticities of productivity with respect to the effective employment density of sector $i$ in region $j$. Rothengatter (2017a) compared the results of estimations...
by Graham (2006) and Legaspi, Hensher, and Wang (2015) and found large differences. Also, the estimations for different Australian cities and for New Zealand vary widely, results that cannot be explained by structural differences. For instance, the elasticity for the sector retail/trade comes out 0.003 for Sydney and 0.08 for Melbourne, which makes a deviation factor of 27. The elasticity for the sector accommodation, cafés, and restaurants comes out −0.003 for Sydney and positive for the other regions of comparison, in particular for Melbourne with 0.09. As there is no fundamental structural difference in the industrial and service industries of the observed regions, one must conclude that the estimation of elasticities may lead to highly unreliable results. However, the main part of impact analysis (agglomeration impacts) is based on these elasticities so that the confidence in the resulting figures of WEI is limited.

Strengths of the elasticity approach:
- Easy application and standardization.
- Clear separation of CBA and additional WEI.
- Clear interpretation of WEI as mainly agglomeration benefits.
- Evidence when applying ex post analysis of impacts: Big cities with HSR stations alongside a well-served corridor show higher productivity growth compared with low-density regions in between HSR stations.

Limitations of the elasticity approach:
- Difficulty estimating elasticities, high variance of results, high uncertainty with applications, results not transferable or usable as default values.
- Elasticities are constants measured for a past economic situation; they are not appropriate for measuring dynamic impacts that may occur in the long-term future.
- The productivity growth measured stems from mobility of human capital from low to high productivity regions. Potential growth of sector productivity through technology change is not captured.

5.3.3 Regional Simulation Modeling

While one branch of regional land-use and transport models is based on equilibrium modeling (see section 5.3.2), a second branch has developed as simulation approaches focusing on a good approximation of the dynamic adjustment processes. One example is the SASI model of Wegener and Böckmann (1998) described in Bröcker et al. (2001). SASI models the European geography by NUTS-3 regions (at the time of development, 1,245 regions) and models GDP and employment,
accessibility, and population structure. In contrast to the equilibrium models, which focus on with/without comparative statics, SASI models the dynamics of indicator developments on a yearly scale and for a long planning horizon. Labor productivity is endogenously influenced by accessibility, an approach that reappears later in the context of the macroeconomic research on endogenous growth (see section 5.3.5). Migration of workers is also simulated based on empirical observations of the dependence of labor migration on regional unemployment differentials.

The model has been constructed to be policy-sensitive, which means that European integration policy and EU-wide harmonized transport investment policy can be analyzed. The dynamic modeling of indicators (e.g., population, employment) is similar to system dynamics, while some differences remain with respect to the construction of feedback mechanisms and the drivers of dynamic development. This model has been a front-runner for comprehensive and integrated spatial modeling of transport policy actions. Major components can be found in follow-up developments.

Strengths of regional simulation modeling:
- Comprehensive multiregional approach.
- Rich regional output modeling: sociodemographic, economic, accessibility changes.
- Detailed modeling of population and employment including migration.
- Detailed modeling of dynamics (by years).
- Possibility to model induced productivity changes.

Limitations of regional simulation modeling:
- No geographic modeling of transport, use of raster cell approach.
- No input-output model integrated for modeling interindustrial feedback.
- Rough national economic model including a subset of indicators of national accounts (mainly GDP, employment).

5.3.4 Input-Output Modeling

Input-output tables are standard information instruments of national accounts and exist with various spatial and sectoral disaggregations. Input-output theory has been developed by W. Leontief and its main equation (for a closed economy without state activity) is included in every textbook on macroeconomics:

$$ AX + Y = X \implies Y = (I - A)X \text{ or } X = (I - A)^{-1}Y. \quad (3)$$
where

\[ X = \text{vector of gross production}, \]
\[ Y = \text{vector of final demand (sum of consumption + investment over all industries = GDP in a closed economy)}, \]
\[ A = \text{matrix of input (Leontief) coefficients (denoting the share of inputs of industry I of the output of industry j)}. \]

Autonomous changes of outputs (e.g., investments) or inputs (e.g., labor) lead to multiplicative changes of GDP, which is known as backward or forward multiplier effects. Input-output (IO) tables make it possible to disaggregate these changes by industries. This allows for measuring indirect effects of investments, which work through inter-industrial interactions and their results for GDP and employment, in addition to direct effects, which stem from initial investment expenditure. The basic scheme (equation 3) has been developed into many directions: multiregional/multisectoral, social account matrices (SAMs) with supply/use tables for industries and products, links to resources, and energy and the environment. One of the most advanced IO/SAM models is EXIOBASE, a model that was developed with support from the European Commission and its Joint Research Center. Some EXIOBASE-3 features are:

- Time series 1995–2011;
- Multiple social and environmental satellite accounts;
- 44 countries (28 EU) plus 5 for rest of the world;
- Rectangular supply/use tables for 163 industries and 200 products;
- Energy accounts: 60 primary and secondary energy products;
- Emissions: 27 pollutants from combustion processes; and
- Further accounts: water, material, land, waste, and labor.

The model is open source and has been further developed in particular by the Norwegian University of Science and Technology. If it is applied as a stand-alone model, the inputs for the changes (outputs or inputs) have to be taken from other model results or estimated by experts.

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16 Constructing social account matrices results in a comprehensive accounting framework that captures the full circular flows of income from production to factor incomes, household income to household consumption, and back to production. In contrast to IO-analysis, the SAMs present highly differentiated income/expenditure flows for households and the state as well as supply/use tables for industries and products.

17 The EXIOBASE model can be found at https://www.exiobase.eu/index.php/welcome-to-exiobase.
exogenously. This option was, for instance, applied by the International Labour Organization (ILO) and is understandable because EXIOBASE offers the option for a high disaggregation of the labor market. Also, this model has supported cooperation between ILO and the United Nations Economic Commission for Europe for estimating the labor market impacts of green transport policy. Furthermore, the model can be combined with macroeconomic models. The Norwegian University of Science and Technology has started experiments integrating EXIOBASE with the models REMES (macroeconomic CGE) and TIMES (energy).

Strengths of input-output modeling:
- Detailed modeling of interactions, combined IO and SAM tables.
- Detailed links to resources, labor market, energy, and environment.
- Assessment of environmental inputs (carbon dioxide) from the production and from the consumption side, e.g., consideration of carbon leakage.
- Comprehensive modeling of all direct and indirect impacts (including forward and backward multipliers) of major investments.

Limitations of input-output modeling:
- Data of IO and SAM tables are often outdated.
- Input coefficients are held constant over time, i.e., no modeling of structural changes.
- For dynamic economic/transportation impact analysis, combinations with economic/transportation models are necessary.
- No disaggregation possible by regions below the country scale, so only applicable for the assessment of national/international plans and programs.
- Integration into a comprehensive modeling framework difficult because of the volume of the tool (14 gigabytes of RAM for the time series 1995–2011).

5.3.5 Macroeconometric Approaches and System Dynamics

Macroeconometric approaches. Macroeconometric approaches are independent from the equilibrium paradigm and try to model the behavior of agents on the basis of observations instead of assumptions about rational behavior. The system of equations is constructed based
on indicators of national accounts; GDP is the leading indicator. All equations are estimated using long-run time series of economic statistics. Cambridge Econometrics, the developers of the advanced E3ME model, promote their model with the argument that it is not limited by many of the restrictive assumptions common to CGEs.\textsuperscript{18} E3ME focuses on the links between economy (modeled according to the system of national accounts, including input-output tables, Keynesian approach), energy, environment, and technology (innovations). In particular, the consideration of technology changes contrasts with the approaches described above, especially the CGEs and SCGEs, and allows for assessing large infrastructure investments or programs against the background of changing trends of technological development driven by expenditures for research and development (R&D). Therefore, this model is a favored instrument for assessing impacts of electrification, reduction of oil dependency, and automation in the transport sector.\textsuperscript{19}

The E3ME model has the following features:

- Geographical coverage: EU countries, three candidate countries, Norway, Switzerland, 11 other major economies, and rest of the world: 53 regions (43 non-EU);
- Industries (IO tables): 69;
- Solution periods: 1995–2050;
- Economic philosophy: Keynesian (demand driven);
- Basic economic model: econometric equations; and
- Structural changes: driven by endogenous growth, related to R&D activity.

**System dynamics modeling.** Systems analysis aims at investigating the static and dynamic relationships between the elements of complex systems for understanding and modeling their development in space and time. This means that systems analysis is not mainly interested in looking only at stimuli and responses, treating the processes inside the system as a black box. Rather, this type of analysis focuses on the processes inside the box to understand the mechanisms working. With this characteristic, systems analysis is not bound to particular economic philosophies such as classical or Keynesian. It also does not depend on the equilibrium paradigm, which dominates economic theory but often causes problems with accurately reconstructing observed dynamic phenomena.

System dynamics models (SDMs) are constructed from level variables (states) and flow variables (rates). Level variables are driven

\textsuperscript{18} The E3ME model is available at https://www.camecon.com/how/e3me-model/.

\textsuperscript{19} See, for example, Harrison (2017).
by dynamic (difference) equations. The drivers are quantified by flow equations, which control the inflow/increase of the outflow/decrease of a level variable. As the flow equations can include the state of level variables at the present or former points in time, chains of impacts can be constructed between the variables. These chains can be combined to form feedback loops. Feedback loops are the heart of SDMs. They can be positive, i.e., reinforcing, leading to a permanent increase or decrease of the levels included, or they can be negative, i.e., dampening, leading to a steady state of the levels included (e.g., car temperature being regulated by air conditioning). As positive and negative feedback loops overlap, changes of trends can be modeled over time. These changes may be induced or reinforced by the analyzed policy actions (e.g., infrastructure, regional development policy, pricing, regulation).

Unlike black box approaches, SDMs try to integrate the relevant feedback mechanisms for all impacted areas within one model framework. In particular, these models try to capture the dynamics working between economic and transport activity variables. The numerical algorithm works sequentially, which implies that it is not bound to achieving equilibrium positions of growth paths. An advantage is that large models can be constructed that integrate many regions and economic sectors (including detailed input-output tables). Efficient software packages exist (e.g., Vensim), which may be coupled with software for particular submodules, e.g., transportation models.

The most advanced system dynamics model is ASTRA, which includes population, macroeconomy including foreign trade and IO tables, regional economy, transport (passenger and goods by cluster modeling), energy/environment, and technology.

ASTRA has the following features:

• 27 EU countries plus the UK, Switzerland, and Norway;
• Regional disaggregation by NUTS-2 (about 230 regions);
• 25 industrial sectors (IO tables);
• Calibration by 10 years ex post forecasts, forecasts until 2050;
• Time interval: 3 months of the economy; medium/long-term reactions possible for other sectors (integration of fast and slow adjustment processes); and
• Software: VENSIM.

Strengths of system dynamics modeling:

• Not bound to particular economic philosophy (neoclassics or Keynesian).

20 Developed by Wolfgang Schade (formerly University of Karlsruhe, now with the M-Five consulting company), together with TRT Italia. Scientific basis: Schade (2005).
• Detailed modeling of dynamic feedback mechanisms with different reaction speeds.
• Multiagent modeling possible, overcoming the assumption of aggregate representative agents.
• Possibilities to combine SDM with other models (in particular: full transportation models with geographical details and behavioral/logistic specificities).
• Modeling of structural changes and changes of trends, endogenous dynamics.
• Modeling of crises and recovering processes.
• Closeness to reality through calibration by ex post forecasting.

Limitations of system dynamics modeling:
• Many variables and parameters (in ASTRA: about 200,000 variables).
• Calibration time-consuming because of many parameters and manifold interdependencies between variables, horizontally and vertically.
• Possible high sensitivity of the SDM with respect to small parameter variations. Also, the dynamic working mechanisms of time lags or assumed nonlinearities (e.g., exponential changes) may lead to unexpected results. Therefore, the model needs careful testing before application.  
• Gaps of knowledge can be filled with “subjective creativity” of modelers, which makes the model sensitive to individual judgements (e.g., the world model for “Limits to Growth,” developed by Meadows et al. [1972]). In this case, the results of the model cannot be reproduced interpersonally.

5.4 Integrated Assessment Modeling

The traditional planning and assessment procedure for transportation projects usually follows a sequential order:
  (i) Analyze and forecast drivers of traffic development (e.g., GDP);
  (ii) Analyze and forecast traffic;
  (iii) Identify bottlenecks;

21 For instance, unexpected cyclical movements can occur in future periods that have not been observed in the calibration period.

22 The use of system dynamics in this model for quantitatively reproducing the subjective thinking of modelers has since that time been a strong argument of economic theorists toward rejecting system dynamics modeling.
(iv) Develop investment alternatives (candidate projects);
(v) Analyze costs and benefits;
(vi) Predict noneconomic impacts (spatial, social, environmental);
(vii) Assess financial feasibility; and
(viii) Prepare investment plans for the transportation modes.

This procedure presupposes that every step is dependent on the preceding but independent from the following steps. This concerns, in the first instance, traffic forecasting and the following steps of investment planning. Clearly, the investment projects will change the traffic forecasts—this is the objective of investment policy. It follows that the traffic forecasting step has to assume a particular configuration of investment projects (e.g., no or all candidate projects) or of the attributes intended to be achieved by the investment plan (e.g., travel times and costs, accessibility of regions). But this configuration may not be congruent with the following steps. For example, financial feasibilities may reduce the volume of investment plans.

A further shortcoming consists in neglecting the feedback between transport investment and the drivers of transport activities, e.g., GDP or employment. Depending on the type and magnitude of investment activity, the time and cost savings can change frequency, length, and spatial orientation of traffic activities (impacts of the first order). Furthermore, additional economic activities can be induced that generate second-round changes of traffic (impacts of the second order).

Interdependencies exist between projects through network effects (synergetic and substitutional) and external effects/constraints (environmental/spatial/social impacts, which can influence the economic performance). Also, the financial feasibilities are not completely exogenous because there may be different opportunities for private cofinancing through public–private partnerships (PPPs), depending on the type of projects.

Therefore, to achieve the goal of consistently capturing all relevant impacts, our evaluation methods must consider the above interdependencies. The discussion on approaches to measure WEI has revealed that there are many developments in the literature and transport consulting business covering subsets of the tasks listed above with different focuses: equilibrium (congruent with neoclassical theory), matching observed behavior (behavioral theory), spatial disaggregation (strong with LUTIs or SASI), sector disaggregation (high with IO/SAM models), transportation network (full geographical or cluster/raster cell modeling), and technology/productivity (constant or included in feedback mechanisms). When it comes to evaluating very large (“mega”) projects, project ensembles, or network configurations (e.g., for HSR),
integrated assessment models can be applied to capture the impacts over sectors, space, and time in a consistent way—as comprehensive as possible but without double-counting.

### 5.4.1 TRANSTOOLS and HIGH-TOOL

About 10 years ago, the European Commission started supporting the development of integrated assessment models. The TRANSTOOLS model was developed for integrating a full geographical transportation model with an SCGE (CGEurope, see section 5.3.2). It was planned to apply TRANSTOOLS for the evaluation of configurations of the Trans-European Network, for which a revised plan was presented in 2004. Several problems with the model emerged. One problem was that the equilibrium modeling of interregional trade flows was very time consuming. A second major problem was that the outcomes of the SCGE did not correspond to observations. This discrepancy resulted mainly from the unrealistic and simplistic optimization assumptions for consumer and producer behavior. Ultimately, the European Commission considered the model not to be mature and presented its results only in internal staff papers.

The HIGH-TOOL approach\(^{23}\) includes modules for transport (passenger, freight, vehicle stock), economic, demography, and environmental/safety modeling. The level of regional disaggregation is NUTS-2 (province level). All modules are simplified versions of partial models. For instance, the transportation model includes no geographical network or traffic assignment steps. Instead, conversion factors are used to generate figures on passenger and ton kilometers. The modules are linked together on a Java platform, which allows for fast calculations and integrating feedback procedures for interdependent components. For instance, feedback loops are considered for the economic and transport modules. The model operates sequentially, comparable to simulation models like SASI (see section 5.3.3); it is based on 2010 data and forecasts the development of all indicators in 5-year steps until the year 2050. HIGH-TOOL is an aggregate, open-source integrated assessment model that allows for fast computations of transport policy scenarios.

### 5.4.2 TRIMODE

The European Commission has launched the TRIMODE project with the intention to fully link detailed partial models for every area of assessment on a common platform for evaluating transport investment

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\(^{23}\) HIGH-TOOL can be found at [http://www.high-tool.eu/](http://www.high-tool.eu/). The final version was submitted in 2016.
programs (e.g., for the Trans-European Network or parts of it like the rail freight corridors) and transport policy programs (e.g., the contribution of the transport policy measures to the Green Deal of the commission). The model context consists of:

- Passenger transport (regional disaggregation NUTS-3, all transportation modes);
- Freight transport (disaggregation by logistic legs, all freight transportation modes);
- Networks for road, rail, air, inland waterways, and coastal shipping, including modeling of congestion, network assignment by equilibrium algorithm of Frank and Wolfe;
- Macroeconomy (CGE for all EU countries and aggregated non-EU regions; IO model);
- Regional economy (Krugman-type assumptions on monopolistic production and other deviations from equilibrium, disaggregation by NUTS-3 regions);
- Vehicle stock development;
- Energy consumption including future changes (electrification of power trains); and
- Environment, climate, and safety.

The model intends to forecast the development of all indicators until the year 2050 subject to the input of scenario assumptions for mega-trends and policy actions. The intended accuracy is high to allow for assessing the optimal design of investment plans. This implies using detailed models for every module, in particular for passenger and freight transport and for the aggregate and regional economy. As a result, the computational requirements are high and intense testing is necessary to calibrate the modules and finally the integrated model by ex post forecasting. The model is in the phase of final calibration and test running for selected scenarios.

5.5 Importance for Financing Schemes

The guidance and handbooks on CBA often include a chapter on financial calculus for preparing a base for private cofinancing through PPPs. This chapter addresses the costs of investment, operation, and maintenance as well as projections for revenues, which can be captured by the project management. The financial instruments that can be considered, such as grants, loans, and project bonds, relate to

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the type of project and its capability to generate direct financial flows. For instance, direct revenues of the rail infrastructure provider stem from rail track charges. If the infrastructure provider is integrated with the operation company, then both the revenue from rail track charging and the net income from ticket sales are captured by the project operator. If the railway system is vertically disintegrated with infrastructure management separated from service provision, then contracted arrangements between infrastructure manager and railway undertakings become necessary.

These arrangements can result in highly complex financial schemes, as in the case of the HSR link between Bordeaux and Tours (302 km distance; an HSR connection between Tours and the capital, Paris, already exists). The project finance for this link includes the following elements:

- A 50-year concession contract has been established between the French railway infrastructure manager Réseau Ferré de France (RFF)\(^\text{25}\) and the concessionaire (LISEA, led by VINCI, a big construction company).
- LISEA is providing €3.8 billion out of the €7.8 billion total financial volume of the project, widely guaranteed by the French government, the European Investment Bank and RFF; the private nonguaranteed contributions are 40%.
- Public grants will come from French government, European Commission, and local communities of €3 billion.
- Additional investment of €1 billion will come from RFF for links to existing infrastructure.
- The concessionaire will receive the revenues from rail track charging, which include incremental costs of infrastructure use plus a markup for fixed cost recovery.
- The revenues of the concessionaire depend on traffic of the service provider SNCF. SNCF argues that the contracted access charges are too high. Therefore, the conflicts about allocation of financial risks are still unresolved and are exacerbated by the impacts of the coronavirus disease (COVID-19) on HSR transport volume.

The conflicts arising with this project finance underline the problems with concession schemes of PPPs, in which the concessionaire is paid by the (traffic dependent) revenues. Alternative PPP schemes based on

\(^{25}\) The French rail infrastructure management company RFF has meanwhile been reintegrated into the public railway company SNCF and is now named “SNCF Réseau” (SNCF network).
availability allocate the traffic risk to public organizations. Compared to a purely public project governance, the rationale of availability schemes consists in expecting a better cost discipline for construction and maintenance.

In Europe, only a few HSR projects have been able to break even financially (the first French TGV investments). Also, in Japan and in the People’s Republic of China, the first projects connecting large agglomerations were financially successful while the follow-up projects connecting less densely populated regions show lower shares of revenue finance. However, the revenue-based financial calculus only considers the direct revenues the operator can capture and not the indirect revenues for the investor, i.e., the state. It may be possible that HSR investments, which are not financially viable when considering the direct project-related revenues only, can turn out profitable if long-run spillover tax income effects are considered. This brings up the question of how this spillover tax income of the state can be estimated.

This question brings WEI into play. WEIs are measured in terms of GDP, employment, and other indicators of national accounts such that it is formally easy to link these aggregate indicators to expected average tax rates of countries. Figure 5.2 shows the wider benefit profile of HSR investment for a longer time horizon. It consists first of short/medium-term benefits stemming from multiplier/accelerator effects, which depend on the level of unemployment in a country. In emerging economies, they can be much larger than in industrially developed countries. A second category of benefits stems from generalized cost savings, which reduce prices and foster demand. The third category is long-term increase of productivity for industries. In the case of logistics, HSR can open options for new services for transporting time-sensitive products like the dynamically developing courier, express, and parcel (CEP) services.

In the segment of passenger transport, improved HSR accessibility can increase the productivity of personnel in high-tech sectors and foster innovation. For example, in an assessment study for the “megaproject” Stuttgart–Ulm in Germany, 26 10 key industrial sectors were identified as the main drivers of economic growth because of their high productivity. These sectors showed high shares of workers with over-average education level so that a high statistical correlation between education level and growth could be proven. A second correlation was established between the weighted education/qualification level and the accessibility of regions, which also came out positive. From both correlations follows

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26 IWW, SrF, and VWI (2009).
that there is a relationship between high-standard regional accessibility, attractiveness for high-level human capital, income level, and tax revenues of the state.

Another more general indication for the potential interrelationship between HSR and the knowledge level was given by Bhatt and Kato (2021), establishing correlations between HSR equipment of countries and patent applications.

The quantification of WEI—compared with other approaches—allows for a much deeper categorization of tax bases, dependent on the applied methodology (e.g., including input-output analysis). This includes:

- Gross value added by sectors and regions (value added taxes);
- Income by household categories (income taxes);
- Consumption by product categories (sales taxes);
- Investment and foreign trade (property taxes, import taxes); and
- Time profiles of tax bases.

Therefore, the estimation of spillover taxation can be developed formally with much more accuracy compared with the use of average figures. However, this formally higher level of accuracy is beneficial only if the essential figures on investment costs and traffic forecasts are reliable. In the case of the Stuttgart–Ulm project mentioned previously, for instance, the initial cost figures have more than doubled so that all
assessment figures and follow-up tax spillover estimations, based on the low cost values, are obsolete. This means that the calculation of spillover tax income only makes sense if the financial figures are based on careful predictions of the most likely development and not biased by promoter’s optimism.

Flyvbjerg et al. (2003) pointed out that a better cost discipline can be achieved by integrating private risk capital into the financing scheme. Following this idea, Yoshino et al. (2018) have suggested financing models that combine the prospects of additional public tax revenues with the participation of private finance. One example is the “tax-kicker bond” proposal for securitizing back-end participation in the future tax revenue growth (Stillman 2018). The idea is to emit bonds to private investors that yield payments based on the future spillover taxation. Depending on the share of financial investment, the private bond holders would participate in the financial returns. Certainly, various problems must be solved before bringing the model to the market, such as the tradability of the bonds, the credit rating, the control of tax records, the treatment of risk (guarantees), and the necessary contractual legacy. Nevertheless, the tax-kicker bond concept could serve as an enrichment to the availability-based PPP model. It would encourage private investors to participate in the finance of large projects or project ensembles, improve the base of a fair risk sharing between public and private investors, and increase the cost discipline in the phases of final planning and construction as well as the propensity of truth-telling about expected benefits and costs (Rothengatter 2017b).

5.6 Further Development Prospects for Removing Boundaries to Application

5.6.1 Theoretical Developments

Neoclassical paradigm to be followed? There is a historical discussion in economics as to whether the neoclassical decision and market models are didactic tools that study human behavior and its market outcomes under abstract laboratory conditions or whether those models can be used for economic forecasting and assessment. As a matter of fact, microeconomic theory lectures at most universities use the fundamental assumptions of optimal behavior under certainty. This yields welfare optimal market results under the assumption of perfect competition. Conventional CBA is based on this configuration of assumptions, assuming that all markets are in equilibrium except for the transport market such that measuring the generalized cost differentials on the
transport market is sufficient for measuring the total welfare changes of investments. The theory of spatial general computed equilibria relaxes the rigid equilibrium assumptions insofar as it allows for the deviation from perfect market equilibrium for some markets. Krugman’s economic geography, for instance, introduces monopolistic competition in at least one market, which leads to spatial concentrations of production. The macroeconomic CGEs may consider further deviations from perfect equilibrium, for instance on the labor market. Nevertheless, the main economic decisions and market mechanisms follow the neoclassical rules, and the question arises whether a further refinement of the CGEs and SCGEs provides a promising way to improve the quality of assessment of transport investments.

While there are many indicators that neoclassical theory does not represent actual behavior in the short run (see, e.g., Thaler 2015; Kahneman and Tversky 2000), the argument of its protagonists is that it reflects the expected behavior in the long run. This has already provoked a controversy between Pigou and Keynes (“in the long run we are all dead”). Although there is no empirical evidence that long-term equilibrium growth paths predicted by neoclassical theory have become reality, it has nevertheless been the mainstream of economic theory and the base of most assessment models. The reasons are twofold: First of all, neoclassical models are based on optimization calculus and provide a consistent micro and macro cosmos of behavior and market results, and secondly, it minimizes the needs for calibrating parameters.

The upcoming mathematical foundation of economic modeling has favored this stream of modeling because there were many possibilities to insert small variations into the general optimization framework while preserving the general equilibrium environment (e.g., theory of second best). Programming software like the General Algebraic Modeling System (GAMS) allowed for solving large equation systems, which countered the argument that this type of model can only be applied for didactic purposes.

The reason for the second argument in favor of this type of modeling—that it minimizes the needs for parameter estimation—is that the general structure of behavioral functions is determined by the assumptions on optimal behavior. If the optimal “homo oeconomicus” behavior would be a good representation for the long-run expected human behavior, then the mathematical optimality operations would come close to the

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27 Keynes (1923: 80). Furthermore: “The classical theorists resemble Euclidean geometers in a non-Euclidean world who, discovering that in experience straight lines apparently parallel often meet, rebuke the lines for not keeping straight—as the only remedy for the unfortunate collisions which are occurring” (Keynes 1936: 16).
long-run reality and avoid the problem of estimating many parameters for model calibration. However, the empirical experiences with equilibrium approaches for the assessment of transport infrastructure support the hypothesis that a wider departure from neoclassical optimality assumptions on human behavior and market conditions will be necessary for achieving a better approximation to reality. This does not mean that optimality approaches are not useful as such. But they have to be adjusted to the observed realities. In this sense, the manifold contributions of mathematics and operations research to decision support for public investment planning (e.g., optimal investment programming) or private logistics (e.g., optimal scheduling in supply chain management) are most valuable. Heuristics have been developed for solving large optimization problems with realistic problem features.

**Extension of Keynesian economics.** In Keynesian economics, quantities are driving the behavior; for instance, income drives consumption or consumption drives investment. As the economy is underemployed, the supply of goods is constrained by the demand. This is the base of models of the business cycle, but this refers to short- and medium-run reactions of the economy and neglects changes of prices and production technology in the longer term. As the assessment of transport infrastructure requires a forecast to a long-term future, the Keynesian model has to be extended. This includes:

- Changes of prices, wages, and interest rates (different market categories can be defined that show different degrees of temporary monopolistic competition and price adjustment);
- Dependence of prices and interest rates on the type of monetary control by the central bank, together with the utilization rate for the production potential;
- Modeling of the production side (production potential) for integrating long-term growth; and
- Consideration of changes in industrial structure/sector productivity, to be modeled endogenously (see the next topic, the Romer approach).

In principle, it is possible to construct CGEs on the base of Keynesian economics, in which the equilibria are constrained and quantities (not prices) are the short-term drivers to equilibrate the markets. But for a good representation of medium- and long-term processes, we must integrate the functioning of flexible prices with different time lags for different markets. Modeling different time lags for economic reactions is difficult in an equilibrium model. Therefore, bringing the typical short-term Keynesian demand-side reactions together with medium-term price changes and long-term changes of production technology
can better be modeled by simulation, econometric, and system dynamic models.

**Productivity effects and technology change: The Romer approach.** Productivity effects are at the core of WEI because they drive the long-term growth (see Figure 5.2). In the SCGE approaches, there is often only through migration of factors (workers) from low- to higher-productivity regions. These agglomeration effects have been observed in Europe particularly with the expansion of the French TGV system, but also with transnational HSR connections like London–Paris–Brussels–Cologne (see Vickerman 2013). The agglomeration effects modeled by SGCEs only refer to the spatial movement of production factors while the productivity of industrial sectors is left unchanged. A second driver of productivity change is the progress of technology within industrial sectors. This may induce growth as well in agglomerations (e.g., innovation-stimulating company contacts) as in less developed regions (e.g., companies moving to lower-density areas to avoid congestion in agglomerations). The latter effect can be supported by allocating universities and research centers to low-density regions for fostering spillovers in high-tech industries in a regionally more balanced way. This relates to the importance of the knowledge economy for economic growth. A prominent contribution to the role of “ideas” versus “objects” for innovation is provided by Romer (1990), for which he was awarded the Nobel Memorial Prize in Economics in 2018 (together with Nordhaus). This model is a powerful didactic guide for the integration of endogenous productivity changes into long-term assessment models and will therefore be explained in some detail.

Economic growth theory was dominated for decades by the model of Solow (1956), which includes the production function

\[ Y = A \times K^\alpha \times L^\beta \] (4)

where
- \( Y \) = output, social product,
- \( K \) = capital input,
- \( L \) = labor input,
- \( A \) = productivity (technology, level of knowledge) factor,
- \( \alpha, \beta \) = production elasticities; \( \alpha + \beta = 1 \) (linear homogeneity, constant returns to scale).

The endogenous growth model of Romer (1990) consists of three sectors: Final (consumption) goods and services, intermediate (capital) goods, and R&D. The real output \( Y^r \) is produced by (low-qualified) labor input \( L \), accumulated intermediate and investment goods (capital)
X and (highly qualified) human capital $H_A$. The technical progress is represented by the total factor productivity $A$.

$$Y^r(H_Y, L, X) = H_Y^\alpha \ast L^\beta \ast A \ast X^\gamma.$$  \hspace{1cm} (5)

where $\alpha, \beta, \gamma < 1$ are parameters (production elasticities).

For the production of one unit of intermediate (capital) good $i$, it is necessary to give up a share of production of consumption goods. The intermediate goods are summed up (without depreciation) to result in the capital stock $X$.

$$x_i = \eta_i \ast Y^r; \quad X = \int_0^\infty x_i \, di \hspace{1cm} (6)$$

$$\dot{A} = \frac{dA}{dt} = \delta \ast H_A \ast A \hspace{1cm} (7)$$

The sector for R&D develops blueprints for new technologies and sells these to the intermediate sector where they can be used for innovative products and processes. The personnel $H_A$ employed in the R&D sector is driving the total factor productivity $A$ with the rate $\delta$. This means that rising technical knowledge is the essential driver of economic growth.

Notations:
- $A$ = total factor productivity (related to blueprints sold by the R&D sector);
- $H_Y$ = (qualified) human capital employed in the production sector;
- $H_A$ = (highly qualified) human capital employed in the R&D sector;
- $L$ = (low-qualified) labor;
- $Y_r$ = real output of consumption goods;
- $x_i$ = intermediate goods of type $i$;
- $\delta$ = productivity parameter of human capital in the R&D sector;
- $\eta$ = share of consumption goods that have to be sacrificed for one unit of intermediate goods; and
- $\alpha, \beta, \gamma$ = production elasticities.

From the theoretical point of view, it is interesting that increasing returns to scale can occur in the case of linear homogeneity of equation (5), i.e., $\alpha + \beta + \gamma = 1$, due to the nonlinear effect of R&D impulses on $A$. From the political point of view, the insight is important that highly qualified human capital in R&D is the key factor for long-term economic growth while low-qualified labor, used for cheap production, can never be a long-term growth driver. This is a lesson to emerging economies insofar
as the attraction or global production through low wages for low-skilled personnel can only be a temporary means of increasing economic growth.

In his discussion on Romer’s pathbreaking paper of 1990, Jones (2019) mentions some key aspects that are most relevant for the development of assessment methodologies for public investment:

- **Entrepreneurs are deciding in an environment of imperfect competition.** This leads to deviations from the perfect competitive equilibrium paradigm, e.g., prices are no longer equal to marginal costs. Firms can make profits by pricing products above marginal costs if they achieve temporary monopoly positions through innovations. This can incur self-enforcing effects because these firms can invest more into R&D and innovative products or technologies (corresponding to the Schumpeter theorem).  

- **Ideas (new knowledge) are at least partly nonrival.** Romer distinguishes the contributions of “objects” and “ideas” to production and growth. Objects are intermediate goods and labor, i.e., the production factors of the Solow production function. Ideas are designs, blueprints, or sets of instructions. Equation (7) is representing the “idea production function.” Assuming nonrivalry of ideas implies that ideas can be used simultaneously by a number of agents as soon as they have been developed. While nonrivalry of ideas does not imply nonexcludability (e.g., excludability through patent rights), it nevertheless generates external effects because ideas can lead to a range of options for providing similar product functions through unpatented technology. This leads to increasing returns to scale because \( F(\lambda^*A, \lambda^*X) > F(A, \lambda^*X) \).

This basic model of Romer’s theory can be developed into several directions.  

28 The most cited elements of Schumpeter’s theory of innovation are the theory of creative destruction and the hypothesis of the big firm being the most powerful engine of technical progress (Schumpeter 1942). But in contrast to Schumpeter, Romer assumes that a big part of the generated technical knowledge is nonrival, i.e., it cannot fully be captured by the generating firm.

29 Other authors have discovered several shortcomings in Romer’s model, for instance, that the solution may imply (undesired) rivalry or that the assumption of constant research productivity does not meet empirical observations. Jones (2019) has shown that minor changes to the Romer model are sufficient for solving such problems.
rates of A (knowledge base) and Y (national output). Remembering the requirements for an academic career in economics at that time, this was a most promising strategy.\(^{30}\)

Aghion and Howitt (1992; 2014) linked Romer’s approach to a Schumpeterian model of creative destruction of old technologies through innovations. This implies that the productivity parameter of the idea production function is changing in a countercyclical manner, i.e., low in a phase of boom and high in a phase of depression. The association with Schumpeter’s theory of evolutionary economics of adaptation (incremental innovations) and mutation (radical innovations), combined with short-, medium-, and long-term cycles of economic dynamics, makes Romer’s approach even more interesting for policy makers compared with deriving the general conditions for a neoclassical equilibrium growth path.

Hartwig (2017) has studied the influence of intellectual property (exclusion) rights on economic growth and the business cycle, using a system dynamics approach. His results show that extreme configurations—a perfect market without protection of property rights as well as a monopolistic market with full property rights—lead to suboptimal situations. If ideas are completely external, then fewer incentives for their production arise and a lower knowledge stock follows. If ideas are completely private (protected) then incentives for idea production are high, but the resulting oligopolistic competition in markets leads to conflicts, fluctuations, and instability. From this follows that narrow definitions of property rights, which protect technical details of mechanisms but not the essential functioning of products, would be incentive-compatible and, at the same time, allow for some externality of knowledge diffusion. Hartwig also shows that the system dynamics approach allows for using the basic Romer ideas as a baseline while integrating them into a larger context of tested economic feedback loops such that the modeled dynamic processes are closer to reality and can be tested against time series of observed data. This allows, in particular, a mix of different types of decision behavior to be introduced for consumers and firms instead of assuming representative uniform agents as usual in didactic models of growth theory. It also allows for a change of market configurations (e.g., change of dominance of rival versus nonrival situations) over time.

\[^{30}\] Romer extended the basic model and introduced a second dynamic relationship such that the equilibrium growth solution required the application of the Hamiltonian theorem, so that his model became acknowledged by the colleagues from mathematical economics who dominated the high-ranked journals.
The Romer model is relevant for the assessment of large infrastructure projects or investment plans in two respects. First of all, it can explain why WEIs occur, which usually cannot be observed or measured in the area of investment and in time periods shortly after investment. If large investments like HSR lead to (at least partly) nonrival impacts, then those impacts spread over sectors, space, and time and cannot be captured by the project management. This is underlined by the finding of Bhatt and Kato (2021) that a correlation can be shown statistically between HSR network length and patent right applications. Obviously, there is no direct link between both phenomena on the micro scale, and the impact mechanisms can only be described qualitatively in the form of hypotheses. Therefore, quantification of such impacts is only possible through statistical testing on the macro scale or simulation experiments. Schade (2005), for instance, suggests construction of “micro-macro bridges” that model the nonobservable reactions by a micro-model that is assumed to be representative for a (macro) group of agents and inserted into a system dynamics model. Ex post forecasts then can be used to contest the hypothesis incorporated in the micro-macro bridge.

One can assume that knowledge is not the only factor that drives productivity. Improving accessibility by reducing transportation times can lead to a better use of production factors like labor and capital. In the case of HSR, labor productivity can be improved by increasing the productive time at the location of destination (compared with conventional rail or car travel) or by providing the option to work on the trip (compared with car and air travel). If HSR tracks can also be used for cargo transport or if HSR leads to more capacity on conventional tracks, then time savings and increased reliability can reduce inventory holding. Such impacts have been studied by testing macroeconomic production functions with introducing transport infrastructure as a production factor (e.g., Yoshino 2020) or by testing regional potential functions (developed by Biehl 1991; applied by IWW, SrF, and VWI 2009). The interesting property of regional potential functions consists in the contingent effectiveness of infrastructure investments for economic growth. They only contribute to higher productivity if they represent a bottleneck for regional production. If a region, for instance, already shows a good accessibility, then the improvement of accessibility will not lead to substantial growth effects. Also, the achievement of small time changes for a large volume of traffic activities, as is often considered in CBA for small and medium-sized road investments, would not be relevant for economic growth impacts. HSR can provide large time savings for highly qualified human capital or highly valued goods with big time sensitivities (see the below section on technology
options to be considered) so that the probability of generating long-term productivity effects is much higher compared with conventional rail or road investments.

5.6.2 Application Aspects

**Design of wider economic impact assessment.** The consideration of WEI depends on the economic, social, and environmental situation of the regions affected by HSR investments. In some countries, such as the People's Republic of China, Japan, France, and Spain, the HSR network is widely developed and additional investments are considered because of regional equity or environmental improvements. In this case, the assessment of WEI can be applied for checking which network configurations are optimal with respect to a set of applied welfare goals. In emerging economies like Viet Nam or Indonesia, the stimulation of the economy alongside a planned HSR corridor is the focus of evaluation. In that case, the structural changes of the economy induced by HSR are the main aspects of political interest, so the main focus of analysis can be laid on the investigation of potential structural changes. This includes the combination of HSR investments with other measures of economic policy.

From these differences, it follows that the objects and goals of assessment can be different and that the instruments of evaluation have to be adjusted to the specific issues of countries, regions, and industrial sectors. This implies that WEI assessment cannot be standardized like CBA can. The attempts of Graham (2006) and the DfT of the UK (2006) of developing a standard instrument using an elasticity approach were, in our view, not successful. The application for assessing urban investments in well-developed areas suffers from the limited agglomeration impacts, while the application for assessing large interurban investments like the HS2 in the UK suffers from the missing consideration of sector productivity impacts in the sense of Romer. When it comes to adjustments of methodologies to large projects, network configurations, or transport policy programs, the macroeconometric and system dynamics approaches appear most appropriate. In particular, the system dynamics models (SDMs) can be easily adjusted to the characteristics of transport investment or transport policy programs. The price to be paid is that many parameters must be estimated and relationships that cannot be tested empirically have to be quantified by assumptions of the modelers or expert ratings. This is because SDMs require a complete modeling of the system to be analyzed and cannot be restricted to partial modeling like CBA, leaving the rest of the world unexplained.
WEI and integrated assessment modeling require the inputs of several engineering and economic disciplines which goes beyond the knowledge of single consultancies. Therefore, it is recommendable to form a team of consultants/institutes with special expertise and to bring the results of the different modules to a common interactive platform, as for instance planned with the TRIMODE project developed for the European Commission. Ex post forecasts are useful to calibrate parameters and to check the plausibility of results. They can also contribute to avoid appraisal biases induced by overoptimistic estimations or overskepticism by looking only at short/medium-term local impacts.

**Technology options to be considered: The case of HSR cargo.** HSR started with passenger transport in Japan in 1964 and in France in 1981. Prospects for high-speed cargo transportation have been developed in parallel or in the context of HSR developments for passenger service. The development of maglev trains in Germany (Transrapid) or in Switzerland (Swiss Metro) included the option from the beginning that the technology also could be used for cargo transport. A number of ideas were presented by inventors and developers to combine high-speed propulsion techniques (e.g., linear engines) with levitation technology based on magnetic or pneumatic (air cushion) technology operated in partial-vacuum tubes (e.g., Talpino, technological vision of Austrian developers for crossing the Alpine mountains\(^{31}\)). Also, ambitious ideas came up with the implementation of HSR passenger services in Europe. Plans were developed to use the HSR infrastructure for cargo services, in particular for transporting high-valued goods with low weight, such as postal and parcel services. SNCF provided HSR service to the French postal company since 1984 on the route from Paris to the south (Lyon, Marseille).

The enthusiasm for implementing HSR cargo faded in the decade after 2005, in particular after the French postal high-speed train service was canceled in 2015. Other planned HSR cargo projects could not make progress, including the parcel intercity project (Deutsche Bahn, Deutsche Post),\(^{32}\) the FEX project (SNCF and Deutsche Bahn), the HSR parcel hub project Leipzig (DHL, Deutsche Bahn), and the CAREX project (air cargo transport between large European airports). The latter was launched in 2006 and planned to establish an HSR cargo network

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\(^{31}\) Project details of Talpino can be found at http://www.prachensky.com/michael/projekte/talpino/talpino-trasse-muenchen-ortler-genua.php.

\(^{32}\) The Intercargo-Express service of Deutsche Bahn AG (line 1 Hamburg–Munich; line 2 Bremen–Stuttgart) was introduced in 1991 and canceled in 1995 for economic reasons.
between 6/9/14 EU airports by 2015/2018/2020, a project that has not been realized. But the development in recent years shows that interest is growing again. The industrial partners (under the lead of SNCF) have developed plans in 2017 and 2018 for the first and second stages of the project and are promoting the project to private investors.

The rising interest in HSR cargo is mainly due to several developments:

- Better train technology for high-speed cargo;
- Better processing technology at terminals;
- Development of logistic concepts with single wagon movement and pallet loads;
- Development of highly time-sensitive market segments; and
- Environmental challenges and political responses.

In this chapter, we restrict our focus to conventional HSR technology. That is, we do not discuss the manifold suggestions for using magnetic or air cushion-based levitation technologies or linear-engine propulsion (e.g., maglev and HYPERLOOP).

**Better train technology for HSR cargo.** The Mercitalia project in Italy includes an HSR cargo connection of Bologna with Maddaloni, a railway node 35 kilometers (km) northeast of Naples.\(^3\) The HS train ETR 500 will be equipped with freight installations such that rolling containers for parcel service (70 x 80 x 180 centimeters) can be transported, similar to the SNCF postal train. The train is designed for 18 trailers and the planned average speed on the 600-km distance is 180 km/hour such that the transportation time is about 3.5 hours. As the airport of Bologna is foreseen to be integrated into the CAREX network, a combination of HSR and air transport is possible in the future. The company, owned by the Italian State Railway and linked to several Trenitalia cargo companies with international service, expects a rapidly developing market for postal and parcel services, as well as for small unitized industrial products. Figure 5.3 shows a potential design of future high-speed cargo trains.

**Better processing technology at terminals.** Processing cargo requires particular facilities at stations, terminals, and freight centers. It is not possible to load or unload an HSR train at a station during a short stop the way passengers get on and off trains. Therefore, sidings for freight processing are required to handle containers/swap bodies/trailers or even smaller units like pallets. Furthermore, automatic

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coupling and decoupling will be needed. This is no problem from the technological point of view (applied for HSR trains with two sets and tested for marshaling processes), but it is a problem of international standardization that could not be solved by the International Union of Railways in the last 90 years. Therefore, agreements between neighbor countries will be necessary to move forward with technical solutions.

**Development of logistic concepts with single wagon movement and pallet loads.** If HSR trains combine passenger and freight transport, then new technologies are needed for automatic coupling and decoupling of freight wagons without disturbing the timetables of passenger service. This is an option for less frequently used HSR links, in particular for links that have been or will be built because of regional equity and environmental goals. Using free capacity for freight may contribute to reducing the financial gaps.

**Market for time-sensitive goods’ transport.** Postal service like express mail was the first market served in France by TGV and this can be extended to CEP and small consignments for industrial trades. The market for e-commerce is developing most dynamically worldwide at growth rates of about 17% annually (see Figure 5.4). In the phase of COVID-19-induced shutdowns, business-to-consumer e-commerce has been boosted even more dynamically and it is unlikely that the market gains will be lost after the shutdowns. On the other hand, it has to be expected that the growth of HSR passenger transport is dampened at least in the medium term through the substitution of business travel by video conferences and home offices. Also, touristic behavior may change. Therefore, it is important to think about new segments for HSR service,
and the segment of e-commerce appears highly relevant because the transport units are small and light while the values of transported goods are high.

**Environmental challenges and political responses.** The challenges are growing for industrialized countries to reduce the carbon dioxide (CO\textsubscript{2}) footprint drastically in the next decades. The European Commission’s “Green Deal,” published in November 2019, foresees carbon-free production and transport in the EU by 2050. The original target of reducing CO\textsubscript{2} emissions by 55% until 2030—which was criticized as overambitious by the industry—has meanwhile tightened to 60% and the EU Parliament is even postulating a 65% reduction compared to 1990. The transport sector has not contributed to these targets in the past and is most challenged in the next decade for a change of trends. This requires a substantial modal change of freight transport from road to rail and inland waterways; several informal documents postulate an increase of the freight modal split from 17% to 25% or even to 30%.

Against the background of shrinking volumes for bulk transport, this is only implementable if the railways improve substantially on their transport quality and adjust to logistical requirements of dynamically developing markets. The European Commission has started a large research program (Shift2Rail) on this issue jointly with the railway

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34 Rail Freight Forward (2016).
industry and results are expected with first implementations in the next budget period, 2021–2027. It appears that there is a strong political will to change the trends and drastically increase the modal share of railways in the freight sector.

5.7 Conclusion

It is widely accepted in the literature that CBA is a partial instrument and does not capture all WEIs stemming from large transport investments like HSR. However, only the elasticity approach propagated by the Department for Transport of the UK allows for separate measurement of CBA and WEI. This approach emphasizes the agglomeration effects, which lead to higher economic productivity through the migration of production factors from low- to high-productivity regions. The sector productivities as such remain unchanged. Furthermore, the approach suffers from the difficulties with empirical estimation of elasticities of industrial productivities with respect to changes of the effective employment density (regional employment density weighted with an accessibility indicator). No other approaches allow for separation of CBA and WEI; that is, they aim at including all project impacts comprehensively.

Economic research has long focused on neoclassical approaches, which were the mainstream of economic research and university education. This resulted in macroeconomic and regional economic equilibrium models based on assumptions on rational economic behavior and perfect competition in markets. The approach of the new economic geography, developed by Krugman (1995) and extended by Venables (2007) and Bröcker, Kaevych, and Schürmann (2010), allows for regional differentiations of impacts related to endowments, regional productivity differentials, and imperfect competition on particular markets. A large CGEurope was developed by Bröcker, Kaevych, and Schürmann (2010) and integrated into an assessment model for evaluating the concept of a Trans-European Network, first published in 2011. However, the results came out to be highly implausible and supported the opinion of critics of neoclassics that the rationality assumptions do not reflect reality and that models of this type are hard to calibrate on the basis of empirical data.

Models that are closer to reality but need many more parameters for their calibration have been developed in the form of regional simulation approaches, macroeconometric models, and system dynamics models. Usually, such models are calibrated on the basis of long-term time series for establishing the single functions and recalibrated for the whole econometric system on the basis of ex post forecasts for past
years (e.g., the last decade). Therefore, these approaches represent
the past development up to the present time period much better than
neoclassical models. The question remains as to which model type
is more appropriate to represent the development expected for the
medium and long-term future. Neoclassical theorists argue that the
assumed “homo oeconomicus” behavior of agents, together with
perfect market conditions and equilibrium constellations, represents
the probable economic reality in the long run. Behavioral economists
present many observations and experiments showing that people follow
different decision principles, also in the long run.

A strong argument against neoclassical theory is its weakness with
endogenously explaining innovations, which are the drivers of economic
growth and induce structural changes (change of trends) in the economy
in the long run. The growth theory of Solow (1956), which dominated
dynamic economic theory for half a century, includes a parameter for
technical knowledge (productivity), but this parameter is exogenous and
not explained by endogenous economic drivers. Romer (1990) breathed
life into this rigid framework by differentiating between the production
of objects (products) and the production of ideas (knowledge) and by
establishing a production function for ideas that create options for
changing production technology by innovations. At least a substantial
portion of ideas is nonrival: these ideas can be applied by many agents
as soon as they are developed. Another portion is temporarily rival and
exclusive—protected by patent rights or internal sealing off of know-
how. While the nonrival property explains the diffusion of knowledge
over organizations, space, and time, the rivalry property is essential for
explaining increasing returns, temporary monopoly, monopoly profits,
and their role for financing R&D. As a result, the dynamic model is no
longer compatible with the neoclassical rules (e.g., marginal costing,
perfect competitive equilibrium) even if the Romer model is integrated
into an equilibrium context. In this case, the growth path of GDP is
dependent in the long run on the investment into the knowledge stock
through R&D.

The Romer model is didactic in nature, and some authors have
shown that inserting empirical figures can lead to implausible results.
Therefore, it is promising to integrate a Romer model into large dynamic
assessment models like macroeconometric or system dynamics models
to embed the model into an empirically valid context. It follows from the
nonrival property of knowledge that it induces diffusions over sectors,
space, and time and cannot be captured by project managers or observed
by local statistical investigations following transport investments.
Reliable numerical figures cannot be compiled by observations in the
small; they have to be generated by statistical correlations in the large or
by simulation experiments. From this follows that the consideration of structural dynamics of the Romer type makes sense in the case of very large projects, investment plans, or transport policy strategies.

The consideration of WEI including productivity impacts, eventually extended by regional equity, energy, and environmental impact analysis, is in particular important for checking the optimal configuration of HSR networks, including the secondary networks; for adding new services on networks (e.g., HSR cargo); and for estimating future tax spillover revenues stemming from the investments for developing new schemes of finance.
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Assessing the Wider Economic Impacts of Transport Infrastructure Investment with an Illustrative Application to the North–South High-Speed Railway Project in Viet Nam

Truong Thi My Thanh and Sybil Derrible

6.1 Introduction

Viet Nam’s is located on the east coast of the Indochinese Peninsula. The Red River Delta and Mekong River Delta are two biggest regions in the country’s north and south, accounting for 70% of the national population. The North–South Corridor spans the main direction of Viet Nam; it covers 110,353 square kilometers of land, 33.6% of the national total. The geography is flat in the coastal areas facilitating the advantages in transport development.

Almost all urban and economic centers of Viet Nam can be connected by just one road (National Highway 1, or NH1) or railway (North–South Railway). This great advantage comes from Viet Nam’s unique geographic factors. In the context of increasingly scarce land and the very high cost of land acquisitions, the railway is preferable to the road because the double railway occupies a width of merely 20–21 meters.

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1 This research was funded by the Ministry of Transport, Viet Nam under the research project DT203022, The Study on Using Wider Economic Impacts for Socio-Economic Assessment of Infrastructure Projects: Application for the Impact Assessment of the North–South High-Speed Railway Project.
while the road requires a width of 70–100 meters for a similar transport volume. In addition, a modern railway system is attractive to passengers in terms of safety, comfort, and reliability.

The North–South Corridor is the backbone of Viet Nam and covers three focal economic zones. Rapid urbanization and economic growth are expected along the corridor (Table 6.1). Ha Noi, Da Nang, and Ho Chi Minh are the centers of the three focal economic zones; the route of the high-speed rail (HSR) passes 3 big cities and 17 provinces. In 2018, the total population in this corridor was 43.6 million, accounting for 45% of the national population. Rapid urbanization is happening in major cities, especially in coastal areas. The gross domestic product (GDP) is high at 7.1% per year, showing rapid economic improvement. The growth is remarkably high in Ha Nam, Ninh Binh, Quang Nam, Quang Ngai, Binh Thuan, and Dong Nai, all provinces that will lead the development of the region.

Table 6.1: Population Size and the Rate of Increase

<table>
<thead>
<tr>
<th>Year</th>
<th>National (1,000 people)</th>
<th>Rate of increase (%)</th>
<th>Urban (1,000 people)</th>
<th>Percentage (%)</th>
<th>Rate of increase (%)</th>
<th>Rural (1,000 people)</th>
<th>Percentage (%)</th>
<th>Rate of increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>86,947.40</td>
<td>1.07</td>
<td>26,515.90</td>
<td>30.50</td>
<td>3.64</td>
<td>60,431.50</td>
<td>69.50</td>
<td>(0.01)</td>
</tr>
<tr>
<td>2011</td>
<td>87,860.40</td>
<td>1.05</td>
<td>27,719.30</td>
<td>31.55</td>
<td>4.54</td>
<td>60,141.10</td>
<td>68.45</td>
<td>(0.48)</td>
</tr>
<tr>
<td>2012</td>
<td>88,809.30</td>
<td>1.08</td>
<td>28,269.20</td>
<td>31.83</td>
<td>1.98</td>
<td>60,540.10</td>
<td>68.17</td>
<td>0.66</td>
</tr>
<tr>
<td>2013</td>
<td>89,759.50</td>
<td>1.07</td>
<td>28,874.90</td>
<td>32.17</td>
<td>2.14</td>
<td>60,884.60</td>
<td>67.83</td>
<td>0.57</td>
</tr>
<tr>
<td>2014</td>
<td>90,728.90</td>
<td>1.08</td>
<td>30,035.40</td>
<td>33.10</td>
<td>4.02</td>
<td>60,693.50</td>
<td>66.90</td>
<td>(0.31)</td>
</tr>
<tr>
<td>2015</td>
<td>91,709.80</td>
<td>1.08</td>
<td>31,067.50</td>
<td>33.88</td>
<td>3.44</td>
<td>60,642.30</td>
<td>66.12</td>
<td>(0.08)</td>
</tr>
<tr>
<td>2016</td>
<td>92,692.20</td>
<td>1.07</td>
<td>31,926.30</td>
<td>34.44</td>
<td>2.76</td>
<td>60,765.90</td>
<td>65.56</td>
<td>0.20</td>
</tr>
<tr>
<td>2017</td>
<td>93,677.60</td>
<td>1.06</td>
<td>32,823.10</td>
<td>35.04</td>
<td>2.81</td>
<td>60,854.50</td>
<td>64.96</td>
<td>0.15</td>
</tr>
<tr>
<td>2018</td>
<td>94,666.00</td>
<td>1.06</td>
<td>33,830.00</td>
<td>35.74</td>
<td>3.07</td>
<td>60,836.00</td>
<td>64.26</td>
<td>(0.03)</td>
</tr>
</tbody>
</table>


The North–South High-Speed Railway (NSHR) Project in Viet Nam has been proposed to the National Assembly for the second time in 10 years. As mentioned in the prefeasibility report (Ministry of Transport 2018), the project requires a large capital investment of $58 billion to build a high-speed railway extending 1,700 kilometers (km) along the North–South Corridor and passing through
20 provinces with diverse economic development areas. The project would take 35 years for the full-scale implementation process. The project was developed considering three main characteristics related to the country’s (i) long, narrow shape, (ii) large population and very high population density, and (iii) goal to develop an industry-oriented economy and tourism services.

Because the construction for this massive railway project requires a considerable amount of money and effort, it is reasonable to divide the whole line into several sections and construct each section. The principles for the sectioning are (i) prioritize the sections in high demand and (ii) due to the characteristics of HSR transport, each section will be at least 300 km long. The first phase of construction for the Ha Noi–Vinh section (284 km) and the Nha Trang–Saigon section (364 km) are expected to start in 2026, with these sections beginning to operate in 2032. The next phase, building the remaining sections, is expected to begin in 2035 and complete the sections in 2040–2045.

International experience shows that high-speed rail promotes economic development since it saves the cost of travel time, creates many “green jobs,” and reduces indirect costs (e.g., traffic accidents, environmental pollution, land use). In addition, high-speed railways are formed by advanced, modern, and highly automated industrial sectors (e.g., metallurgy, mechanics, electricity, information signals, automation control). This mode of transport provides high-quality service due to its safety, comfort, speed, and reliability, thus having a great impact on economic restructuring and increasing labor productivity. The high-speed railway will shorten travel time, directly connecting famous tourist areas along the North–South Corridor. It will also be an important means for reaching other tourist destinations across the country. Besides, high-speed rail is a very safe and convenient mode of transport. Compared to aviation, high-speed rail fares are cheaper. Therefore, if this high-speed railway is invested in and built, it will create a strong motivation to develop Viet Nam’s tourism industry and the country’s economy overall.

Despite these benefits of high-speed rail, the results of socioeconomic analysis for this project are usually not attractive to investors because of the low economic internal rate of return and negative net present value. Therefore, investors are hesitant to commit to this project. The question of whether the project is feasible for investment has not been satisfyingly answered.

The benefits and costs of transport infrastructure investment have been assessed using traditional approaches. However, there is a growing interest in investigating the wider effects of such investment, which are called wider economic impacts (WEIs). The theoretical definition of
WEIs has been well developed, but empirical evidence is lacking due to insufficient data. The agglomeration effect has been developed as one source of the WEIs of transport system improvement (Rothengatter 2017; Wangsness, Rødseth, and Hansen 2017). Agglomeration means to generate some economies of scale external to the entrepreneur and industry, but internal to a particular urban area (Graham and Gibbons 2019; Graham and Melo 2011). This will result in improvement of labor productivity.

This chapter aims to propose a mechanism to capture the spillover effects of transport infrastructure by identifying the employment agglomeration impact of transport development through the changes in business development and effective employment density. The model was applied to the NSHR Project in Viet Nam to illustrate the capability of the model to identify a certain markup over the conventional transport user benefit. The study provides empirical evidence for project evaluation and prioritization regarding wider economic impacts that will benefit decision makers and project developers.

The remainder of this chapter is organized as follows. Section 6.2 positions this study in the WEI-related transport literature. Section 6.3 discusses the data collection and research methodology. Section 6.4 presents the quantitative results with the illustration from the Ha Noi–Vinh high-speed railway section, which is a part of the proposed NSHR Project. Finally, Section 6.5 concludes the chapter.

### 6.2 Literature Review

In the study of Chen and Haynes (2015), surveys of HSR passengers revealed that 61% of HSR trips were for business purposes, of which 34% were for company training and instruction and 66% were for contacting business partners for contract negotiation and marketing surveys. The differences in impact depending on the level of economic development was argued in the research of Cheng, Loo, and Vickerman (2015).

The concept of “employment density” was developed to measure the improvement in labor productivity as a consequence of transport investment (Vickerman 2000). Agglomeration elasticity measures the improvement in productivity, which is the result of effective employment density. Such density is not only the amount of employment physically in certain locations, but also the positions of these locations in relation to reference points, for instance, city centers. Transport investment, hence, can influence the effective employment density without physical changes (Banister and Berechman 2001; Venables, Laird, and Overman 2014).
However, physical distances are utilized instead of travel time to investigate the positions of employment because travel time might be affected by congestion (Cao et al. 2013; Ke et al. 2017). It is important to highlight that transport investment does not have a direct influence on physical employment, so it cannot change effective employment density. Therefore, it is hard for transport investment to have an impact on employment productivity (Banister and Givoni 2013).

To simplify the analysis, there is an assumption that transport investment has an impact solely on travel behavior while other activities remain the same (Xu et al. 2018; Jiao, Wang, and Jin 2017; Xu, Grant-Muller, and Gao 2015). However, in long-term equilibrium analysis, the impact of the transport system can be considered with interrelated decisions, for instance, housing and employment redistribution (Albalate, Bel, and Fageda 2015; Albalate and Bel 2012; Campos and de Rus 2009).

Consequently, the impact of transport investment is on travel time in the short term. In the longer term, this investment will affect other activities such as housing, employment redistribution, and employment densities (Vickerman 1997). Transport improvement can cause agglomeration and disagglomeration in certain locations, and hence can affect effective densities and labor productivity. The objective of this study is to model these effects that require specific analysis on the integration of transport use and land use.

### 6.3 Data Collection and Method

#### 6.3.1 Introduction of Ha Noi–Vinh Corridor

The Ha Noi–Vinh section is a part of the proposed NSHR Project. The study area is 284 km long and comprises 5 provinces and cities, including Ha Noi City, Ha Nam Province, Nam Dinh Province, Ninh Binh Province, Thanh Hoa Province, and Nghe An Province with six stations planned.

The total population in the Ha Noi–Vinh Corridor is 17.9 million (2018), equal to 19% of the national total. Currently the average population growth rate in the region is 0.8%. Population growth is high in Ha Noi, but this was due to the expansion of the growth boundary to the original Ha Tay Province. Ha Nam and Nam Dinh Provinces see a slight decrease in population. The population is distributed around the main cities in the region, namely, Ha Noi, Phu Ly, Nam Dinh, Ninh Binh, Thanh Hoa, and Vinh. Population density is generally low (Table 6.2). Although the overall urbanization rate is low for the provinces (only
40.8% even for Ha Noi), urbanization is occurring around these main cities, and the rate of growth for urbanization is actually high. The region is connected to neighboring provinces by many national highways: NH1 and NH15 (Ho Chi Minh Highway) for the north–south direction and other feeder roads. Although NH1 is the main road corridor on the section, most of the highway in this section has only two lanes and is planned to be expanded to four lanes in the future. In addition, the North–South Expressway is planned to be developed along NH1. The North–South Railway stretches from Ha Noi to the south, where it connects to other lines reaching Lao Cai, Lang Son, and Hai Phong.

The data used for this study come from a travel survey conducted in 2009 in Ha Noi (JICA 2010), a travel interview survey conducted in 2010 by the Japan International Cooperation Agency (JICA 2013), and a household interview survey conducted in 2019 by the authors. The database consists of approximately 15,000 records of the commutes of workers along the Hoi–Vinh Corridor with details of their occupations in different industry classifications, together with information on gross household income and personal income.

### 6.3.2 Measurement of Effective Employment Density

We analyzed the employment level of each occupation category based on travel survey data. The analysis covers 18 zones (districts) in Ha Noi and Nghe An Provinces. The following formula was used to calculate the effective employment density measured for each zone (Graham 2007; Graham and Gibbons 2019; Graham and Melo 2011):

$$
\text{Effective Employment Density} = \frac{\text{Number of Employed Workers}}{\text{Total Population Density}}
$$

### Table 6.2: Demographic Data (2018) of Six Provinces of High-Speed Railway Ha Noi–Vinh Section

<table>
<thead>
<tr>
<th>Province</th>
<th>Area (km²)</th>
<th>Population (individuals)</th>
<th>Population Density (person/km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ha Noi</td>
<td>3,358.6</td>
<td>7,520,700</td>
<td>2,239</td>
</tr>
<tr>
<td>Ha Nam</td>
<td>861.9</td>
<td>808,200</td>
<td>938</td>
</tr>
<tr>
<td>Nam Dinh</td>
<td>1,668.5</td>
<td>1,854,400</td>
<td>1,111</td>
</tr>
<tr>
<td>Ninh Binh</td>
<td>1,386.8</td>
<td>973,300</td>
<td>702</td>
</tr>
<tr>
<td>Thanh Hoa</td>
<td>11,114.6</td>
<td>3,558,200</td>
<td>320</td>
</tr>
<tr>
<td>Nghe An</td>
<td>16,481.6</td>
<td>3,157,100</td>
<td>192</td>
</tr>
</tbody>
</table>

Assessing the Wider Economic Impacts of Transport Infrastructure Investment with an Illustrative Application to the North–South High-Speed Railway Project in Viet Nam

\[ U_{iz} = \frac{E_{iz}}{\left(\sqrt{A_z/\pi}\right)^{\alpha}} + \sum_{s \neq z} \left[ \frac{E_{isz}}{(d_{zs})^{\alpha}} \right] ; \quad i = 1, \ldots, I; \quad z, s = 1, \ldots, z..

where \( E_{iz} \) is a measure of employment in industry \( i \) in zone \( z \), and \( d_{zs} \) is the distance between zone \( z \) and zone \( s \). \( A_z \) is the land area of zone \( z \), so that \( \sqrt{A_z/\pi} \) is an estimate of the average distance between jobs within zone \( z \).

In the next section, we apply the analysis to the proposed NSHR in Viet Nam with a focus on Ha Noi–Vinh section (the North Corridor) to estimate the wider economic impacts.

6.4 Results

6.4.1 Conventional Benefits of High-Speed Rail

**Changes in accessibility.** After commencement of operations of the HSR service, stations will be connected with 36 trains a day in 2030 and with 72 trains a day in 2040. The required time among major stations is expected to shorten to less than one-sixth of the time required for conventional rail travel (Figure 6.1). The improvement in accessibility is the key impact of HSR, especially the significant reduction in travel time between major cities (Table 6.3).

<table>
<thead>
<tr>
<th>Departure Station</th>
<th>Type of Rail</th>
<th>Arrival Station</th>
<th>Ha Noi (Ngoc Hoi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinh</td>
<td>Conventional</td>
<td>6:00:00</td>
<td>Vinh</td>
</tr>
<tr>
<td></td>
<td>High-speed</td>
<td>0:57:30</td>
<td></td>
</tr>
<tr>
<td>Da Nang</td>
<td>Conventional</td>
<td>15:56:00</td>
<td>9:56:00 Da Nang</td>
</tr>
<tr>
<td></td>
<td>High-speed</td>
<td>2:23:00</td>
<td>1:24:00</td>
</tr>
<tr>
<td>Nha Trang</td>
<td>Conventional</td>
<td>25:45:00</td>
<td>19:45:00 9:49:00 Nha Trang</td>
</tr>
<tr>
<td></td>
<td>High-speed</td>
<td>3:58:30</td>
<td>2:59:30 1:34:00</td>
</tr>
<tr>
<td>Ho Chi Minh City</td>
<td>Conventional</td>
<td>33:09:00</td>
<td>27:09:00 17:13:00 7:24:00</td>
</tr>
<tr>
<td>(Thu Thiem)</td>
<td>High-speed</td>
<td>5:20:00</td>
<td>4:21:00 2:55:30 1:20:00</td>
</tr>
</tbody>
</table>

Note: Times are given in the format hours : minutes : seconds.
Source: Adapted from JICA (2013) with updated data.
HSR development will significantly reduce the travel time, improving accessibility between major cities in Viet Nam. The possibility to connect regions with daily return trips means people may shift from air transport to trains for these trips. Furthermore, the reduced travel time may generate more trips and hence induce economic interaction between cities in huge regions.

It is estimated that a total of 400,000 passengers travel between Ha Noi and Ho Chi Minh City and 65,000 travel between Ha Noi and Vinh (JICA 2013). As a result of these changes in travel times (by train) between cities, people will be more likely to choose the train as their main mode of travel between different provinces. The modal share of HSR is estimated at approximately 15% for the temporary stage with one section of Ha Noi–Vinh (2030) and approximately 40% for the full operation stage (2050). The study results also confirm that in 2050,
more transport users are willing to use HSR as the main mode of travel from Ha Noi to Vinh and other cities along the HSR corridor.

HSR development will greatly increase accessibility and will hence enlarge the market areas between major cities along the project corridor. Such improvement will also facilitate the increase of competitiveness and productivity of firms in the regions, since the travel time savings of passengers directly improve the productivity. Increased accessibility will lead to new potential travel demand, which will increase induced benefits. Recent research has confirmed that transport development reduces travel cost and hence interacts with economic improvement.

**Benefits from passenger time savings.** Willingness-to-pay surveys, based on stated preferences of individuals, provide information for the analysis of passenger value of time. The values of $4.00 (for car and air passengers) and $2.40 (for bus and rail passengers) were adopted in the economic evaluation. Using this value of time, the benefits from passenger time savings are shown on Table 6.4.

### Table 6.4: Passenger Time Savings

<table>
<thead>
<tr>
<th>Cases for the North HSR</th>
<th>Passenger-Hours/Day (million)</th>
<th>Savings (hours/day)</th>
<th>Total Passenger Time Savings ($ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Car/ Air</td>
<td>Bus/ Rail</td>
<td>Car/ Air</td>
</tr>
<tr>
<td>0 Without Project</td>
<td>3.574</td>
<td>9.133</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.238</td>
</tr>
<tr>
<td>1 Ticket Price Level: 50% of airplane</td>
<td>3.335</td>
<td>9.158</td>
<td>0.238</td>
</tr>
<tr>
<td>2 Ticket Price Level: 75% of airplane</td>
<td>3.414</td>
<td>9.245</td>
<td>0.160</td>
</tr>
<tr>
<td>3 Ticket Price Level: 100% of airplane</td>
<td>3.505</td>
<td>9.247</td>
<td>0.069</td>
</tr>
</tbody>
</table>

HSR = high-speed rail.
Source: Adapted from JICA (2013) with updated data.

The analysis for total benefits from passenger time savings is for the year 2030. They account for about one-third of total benefits. The results also suggest that the viability of a shorter HSR is more sensitive to passengers’ value of time, whereas the full-line HSR is more sensitive to operating costs of other modes.

We also estimated the wider economic benefits. The HSR would enable the growth of secondary cities (e.g., Vinh), relieve high prices of land in Ha Noi, and bring businesses and new jobs to other cities. For Viet Nam, the HSR may relieve the air traffic congestion between
Ha Noi and Ho Chi Minh City, allowing the country to avoid investments in airport facilities and aircrafts.

6.4.2 Changes in Business Enterprises and Employment Density

We have explained the agglomeration effect, that with investment in transport, firms and industries get closer (static clustering) and relocate (dynamic clustering), leading to higher levels of productivity. As a result, there is an employment effect that with investment in transport, accessibility to jobs is improved, demands for labor at local levels are changed, and employment opportunities are generated. Moreover, there is an induced investment effect that with investment in transport, the attractiveness of a location changes, resulting in a net increase of investment.

We assume that changes in business enterprises result from the better connection between Ha Noi and Vinh, with the improvement of accessibility reducing travel time. The effects occur in many districts in Nghe An Province, and the strongest effects happen in six districts: Vinh, Dien Chau, Nghi Loc, Quynh Luu, Yen Thanh, and Cua Lo. Those districts have the fastest growing and most vibrant economies in Nghe An. Therefore, they have the strongest impacts under the development of the North Corridor (Ha Noi–Vinh section).

Other important changes in business enterprises are in Ha Noi with special impacts on 12 districts that are closer and have better accessibility to the HSR station (Ngoc Hoi station in Ha Noi). They are Ba Dinh, Hoan Kiem, Tay Ho, Long Bien, Cau Giay, Dong Da, Hai Ba Trung, Hoang Mai, Thanh Xuan, Bac Tu Liem, Nam Tu Liem, and Ha Dong. The changes in total business enterprises under the impact of NSHR are illustrated in Table 6.5.

From the changes in total business enterprises in 18 districts in Ha Noi and Nghe An, it could be seen that Nghe An will experience stronger impacts than Ha Noi. The percentage change in business enterprises with and without the project in Nghe An is much higher than in Ha Noi, for instance, 1.875% in Dien Chau, and 1.714% in Vinh compared with 0% in Long Bien. The average percentage change in total business enterprises in Nghe An is 1.580%, much higher than in Ha Noi (0.183%).

Travels by air to or from Ha Noi take around 3 to 4 hours in total travel time irrespective of the distance between Ha Noi and Vinh, compared with the total travel time of 1.5 hours (including 57 minutes on board HSR). That advantage gives location competitiveness to Vinh and some surrounding districts.
Table 6.5: Changes in Total Business Enterprises as a Consequence of the North–South High-Speed Rail Project

<table>
<thead>
<tr>
<th>Zone No.</th>
<th>Work Place</th>
<th>Number of Enterprises (2019)</th>
<th>Number of Enterprises (2032) - Without Project</th>
<th>Number of Enterprises (2032) - With Project</th>
<th>Absolute Change (With - Without Project)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ba Dinh</td>
<td>24,418</td>
<td>26,274</td>
<td>26,332</td>
<td>58</td>
<td>0.221</td>
</tr>
<tr>
<td>2</td>
<td>Hoan Kiem</td>
<td>18,562</td>
<td>19,943</td>
<td>19,985</td>
<td>42</td>
<td>0.211</td>
</tr>
<tr>
<td>3</td>
<td>Tay Ho</td>
<td>12,291</td>
<td>13,205</td>
<td>13,224</td>
<td>19</td>
<td>0.144</td>
</tr>
<tr>
<td>4</td>
<td>Long Bien</td>
<td>15,605</td>
<td>16,579</td>
<td>16,579</td>
<td>0</td>
<td>0.000</td>
</tr>
<tr>
<td>5</td>
<td>Cau Giay</td>
<td>32,201</td>
<td>34,602</td>
<td>34,657</td>
<td>55</td>
<td>0.159</td>
</tr>
<tr>
<td>6</td>
<td>Dong Da</td>
<td>34,716</td>
<td>37,312</td>
<td>37,385</td>
<td>73</td>
<td>0.196</td>
</tr>
<tr>
<td>7</td>
<td>Hai Ba Trung</td>
<td>24,670</td>
<td>26,545</td>
<td>26,609</td>
<td>64</td>
<td>0.241</td>
</tr>
<tr>
<td>8</td>
<td>Hoang Mai</td>
<td>25,392</td>
<td>26,937</td>
<td>26,957</td>
<td>20</td>
<td>0.074</td>
</tr>
<tr>
<td>9</td>
<td>Thanh Xuan</td>
<td>26,587</td>
<td>28,246</td>
<td>28,287</td>
<td>41</td>
<td>0.145</td>
</tr>
<tr>
<td>10</td>
<td>Bac Tu Liem</td>
<td>11,296</td>
<td>12,001</td>
<td>12,023</td>
<td>22</td>
<td>0.183</td>
</tr>
<tr>
<td>11</td>
<td>Nam Tu Liem</td>
<td>16,497</td>
<td>17,526</td>
<td>17,597</td>
<td>71</td>
<td>0.405</td>
</tr>
<tr>
<td>12</td>
<td>Ha Dong</td>
<td>18,083</td>
<td>19,211</td>
<td>19,256</td>
<td>45</td>
<td>0.234</td>
</tr>
<tr>
<td>13</td>
<td>Vinh</td>
<td>13,071</td>
<td>13,887</td>
<td>14,125</td>
<td>238</td>
<td>1.714</td>
</tr>
<tr>
<td>14</td>
<td>Dien Chau</td>
<td>1,371</td>
<td>1,440</td>
<td>1,467</td>
<td>27</td>
<td>1.875</td>
</tr>
<tr>
<td>15</td>
<td>Ngh Loc</td>
<td>1,201</td>
<td>1,262</td>
<td>1,273</td>
<td>11</td>
<td>0.872</td>
</tr>
<tr>
<td>16</td>
<td>Quynh Luu</td>
<td>1,137</td>
<td>1,194</td>
<td>1,204</td>
<td>10</td>
<td>0.838</td>
</tr>
<tr>
<td>17</td>
<td>Yen Thanh</td>
<td>973</td>
<td>1,022</td>
<td>1,032</td>
<td>10</td>
<td>0.978</td>
</tr>
<tr>
<td>18</td>
<td>Cua Lo</td>
<td>951</td>
<td>999</td>
<td>1,016</td>
<td>17</td>
<td>1.702</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>279,022</strong></td>
<td><strong>298,128</strong></td>
<td><strong>298,703</strong></td>
<td><strong>823</strong></td>
<td><strong>0.276</strong></td>
</tr>
</tbody>
</table>

Source: Compiled by authors.

6.4.3 Relocation of Employment, Especially for Knowledge-Based Industry

With the implementation of the NSHR Project in Viet Nam, a backbone will be formed that connects the two largest cities of Viet Nam: Ha Noi and Ho Chi Minh City. Considering more specifically the North Corridor with the Ha Noi–Vinh section, due to the reduction of travel time, the
high-speed railway will bring enormous impacts to the business sector by providing reliable travel services for businesspeople. The wider economic impacts (WEIs) were estimated based on the redistribution of employment along the project corridor (Table 6.6). To simplify the assessment, the exogenous shocks to factors were assumed at zero. Such shocks may result in the increase of employment opportunities, especially shocks to factors outside of the project.

### Table 6.6: Changes in Employment as a Consequence of the North–South High-Speed Rail Project

<table>
<thead>
<tr>
<th>Zone No.</th>
<th>Work Place</th>
<th>Number Employed (2019)</th>
<th>Number Employed (2032) - Without Project</th>
<th>Number Employed (2032) - With Project</th>
<th>Absolute Change</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ba Dinh</td>
<td>129,108</td>
<td>141,502</td>
<td>141,749</td>
<td>247</td>
<td>0.175</td>
</tr>
<tr>
<td>2</td>
<td>Hoan Kiem</td>
<td>82,899</td>
<td>90,857</td>
<td>90,952</td>
<td>95</td>
<td>0.105</td>
</tr>
<tr>
<td>3</td>
<td>Tay Ho</td>
<td>81,251</td>
<td>89,051</td>
<td>89,106</td>
<td>55</td>
<td>0.062</td>
</tr>
<tr>
<td>4</td>
<td>Long Bien</td>
<td>143,731</td>
<td>157,529</td>
<td>157,533</td>
<td>4</td>
<td>0.003</td>
</tr>
<tr>
<td>5</td>
<td>Cau Giay</td>
<td>133,893</td>
<td>146,747</td>
<td>147,081</td>
<td>334</td>
<td>0.228</td>
</tr>
<tr>
<td>6</td>
<td>Dong Da</td>
<td>213,602</td>
<td>234,108</td>
<td>234,913</td>
<td>805</td>
<td>0.344</td>
</tr>
<tr>
<td>7</td>
<td>Hai Ba Trung</td>
<td>167,978</td>
<td>184,104</td>
<td>184,378</td>
<td>274</td>
<td>0.149</td>
</tr>
<tr>
<td>8</td>
<td>Hoang Mai</td>
<td>194,034</td>
<td>210,332</td>
<td>210,343</td>
<td>11</td>
<td>0.005</td>
</tr>
<tr>
<td>9</td>
<td>Thanh Xuan</td>
<td>141,444</td>
<td>153,325</td>
<td>153,369</td>
<td>44</td>
<td>0.029</td>
</tr>
<tr>
<td>10</td>
<td>Bac Tu Liem</td>
<td>170,371</td>
<td>184,682</td>
<td>184,723</td>
<td>41</td>
<td>0.022</td>
</tr>
<tr>
<td>11</td>
<td>Nam Tu Liem</td>
<td>123,843</td>
<td>134,246</td>
<td>134,317</td>
<td>71</td>
<td>0.053</td>
</tr>
<tr>
<td>12</td>
<td>Ha Dong</td>
<td>151,281</td>
<td>163,989</td>
<td>164,381</td>
<td>392</td>
<td>0.239</td>
</tr>
<tr>
<td>13</td>
<td>Vinh</td>
<td>300,102</td>
<td>325,311</td>
<td>331,041</td>
<td>5,730</td>
<td>1.761</td>
</tr>
<tr>
<td>14</td>
<td>Dien Chau</td>
<td>156,497</td>
<td>167,765</td>
<td>169,860</td>
<td>2,095</td>
<td>1.249</td>
</tr>
<tr>
<td>15</td>
<td>Nghi Loc</td>
<td>113,311</td>
<td>121,470</td>
<td>122,928</td>
<td>1,458</td>
<td>1.200</td>
</tr>
<tr>
<td>16</td>
<td>Quynh Luu</td>
<td>168,993</td>
<td>181,160</td>
<td>182,698</td>
<td>1,538</td>
<td>0.849</td>
</tr>
<tr>
<td>17</td>
<td>Yen Thanh</td>
<td>166,516</td>
<td>178,505</td>
<td>179,611</td>
<td>1,106</td>
<td>0.620</td>
</tr>
<tr>
<td>18</td>
<td>Cua Lo</td>
<td>41,428</td>
<td>44,411</td>
<td>45,081</td>
<td>670</td>
<td>1.509</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>2,680,281</strong></td>
<td><strong>2,909,093</strong></td>
<td><strong>2,924,039</strong></td>
<td><strong>14,970</strong></td>
<td><strong>0.515</strong></td>
</tr>
</tbody>
</table>

Source: Compiled by authors.
corridor. Hence, the impacts of employment redistribution along the project corridor are the major WEIs that the study captured.

The increase and redistribution of employment result from two different effects. First, employment increases due to the increase in business enterprises. Second, workers can choose different work locations between Ha Noi and Vinh since the travel distance is significantly reduced. As a result, more work opportunities could be accessed by local workers, especially for Nghe An Province; employment will increase in Vinh (1.761%), Dien Chau (1.249%), Nghi Loc (1.200%), and Cua Lo (1.509%).

The shift in the labor supply must balance with the changes in labor demand since the wage rate influences people's selection of work location. Due to a lack of empirical data, we assume that labor demand is elastic with the wage rate. Furthermore, the wages change when the demand for labor also shifts as a result of changes in labor productivity caused by agglomeration effects.

In summary, the analysis generates important results. First, it shows that the network as a whole has a positive impact and the highest positive impacts are in the more peripheral, poorer regions, such as Vinh, Dien Chau, Quynh Luu, and Cua Lo in Nghe An Province. Second, specific investments can be seen to have differential impacts both on the specific regions they serve and on the Vietnamese economy as a whole.

HSR development will form a trunk network connecting major cities in Viet Nam, including Ha Noi and Vinh. The implementation could dramatically impact the business world. From the changes in total business enterprises in 18 districts in Ha Noi and Nghe An, we could see that Nghe An, with its smaller economic scale and lower population density, would experience a stronger impact than Ha Noi would. It is also expected that project implementation will make Vietnamese industry more internationally competitive by providing reliable travel services for businesspeople.

The model results demonstrate that the redistributive effects give rise to additional benefits for the NSHR Project as measured by improved labor productivity and employment redistribution along the Ha Noi–Vinh Corridor. It can be said that the development of the NSHR Project would have a positive impact on the economic development of the North–South Corridor. With a focus on the North Corridor (Ha Noi–Vinh section), the analysis shows improvement in both business enterprise and employment opportunities.
6.5 Conclusion

Improving people’s access to employment opportunities and housing is a major purpose of transport investment in both short and medium term. Conventional cost-benefit analysis captures such benefits through the impacts on users of the transport network. Since transport is considered as an input of other economic activities, the benefits of transport investment can be extended to cost reduction. In traditional analysis, only conventional costs and benefits are addressed, and the wider economic impacts are excluded.

This study has provided research evidence on the way that HSR services change business development and employment opportunities in regions. Going beyond the benefits transport users gain, we analyzed productivity and agglomeration changes and investigated the wider economic impacts associated with the railway development. It is important to highlight that the impact of HSR development depends significantly on location and such results are not easily transferred. The question of whether transport improvement directly leads to local economic development and economic integration remains open since it also involves the border linkages between regions.

Further research should focus on two directions. First, the connection between economic changes and changes in accessibility should be investigated. Second, a more micro level of the economic changes should be analyzed. The first research direction will require data on travel demand of transport users of HSR services, especially the origin and destination data. The second research direction will require occupation data from business sectors. Such research will facilitate a more definitive analysis of the HSR services.
References


7

Estimating the Environmental Benefits from the Development of High-Speed Rail in Viet Nam

*Pham Thi Kim Ngoc, An Minh Ngoc, and Le Thu Huyen*

### 7.1 Introduction

Research findings on the benefits of high-speed rail (HSR)—such as impacts on the natural world (e.g., air and noise quality) (Forkenbrock and Weisbrod 2001) and the human environment (e.g., community cohesion, economic development, safety, mobility, and property values) (Wilhelms 2014)—are inconsistent. For instance, some studies indicate that HSR plays crucial roles, such as changing travel behavior and facilitating interregional trade flows (Glaeser and Gottlieb 2009; Chan and Yuan 2017; Ren et al. 2019). Meanwhile, other studies suggest that the benefit of HSR may not always be significant (Agarwal 2018).

Some studies, such as Jiao et al. (2014), indicate that HSR has a significant effect on improving regional accessibility, thus facilitating knowledge spillovers through improved passenger mobility. Consequently, the environmental impact of passenger transport will be lessened. To measure the environmental benefit of HSR, modal share is often considered an important indicator.

Many studies have attempted to reveal the changes in travel behavior caused by the operation of HSR (Ren et al. 2019). Higher

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1 This chapter refers mainly to these projects: Addressing Climate Change in Transport (Oh et al. 2019), A Prefeasibility Study on North–South High-Speed Rail (TEDI, TRICC, and TEDI SOUTH 2016), and The Comprehensive Study on the Sustainable Development of Transportation System in Vietnam (VITRANSS) (JICA 2010). We thank all those who have been a part of these projects. We extend sincere thanks to Diep Anh Tuan for contributing the data for this study.
emissions from highways and aviation will be replaced by lower carbon emissions from HSR systems (Wang, Xia, and Zhang 2017; Xia and Zhang 2017). However, on the negative side, the development of HSR will boost economic activities and spur massive labor migration, thus causing more energy consumption.

This chapter provides new evidence to help answer the following question: How significant is the environmental benefit of HSR in Viet Nam? This study has the following research highlights compared with previous studies. First, a change of travel demand should be calculated to evaluate the impact of HSR. Luckily, we could refer to the analysis of demand by mode from previous research (JICA 2010). Second, a business as usual scenario captures the transport activities and emissions in the case that no additional policies or avoid-shift-improve strategies are deployed. Last, we examine the environmental impact of HSR development. Within this study, only greenhouse gas (GHG) emissions are examined as a factor of environmental impact.

The remainder of this chapter is organized as follows: Section 7.2 reviews the relevant literature, which will help to understand the relationship between HSR and travel behavior. Section 7.3 introduces the data characteristics and methodology, Section 7.4 provides background information about long-distance passenger transport services in Viet Nam, and Section 7.5 describes the scenarios and our assumptions for this study. Section 7.6 discusses the empirical results, and Section 7.7 concludes the chapter.

### 7.2 Literature Review

The influence of HSR on changing travel behavior has been widely discussed in the literature over the last decade. Examples include studies on the impact of HSR on improving regional accessibility (Gutiérrez, González, Gómez 1996; Jiao et al. 2014; Chen et al. 2016), enhancing intercity connections (Jin and Wang 2004; Wang and Jin 2005), and facilitating urban agglomeration and labor force evolution (Kim 2000; Garmendia, Ribalaygua, and Ureña 2012; Chen and Hall 2011; Haynes 1997). Many studies indicated that HSR has changed both the spatial perception of travelers and the spatial distribution of travel demand (Hou et al. 2011; Li, Liu, and Cao 2014; Long and Meng 2015; Li et al. 2006; Mou, Li, and Cui 2014).

From the economics perspective, the influence of HSR has been relevant to travel time savings (Rietveld 1989; Chen et al. 2016), improvement of regional conditions (Gutiérrez 2001), promotion of industrial structure (Chen and Hall 2011), economic growth (Campos and de Rus 2009), and the fostering of regional competition and
cooperation (Ding et al. 2013). However, some studies revealed that HSR can have negative effects, such as increasing housing prices in small and medium-sized cities (Chen and Haynes 2015).

In terms of the environmental effects of HSR, the research findings in the literature appear to be mixed. For instance, some studies found that more ridership of HSR will reduce transport (measured in terms of passenger kilometer traveled [PKT] and freight transport traveled [FKT]) (Bueno-Cadena 2017) and that travel time savings brought by HSR could generate a positive modal shift, thus indirectly impacting air quality (Rietveld 1989; Chen et al. 2016). It was revealed that emissions from HSR are less than one-third of those from highways and much less than those from aviation (Wee, Janse, and Brink 2005; Janic 2011; Givoni 2007). According to Fu, Liu, and Zhang (2013), HSR operation requires significantly less energy consumption compared to conventional railways, and thus aviation and highways cannot match HSR in terms of emission reduction due to economic scale.

Going back in history, Japan was the first country in the world to develop HSR (Hall and Banister 1993). At the initial stage, Japanese HSR was operating with a maximum speed of 210 kilometers (km) per hour, making an impression in railway technological development since 1964. However, the most successful project was highlighted in France in 1981, with a route connecting Paris and Lyon at a maximum speed of 270 km per hour (Arduin and Ni 2005). The success of France’s railway motivated other European countries such as Germany, Italy, Spain, Belgium, the United Kingdom, and the Netherlands to construct HSR within and across their borders, forming a high-speed network across the continent. Since 2000, HSR has spread throughout Asia, including the Republic of Korea (2004) and the People’s Republic of China (2008). Among Asian countries, although the People’s Republic of China is not the first country in development of HSR, it has the fastest expanding HSR network. Li, Strauss, and Liu (2019) calculated that its HSR network increased from 12,000 km in 2008 to more than double in 2017 with the total length of 25,000 km covering 180 provinces.

In Viet Nam, the Ministry of Transport has developed a proposal for two-phase implementation of a system of high-speed trains spanning the country’s north and south. The first phase would provide services from Ha Noi to Vinh and from Ho Chi Minh City to Nha Trang, running on about 640 kilometers of tracks (with a 280-km link between Ha Noi and Vinh as well as 360-km portion connecting Ho Chi Minh City and coastal Nha Trang). Later phases would extend services from Vinh to Nha Trang with the total length of 920 kilometers of rail lines. Plans call for construction to begin in 2026, with passenger services on the first phase of the system by 2032.
According to the prefeasibility study (TEDI, TRICC, and TEDI SOUTH 2016), trains will carry 740 passengers each in the initial operation period and up to 1,220 passengers at a later operation period, at speeds up to 350 km per hour. Up to 23 stations will be built. The time between trains (headways) will be 20 minutes in peak hours and 30 minutes in off-peak hours. Fares are estimated to be from $50 to $90, about the same as a plane ticket today.

The project proposal estimates that ridership could reach 13.6 million or more a year by 2030 and 47.3 million or more a year by 2040. The cost of the system is calculated at about $58.7 million (TEDI, TRICC, and TEDI SOUTH 2016).

In 2010, the Japan International Cooperation Agency (JICA) presented a report, The Comprehensive Study on the Sustainable Development of Transportation System in Vietnam (VITRANSS 2). As it is more quantitative-oriented, the study offers systematic data analysis. Data presented by VITRANSS 2 indicate that the creation of HSR resulted in a 10.1% loss of market share for aircraft and a 3.0% increase in car and bus travel in 2030 (JICA 2010).

In the prefeasibility study on North–South High-Speed Rail, the consortium TTEDI, TRICC, and TEDI SOUTH used the same study framework as JICA (2010) with updated sociodemographic data. With respect to modal share, data indicate that HSR accounts for 11.2% in 2030 of the total passenger market over long distances in Viet Nam and is projected to increase to 40.5% in 2050. Comparatively, a 16.9% loss of market share is projected for aircraft and an 11% loss is projected for roads in 2030–2050 (TEDI, TRICC, and TEDI SOUTH 2016).

7.3 Data and Methodology

This section describes how the environmental impact is analyzed using the data set. The first part represents the data collection and assumptions. The following one provides the model framework of scenario development

7.3.1 Data

The data used in this analysis were obtained from various sources. For instance, socioeconomic data were obtained from statistical yearbooks and vehicle data were collected from transport authorities. Others were collected from prevailing publications, official statistics, and related agencies’ documents. Table 7.1 the lists data and assumptions, including the sociodemographic and transport activities.
Table 7.1: List of Input Parameters for Developing Scenarios

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic Growth</td>
<td>2020–2030: 7%</td>
</tr>
<tr>
<td>Population</td>
<td>From 95 million people in 2018 to 110 million people in 2050</td>
</tr>
<tr>
<td>Mean Monthly Household Expenditure</td>
<td>Growth rate is assumed to change percent of population of urban or rural by report of General Statistics Office (GSO) and the United Nations Population Fund (UNFPA).</td>
</tr>
<tr>
<td>Passenger Car</td>
<td>2018: 1,737,686 units</td>
</tr>
<tr>
<td></td>
<td>Projection of passenger car ownership is based on the relationship between number of households owning vehicles and expenditure of household. A Gompertz function is used to forecast vehicle ownership over the analytical period as a function of increasing household income.</td>
</tr>
<tr>
<td>Passenger Kilometers Traveled</td>
<td>2018–2022: Annual growth rate of 5.3%</td>
</tr>
<tr>
<td></td>
<td>2023–2033: Annual growth rate of 5.2%</td>
</tr>
<tr>
<td></td>
<td>From 2034: Annual growth rate of 5.1%</td>
</tr>
<tr>
<td>Emissions Standard</td>
<td>100% of sold passenger cars met Euro 2 standard from 2015 onwards</td>
</tr>
<tr>
<td>Fuel Consumption</td>
<td>Based on EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016</td>
</tr>
<tr>
<td>Travel Distance</td>
<td>• Passenger car: Travel distance increases 1.3% annually</td>
</tr>
<tr>
<td></td>
<td>• Light commercial vehicle passenger: Travel distance remains constant at 26,868 km per year</td>
</tr>
<tr>
<td></td>
<td>• Coach: Travel distance remains constant at 41,709 km per year</td>
</tr>
<tr>
<td>Trip Length</td>
<td>• Passenger car: 148 km</td>
</tr>
<tr>
<td></td>
<td>• Bus: 155 km</td>
</tr>
<tr>
<td></td>
<td>• Conventional rail: 269 km</td>
</tr>
<tr>
<td></td>
<td>• Aviation: 682 km</td>
</tr>
</tbody>
</table>

EEA = European Environment Agency, EMEP = European Monitoring and Evaluation Programme, km = kilometer.
Source: Compiled by authors from various sources.

7.3.2 Methodology

The impact on the environment from transport activities can be measured by multiplying the vehicles traveled, fuel consumption coefficient, and emissions factor. To calculate the vehicles traveled, the outputs of transport services, such as passenger kilometers traveled or freight transport kilometers traveled, are estimated in line with the load factor.

To estimate the environmental impact of HSR, we developed and analyzed two scenarios: a scenario with business as usual (BAU) and
a scenario with HSR present. A part of the BAU projection was taken from previous research of the World Bank (Oh et al. 2019) with the same bottom-up approach. The details of vehicles traveled, number of vehicles by type, modal shift, and fuel consumption in the base year were inherited from this study. However, Oh et al. (2019) did not mention HSR in their scenarios, and their projections of transport activities were limited to 2030, points on which the results from this study differ.

Figure 7.1 shows the model framework of the BAU scenario. The same model was also applied in the HSR scenario.

Mode shift is calculated by forecasting changes in future demand for HSR service that incorporate modal shift. The modal share of HSR results from the shift of travel demand in aviation and highway in terms of time savings and interconnectivity. HSR will be effective and attractive for trips with a distance of less than 800 km (de Rus and Nash 2009; Campos and de Rus 2009). This means that HSR has a big advantage for trips that have a total travel time of 3 hours or less. With a longer distance, aviation is much more favorable than HSR.

Insights from a focus group interview for Viet Nam HSR suggest that HSR will be highly profitable in places with a large travel demand and a distance of 300–600 km (TEDI, TRICC, and TEDI SOUTH 2016). This means that the ideal distance for HSR attracting ridership is long distance, so we projected PKT only for long-distance vehicles such as buses, conventional rail, and planes.

The base year of this study is 2018 to update information including number of vehicles and annual distance traveled, together with average ridership. The PKT was calculated from these inputs. In the next step,
the PKT derived from a statistical book was compared with calculated PKT to calibrate the model.

From the development of the economy and population, total PKT was then projected over the period 2018–2050 using transnational comparisons as needed to estimate possible changes in PKT travel distance in line with the economic development levels.

Based on the PKT between the BAU and HSR scenarios, carbon emissions in line with energy consumption was calculated, and the reduction was drawn as follows:

\[
\text{Reduction} = \left\{ \sum_{i=1}^{m} (\text{PKT}_i \times F_j \times EF_{i,j}) \right\}_{\text{without HRS}} - \left\{ \sum_{i=1}^{m} (\text{PKT}_i \times F_j \times EF_{i,j}) \right\}_{\text{with HRS}}
\]

in which:  
\( \text{PKT}_i \) = passenger kilometers traveled by mode i  
\( F_j \) = consumption rate of fuel type j  
\( EF_{i} \) = emission factor of fuel type 1 with mode i

7.4 Long-Distance Transport Services for Passengers in Viet Nam

In line with economic development and population growth, passenger transport services have developed significantly. The vehicle fleet, particularly that of road vehicles, has sharply increased. As of 2018, there were 2.1 million cars for passenger services, which amounted to a quadruple increase over the course of 2008–2018 (an average annual growth rate of about 15.4%), from 498,000 cars in 2009. In terms of long-distance vehicles, intercity bus slightly increased over the same 10 years, from 14,000 in 2008 to 20,200 units in 2018 (Figure 7.2).

Little change took place in the railway sector from 2008–2018. Passenger transport activities depend mainly on the North–South Corridor, which operates on a single-track meter gauge. Several bottleneck sections with poor alignment, steep inclines, and sharp curves constrain operation. The quality of railway services has markedly declined, clearly indicated by the annual decrease in passenger volume.

Contrary to the decline of the railway subsector, the aviation industry grew strongly in its aircraft fleet and the expansion of airports. The country has 21 airports as of June 2016. Among them, 20 have scheduled domestic services, while the big three (Tan Son Nhat, Noi Bai, and Da Nang International Airports) offer both international and domestic flights. Two other airports, Phu Bai and Cam Ranh, were recently classified as international.
In terms of percentage of passenger transport services, among other subsectors, roads make up for the majority of intercity passenger traffic with 94.4% of transport volume, followed by inland waterway transport (IWT) with 4.3% of transport volume. From 2008 to 2018, as shown in Figure 7.3, passenger demand grew annually by 10.0%. In the same period, road usage grew by 9.9% in terms of kilometers traveled. This

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**Figure 7.3: Passenger Volume by Transport Subsector**

- **Aviation**
- **IWT**
- **Railway**
- **Road**

IWT = inland waterway transport.

Source: General Statistics Office (n.d.).
growth has resulted in an increase of congestion on the highways and on major intercity links.

However, in terms of passenger kilometers per capita, there has been a clear shift from road transport modes and conventional rail to aviation, with an increase of 1.5 times for PKT per capita in aviation. Roads remain the majority mode in Viet Nam, with 66.9% of the trips in 2018. Railways, of course, experienced a significant decline, from 5.8% to 1.7% (Figure 7.4). It is therefore not surprising that pollution levels have significantly risen in recent years.

![Figure 7.4: Mode Share of Passenger Kilometers Traveled per Capita](image)

Source: General Statistics Office (n.d.).

### 7.5 Scenario Descriptions and Assumptions

This section outlines the scenarios for the years 2018–2050 within and without HSR. BAU is understood to mean that no improvements are made to the current scenario, and the impact of HSR is indicated in terms of modal split change.

#### 7.5.1 Transport Activity under Business as Usual

Without HSR, long-distance travel demand depends mainly on three modes: intercity bus, conventional rail, and aviation. The development
of the national highway network in the BAU scenario strongly affects traffic flow, driving habits, and travel demand, resulting in an increase of on-road PKT (Figure 7.5).

Figure 7.5: Percent Increase of On-Road Passenger Kilometers Traveled

Source: Authors.

Figure 7.6: Projection of Passenger Kilometers Traveled on Long-Distance Services (under Business as Usual)

Source: Authors.
Figure 7.6 shows the modal share of PKT for long-distance services in the period 2018–2050 under BAU. PKT in the aviation subsector is projected to grow sharply from 84 billion in 2018 to 410 billion in 2050. Conventional rail contributes a small demand share, from 3.86 billion PKT in 2018 to 19.26 billion in 2050. The road subsector represents two-thirds of the total long-distance trips by 2050.

Based on the projected PKT, vehicle kilometers traveled (VKT) was calculated. Between 2018 and 2050, the kilometers traveled of on-road vehicles increases from 4.9 billion kilometers toward the range of 24–25 billion kilometers per year. The kilometers traveled by of aircraft increases about five times between 2018 and 2050 (Figure 7.7). To some extent, this is the result of promoting transport activities when the economy improves.

Since products of transport services have been carried mainly by on-road vehicles, energy consumption of transport depends heavily on gasoline and diesel fuels, as depicted in Table 7.2. Without energy efficient modes such as electric vehicles and hydrogen vehicles, conventional internal combustion engines strongly increases carbon emissions.
7.5.2 Modeling Travel Demand with High-Speed Rail Scenario

The impact of HSR on modal shift is based on the results of the aggregate logit model of a new HSR line projected by JICA (2010) and the consulting consortium TEDI, TRICC, and TEDI SOUTH (2016).

According to JICA (2010), at the early stage, HSR accounts for 5.0% of passenger volume and 11.6% in terms of passenger kilometers traveled. The share of HSR is mainly due to the shift from the aviation and road subsectors. The conventional railway has not been affected by HSR; it plays a role of connectivity.

Table 7.3 lays out the detailed level of modal share by subsector, based on the review of the existing prefeasibility study. The presence of HSR is expected to completely change the market share for long-distance transport service. At the initial stage, HSR serves only the first two points of the North–South Corridor. Expansion of its coverage leads to a shift in travel demand from road and aviation in the next stage,

Table 7.2: Energy Consumption by Fuel Type under Business as Usual

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>2018</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
<th>2045</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>1.7</td>
<td>5.9</td>
<td>8.8</td>
<td>11.5</td>
<td>13.4</td>
<td>14.6</td>
</tr>
<tr>
<td>Diesel</td>
<td>1.1</td>
<td>3.0</td>
<td>4.3</td>
<td>5.7</td>
<td>7.1</td>
<td>8.5</td>
</tr>
<tr>
<td>Jet Kerosene</td>
<td>2.9</td>
<td>5.1</td>
<td>6.3</td>
<td>7.6</td>
<td>9.1</td>
<td>11.0</td>
</tr>
<tr>
<td>Electricity</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Note: Fuels in million tons, electricity in gigawatt hours.
Source: Authors.

Table 7.3: Projection for Share of Passenger Kilometers Traveled with the Existence of High-Speed Rail

<table>
<thead>
<tr>
<th>Year</th>
<th>Road</th>
<th>Conventional Rail</th>
<th>High-Speed Rail</th>
<th>Aviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030</td>
<td>66.86%</td>
<td>4.26%</td>
<td>11.55%</td>
<td>17.33%</td>
</tr>
<tr>
<td>2035</td>
<td>58.84%</td>
<td>3.67%</td>
<td>15.24%</td>
<td>22.25%</td>
</tr>
<tr>
<td>2040</td>
<td>46.89%</td>
<td>2.41%</td>
<td>40.50%</td>
<td>10.20%</td>
</tr>
<tr>
<td>2045</td>
<td>46.28%</td>
<td>2.43%</td>
<td>39.91%</td>
<td>11.37%</td>
</tr>
<tr>
<td>2050</td>
<td>45.77%</td>
<td>2.41%</td>
<td>39.36%</td>
<td>12.46%</td>
</tr>
</tbody>
</table>

Sources: Adjusted from JICA (2010) and TEDI, TRICC, and TEDI SOUTH (2016).
pushing HSR to reach a share of 40.5% in 2040, a level the subsector retains for the remainder of the study period.

Demand segmentation mainly takes place at a distance of less than 100 km, which is suitable for travel on roads. Therefore, the road subsector remains a major choice. In line with the findings of various researchers, HSR attracts a large demand with a distance of less than 800 km. In links where HSR passes through, it will greatly reduce road vehicles. For example, for trips of 300–800 km, about 11.2% of travel demand tends to be attracted by HSR (Table 7.4), and the number of intercity buses will decrease accordingly, resulting in a safer, more economical, and more environmentally friendly transport sector.

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
<th>2045</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–100</td>
<td>55.2%</td>
<td>54.7%</td>
<td>54.2%</td>
<td>53.9%</td>
<td>53.6%</td>
</tr>
<tr>
<td>100–300</td>
<td>26.2%</td>
<td>26.4%</td>
<td>26.5%</td>
<td>26.6%</td>
<td>26.7%</td>
</tr>
<tr>
<td>300–800</td>
<td>11.2%</td>
<td>11.7%</td>
<td>12.2%</td>
<td>12.5%</td>
<td>12.7%</td>
</tr>
<tr>
<td>800–1,500</td>
<td>3.6%</td>
<td>3.6%</td>
<td>3.6%</td>
<td>3.6%</td>
<td>3.6%</td>
</tr>
<tr>
<td>&gt; 1,500</td>
<td>3.8%</td>
<td>3.7%</td>
<td>3.6%</td>
<td>3.5%</td>
<td>3.4%</td>
</tr>
</tbody>
</table>

**Table 7.4: Demand for High-Speed Rail Segmented by Distance**

km = kilometers.
Source: TEDI, TRICC, and TEDI SOUTH (2016).

The modal shift results in a reduction in expected fuel consumption compared to the scenario under BAU, as indicated in Table 7.5. Gasoline consumption drops by 4.1% in 2030 and by 31.6% in 2050. The outcome is similar with diesel; consumption would decrease by 35.9% compared to BAU in 2050. Emissions from aviation operations will be remarkably decrease due to reduced jet kerosene consumption.

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>2018</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
<th>2045</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>1.7</td>
<td>5.6</td>
<td>6.9</td>
<td>7.1</td>
<td>8.6</td>
<td>10.0</td>
</tr>
<tr>
<td>Diesel</td>
<td>1.1</td>
<td>2.9</td>
<td>3.6</td>
<td>3.8</td>
<td>4.6</td>
<td>5.5</td>
</tr>
<tr>
<td>Jet Kerosene</td>
<td>2.9</td>
<td>3.1</td>
<td>5.5</td>
<td>3.2</td>
<td>4.4</td>
<td>5.7</td>
</tr>
<tr>
<td>Electricity</td>
<td>0.0</td>
<td>275.4</td>
<td>355.2</td>
<td>432.9</td>
<td>510.2</td>
<td>591.8</td>
</tr>
</tbody>
</table>

**Table 7.5: Energy Consumption by Fuel Type under High-Speed Rail Scenario**

Note: Fuels in million tons, electricity in gigawatt hours (GWh).
Source: Authors.
7.6 Results and Discussion

This section includes the results of estimating the environmental impacts of HSR and discussions of the benefits of HSR in decarbonizing Viet Nam’s passenger transport sector.

7.6.1 Carbon Dioxide Emissions

Figure 7.8 presents the total carbon dioxide (CO$_2$) emissions in the two scenarios (BAU and with HSR) for the period of 2018–2050. Without any target for emission mitigation, the line in BAU shows a high slope trajectory. This reflects an explosion of motorization and rapid economic growth and also indicates a serious consequence for the environment.

Figure 7.8 also implies that a supplement of HSR would significantly reduce emissions. In the situation of Viet Nam, the operation of HSR would drop to two-thirds the rate of carbon emissions compared to BAU, a reduction from 107.6 million tons of CO$_2$ to 66.8 million tons in 2050.

The share of subsectors in the total CO$_2$ emissions in the base year, in 2030, and in 2050, for both the BAU and HSR scenarios, is shown in Figure 7.9. BAU presents an intense rise in road passenger CO$_2$, which
would grow by about 2.5 times between 2030 and 2050. In 2050, the road subsector in the HSR scenario has 34% lower CO\textsubscript{2} emissions than it does in BAU, and aviation has 48% lower CO\textsubscript{2} emissions than it does in BAU. HSR is therefore clearly a highly effective means to reduce the CO\textsubscript{2} emissions of long-distance transport services.

![Figure 7.9: Total Emissions by Subsector](image)

**Figure 7.9: Total Emissions by Subsector**

<table>
<thead>
<tr>
<th>Year</th>
<th>BAU</th>
<th>HSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>2030</td>
<td>40</td>
<td>55</td>
</tr>
<tr>
<td>2050</td>
<td>80</td>
<td>120</td>
</tr>
</tbody>
</table>

BAU = business as usual, HSR = high-speed rail.

Source: Authors.

### 7.6.2 Discussion

As one of the developing countries most affected by climate change, Viet Nam has committed to implement ambitious climate actions. In its nationally determined contribution under the Paris Agreement, adopted in 2015, Viet Nam committed to reduce its GHG emissions by 8% against a baseline projection by 2030. The measures identified in the agreement consist of “avoid–shift–improve” strategies aimed at changing the fuel structure in the transport sector and moving from fossil to low carbon fuels.

The transport sector is becoming a major contributor to total GHG emissions in Viet Nam, accounting for 18% of total CO\textsubscript{2} energy-related emissions in 2014. Under the BAU scenario, it is estimated that emissions from the transport sector will rise sharply from 33 metric tons of CO\textsubscript{2} in 2014 to 89 metric tons of CO\textsubscript{2} by 2030 with road transport being the dominant source, contributing 80% of all transport emissions (Oh et al. 2019).
Commercial vehicles represent a large share of intercity vehicles. Accordingly, they represent a significant share of emissions and contribute to interprovince traffic woes beyond their numbers due to much higher vehicle utilization rates and higher fuel consumption of commercial compared to private vehicles.

Electrified transport modes offer a promising potential to transform and decarbonize Viet Nam’s passenger transport sector. HSR is increasingly developing in countries worldwide. In various cases, high-speed rail systems are already cost-competitive while reducing air pollution, GHG emissions, and noise. It is the best evidence of a “shift” measure in long-distance transport services—basically, travel by unsafe intercity buses drops and travel by rail increases, leading to an improvement of the environment due to a reduced use of energy and carbon-based fuel.

This study takes a narrow scope in estimating the environmental benefits of HSR without considering other possible measures. However, the results show that HSR would provide a positive way to achieve the $\text{CO}_2$ reduction target for transport. The scenario mentioned in this study represents an illustration of a “shift” strategy among the set of “avoid–shift–improve” strategies. Therefore, we believe that a combination of strategies—including but not limited to building HSR—will contribute more to reducing climate hazards in transport activity.

### 7.7 Conclusion

Despite the fact that interest in understanding the environmental benefits of HSR networks is on the rise, little empirical work has been done with a focus on examining the impact of HSR on reducing climate hazards in transport activity at the national and local levels. This dearth of empirical work is partially due to the complicated nature of bottom-up approaches in this case, given the difficulty in identifying the details of vehicle travel, number of vehicles by type, modal shift, and fuel consumption. Our study aimed to fill this gap by providing some new evidence with a focus on examining the impact of HSR on addressing climate change using indicators of economic growth, vehicle growth, modal shift, and vehicle kilometers traveled (VKT).

In this study, HSR was revealed to be an effective mode to reduce $\text{CO}_2$ emissions and it had a significant and positive effect on sustainable mobility. HSR would create a new market of long-distance transport service in Viet Nam. In the early stage, HSR would attract 11.2% of the travel demand from road and aviation; after 10 years, it would reach 40.5%. However, the environmental contribution of HSR is only significant if its market share is large. In addition, because this study
only considers the operation period of HSR, ignoring the construction and maintenance periods, these findings may be contradictory to those of other studies.

Considering the magnitude of environmental issues, the most important contribution of the HSR to sustainable mobility lies in its ability to reduce environmental impacts, especially GHG emissions. In the case of the HSR project in Viet Nam, GHG emissions can be reduced by up to 48% by 2050.
References


8

Empirical Analysis on Industrial Sectors for Quality of Life Improvement along High-Speed Rail Corridors

Shuji Sugimori, Yoshitsugu Hayashi, and Hiroyuki Takeshita

8.1 Introduction

High-speed rail (HSR) is commonly recognized as one of the most important intercity transport modes to enhance regional economies with lower emissions and while assuring safety on dedicated tracks. Spillover effects brought by HSR have two main types. One is on regional economies related to industrial interactions, which includes income growth and new business emerging. The other is on personal well-being created by travel time reduction and affected by induced lifestyle changes. The former would result in growth in gross regional product (GRP), and the latter would result in increase in gross regional happiness (GRH), which means that not only HSR users but also residents along the HSR corridor would obtain a higher quality of life (QoL). This research aims to clarify the whole mechanism of spillover effects brought by HSR, in line with the final Sustainable Development Goal to “leave no one behind” of the Sustainable Development Goals. This chapter shows the primary steps of the whole research.

The QoL model introduced by Hayashi et al. (2019) explains how residents in one district will gain QoL from surrounding facilities (Figure 8.1). The “existing values” of some facilities such as shopping malls and hospitals will decay by distance impedance, which we call “accessible values.” Then these values will be accumulated for each person according to their respective perception, namely “perceived values,” which we define as QoL. Once HSR lines are opened, QoL along the HSR corridor would be affected by two steps. The first effect is the
direct user benefit due to the shorter travel time the new HSR enables, and the second is an increase in the level of regional products affected by interregional and inter-sectoral interactions. These effects enhance residents’ personal income as a factor of QoL and grow the existing values of surrounding regions.

Figure 8.1: Quality of Life Model

HSR = high-speed rail.
Source: Hayashi et al. (2019).

Reviewing recent analysis, Hayashi et al. (2019) tried to visualize QoL improvement along the Mumbai–Ahmedabad High Speed Rail (MAHSR) Corridor, which is planned by the Indian government. The results indicate that QoL will be well enhanced in the areas around intermediate stations rather than the urban areas of Mumbai, Surat, Vadodara, and Ahmedabad. That means the results showed only a first effect of HSR. Additionally, some of the QoL indicators mentioned here such as job opportunities and shopping opportunities would also be affected by industrial interaction. Therefore, this chapter focuses on industrial interaction as a second step.

8.2 Methodology

In order to explain industrial interaction brought by HSR, a regression model referred to as the industrial location model (Nakamura, Hayashi, and Miyamoto 1983) was developed. By this model, the number of
employees as an indicator representing the economic scale of each industry will be explained by (i) industrial interdependence and (ii) final consumption demand as follows:

\[
\ln(EMPL_t^k) = \alpha^k \ln(InterD_t^k) + \beta^k \ln(ConsD_t^k) + C^k, \tag{1}
\]

where \( EML_t^k \) is the number of employees of industry \( k \) in prefecture \( i \); \( InterD_t^k \) is a function of industrial interdependence of industry \( k \) in prefecture \( i \), which indicates the influence by other industries in other areas; and \( ConsD_t^k \) is final consumption demand from neighboring areas for the products or services offered by industry \( k \) in prefecture \( i \). \( C^k \) is a constant.

The explanatory variable \( InterD_t^k \) is defined as follows:

\[
InterD_{n_i}^k = \sum_m \theta^{mk} (\sum_j s_{ji}^n \times EML_j^m \times PL_{ji}^{mk}), \tag{2}
\]

where \( \theta^{mk} \) is input-output ratio for employment between industry \( m \) and industry \( k \), which indicates that the larger \( \theta^{mk} \) is, the more important industry \( m \) is for industry \( k \); \( s_{ji}^n \) is the share of transport mode \( n \) from prefecture \( j \) to prefecture \( i \); \( EML_j^m \) is the number of employees of \( k \)’s relevant industry \( m \) in neighboring prefecture \( j \); and \( PL_{ji}^{mk} \) is the probability of industry \( m \) of prefecture \( j \) in choosing prefecture \( i \) to trade with industry \( k \), defined by a logit-induced model:

\[
PL_{ji}^{mk} = \frac{EMPL_i^k \times \exp(\lambda^{mk} \times GC_{ji})}{\sum_j EML_j^m \times \exp(\lambda^{mk} \times GC_{ji})}, \tag{3}
\]

where \( \lambda^{mk} \) is a travel impedance decay parameter between industry \( m \) and industry \( k \), which is assumed as \(-0.0001\) according to Han et al. (2012). Here, \( GC_{ji} \) is the weighted average generalized travel cost for passengers from prefecture \( j \) to prefecture \( i \), defined as follows:

\[
GC_{ji} = \sum_{n \in N} s_{ji}^n \cdot (F_{ji}^n + \omega \cdot t_{ji}^n), \tag{4}
\]

where \( n \) is mode of intercity transport (e.g., air, rail), \( s_{ji}^n \) is the modal share (MLIT 2010) of \( n \) in the total transport volume from prefecture \( j \) to \( i \), \( F_{ji}^n \) is the transport fare (MLIT 2010) of mode \( n \) from \( j \) to \( i \) in Japanese yen (¥), \( t_{ji}^n \) is the travel time (MLIT 2010) of mode \( n \) from \( j \) to \( i \) in minutes, and \( \omega \) is the time value in ¥/minute.

The explanatory variable \( ConsD_t^k \) is defined as follows:

\[
ConsD_{n_i}^k = \sum_j s_{ji}^n \times POP_j \times PL_{ji}^k, \tag{5}
\]
where $P_{j|i}^k$ is the share of prefecture $j$, which is chosen for trade by industry $k$ of prefecture $i$ defined as below:

$$P_{j|i}^k = \frac{EMPL_i^k \times \exp(\lambda^k \times GC_{ji})}{\sum_j EMPL_j^k \times \exp(\lambda^k \times GC_{ji})},$$  \hspace{1cm} (6)$$

where $EMPL_i^k$ is the number of employees of industry $k$ in prefecture $i$.

### 8.3 Results

The input-output ratio for employment, $\theta^{mk}$, was calculated by the cross-section data of input-output tables (Statistics Bureau of Japan 2011, 2015a) multiplied by the share in the number of employees (Statistics Bureau of Japan 2010, 2015b) of each industry. Table 8.1 shows the value of $\theta^{mk}$ in 2015 in Japan. The arrows in Figure 8.2 mean the size of trade and the dependence direction between industrial sectors.

Table 8.2 shows the estimated parameters of the regression model using the data of employment in 39 zones of Japan pooling two points of time, 2010 and 2015. Figure 8.3 shows the t-value for the explanatory variable InterD. With these results, it is assumed that the economic scales of the four industries (3. construction, 4. infrastructure services, 7. hotels and restaurants, and 8. other services) have significant positive relations with intercity rail transport because of their higher t-values. We must note that this model deals not with freight transportation but with services for passengers.

The elasticity of industrial interdependence by rail passenger transport was calculated as follows. For example, $\alpha_2$ (InterD Rail) in the construction sector is 4.315, which indicates that a 100% increase of industrial interdependence will result in a 432% growth of the number of employees in the industry. In addition, $R^2$ values for most industries are high, which suggests that the developed model of inter-sectoral and interregional industrial interactions has a reasonable explanatory capability, and the model indicates that the degrees of increase and decrease in employment are influenced by HSR improvement.
### Table 8.1: Input-Output Ratio for Employment: θ

<table>
<thead>
<tr>
<th>Input</th>
<th>Agriculture, Forestry, and Fishery</th>
<th>Manufacturing (Incl. Mining)</th>
<th>Construction</th>
<th>Infrastructure</th>
<th>Wholesale</th>
<th>Retail</th>
<th>Hotels and Restaurants</th>
<th>Other Services</th>
<th>Public Administration</th>
<th>Private Final Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.43</td>
<td></td>
<td>0.12</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>0.13</td>
<td>0.01</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>3</td>
<td>0.19</td>
<td></td>
<td>0.51</td>
<td>0.34</td>
<td>0.12</td>
<td>0.04</td>
<td>0.22</td>
<td>0.09</td>
<td>0.06</td>
<td>0.19</td>
</tr>
<tr>
<td>4</td>
<td>0.07</td>
<td></td>
<td>0.07</td>
<td>0.08</td>
<td>0.18</td>
<td>0.20</td>
<td>0.13</td>
<td>0.10</td>
<td>0.15</td>
<td>0.12</td>
</tr>
<tr>
<td>5</td>
<td>0.07</td>
<td></td>
<td>0.07</td>
<td>0.08</td>
<td>0.18</td>
<td>0.20</td>
<td>0.13</td>
<td>0.10</td>
<td>0.15</td>
<td>0.12</td>
</tr>
<tr>
<td>6</td>
<td>0.05</td>
<td></td>
<td>0.08</td>
<td>0.11</td>
<td>0.02</td>
<td>0.02</td>
<td>0.12</td>
<td>0.04</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>7</td>
<td>0.12</td>
<td></td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
<td>0.17</td>
<td>0.02</td>
<td>0.03</td>
<td>0.12</td>
</tr>
<tr>
<td>8</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.03</td>
<td>0.00</td>
<td>0.00</td>
<td>0.07</td>
</tr>
<tr>
<td>9</td>
<td>0.08</td>
<td></td>
<td>0.13</td>
<td>0.42</td>
<td>0.42</td>
<td>0.58</td>
<td>0.15</td>
<td>0.46</td>
<td>0.41</td>
<td>0.44</td>
</tr>
<tr>
<td>Total</td>
<td>1.00</td>
<td></td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table 8.2: Weight of Each Explanatory Variable for Each Industry

<table>
<thead>
<tr>
<th>Industry</th>
<th>( \alpha_1 ) (InterD Air)</th>
<th>( \alpha_2 ) (InterD Rail)</th>
<th>( \beta_1 ) (ConsD Air)</th>
<th>( \beta_2 ) (ConsD Rail)</th>
<th>C</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Agriculture, forestry, and fishery</td>
<td>0.908***</td>
<td>-0.003</td>
<td>-0.425</td>
<td>0.178</td>
<td>6.477</td>
<td>0.777</td>
</tr>
<tr>
<td></td>
<td>(2.94)</td>
<td>(-0.01)</td>
<td>(-1.35)</td>
<td>(0.46)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Manufacturing (incl. mining)</td>
<td>0.541</td>
<td>1.150*</td>
<td>-0.047</td>
<td>-0.894</td>
<td>7.470</td>
<td>0.927</td>
</tr>
<tr>
<td></td>
<td>(0.67)</td>
<td>(1.91)</td>
<td>(-0.06)</td>
<td>(-1.49)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Construction</td>
<td>-3.850***</td>
<td>4.315***</td>
<td>4.376***</td>
<td>-4.120**</td>
<td>4.182</td>
<td>0.894</td>
</tr>
<tr>
<td></td>
<td>(-2.81)</td>
<td>(2.70)</td>
<td>(3.20)</td>
<td>(-2.57)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Infrastructure</td>
<td>-2.082</td>
<td>5.094**</td>
<td>2.623</td>
<td>-4.880*</td>
<td>11.281</td>
<td>0.927</td>
</tr>
<tr>
<td></td>
<td>(-1.01)</td>
<td>(2.02)</td>
<td>(1.27)</td>
<td>(-1.93)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Wholesale</td>
<td>0.012</td>
<td>0.665</td>
<td>0.501</td>
<td>-0.448</td>
<td>4.746</td>
<td>0.902</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.53)</td>
<td>(0.42)</td>
<td>(-0.36)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Retail</td>
<td>0.199</td>
<td>0.758</td>
<td>0.332</td>
<td>-0.546</td>
<td>6.982</td>
<td>0.913</td>
</tr>
<tr>
<td></td>
<td>(0.25)</td>
<td>(0.92)</td>
<td>(0.42)</td>
<td>(-0.67)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Hotels and restaurants</td>
<td>-3.033***</td>
<td>2.850***</td>
<td>3.582***</td>
<td>-2.650**</td>
<td>1.220</td>
<td>0.913</td>
</tr>
<tr>
<td></td>
<td>(-2.87)</td>
<td>(2.77)</td>
<td>(3.38)</td>
<td>(-2.57)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Other services</td>
<td>0.546</td>
<td>5.099**</td>
<td>0.005</td>
<td>-4.901**</td>
<td>14.091</td>
<td>0.919</td>
</tr>
<tr>
<td></td>
<td>(0.27)</td>
<td>(2.53)</td>
<td>(0.00)</td>
<td>(-2.42)</td>
<td></td>
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</tr>
<tr>
<td>9. Public services</td>
<td>-1.050</td>
<td>1.963</td>
<td>1.593</td>
<td>-1.776</td>
<td>5.707</td>
<td>0.880</td>
</tr>
<tr>
<td></td>
<td>(-0.94)</td>
<td>(1.78)</td>
<td>(1.43)</td>
<td>(-1.60)</td>
<td></td>
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</tr>
</tbody>
</table>

Notes:
The upper value of each box is the parameter, and the lower value is the t-value.
Significance levels: *** 1%, ** 5%, * 10%.
Source: Authors.
8.4 Studies in the Kyushu Shinkansen Corridor in Japan

To compare the calculation results with actual data, we selected the Kyushu Shinkansen corridor for a study on industrial interactions as an example of recently opened HSR lines in Japan. The Kyushu Shinkansen was fully opened between Fukuoka City and Kagoshima City in 2011 after being partially opened between Yatsushiro City and Kagoshima City in 2004. The total length was about 300 kilometers, and the shinkansen (bullet train) drastically reduced travel time to 76 minutes, compared to 132 minutes via the conventional line with a partially opened shinkansen. The stations are located in 12 cities along the corridor.

Among all shinkansen lines in Japan, the Kyushu Shinkansen’s ridership is about one-tenth of that of the Tokaido Shinkansen. The statistical data in the following figures indicate that HSR brings some spillover effects on industrial interactions along the HSR corridor, even if the ridership is lower than that of a metropolitan-connecting HSR.
Figure 8.4 shows the increase rate of employees (METI 2012, 2016) from 2005 to 2015 in each industry, comparing the 12 cities to the whole of Kyushu Island and also the whole of Japan. Three out of the four industries (except hotels and restaurants) picked up by the regression model have higher positive rates and lower negative rates in employment in the 12 cities than do those of Kyushu Island and the whole of Japan.

Figure 8.5 shows the share of employment of the 12 cities in the whole of Japan. Three out of the four industries (except hotels and restaurants) in the 12 cities have increased their share in employment from 2005 to 2015.

Although these actual data are influenced by various economic conditions and social circumstances, it is found that almost all of the industries would gain positive impacts from the opening of HSR. The developed model could be a reasonable method to evaluate the future trends of interregional industrial interactions.
8.5 Conclusion

In this chapter, empirical analysis of the Kyushu Shinkansen has clarified the effects brought by HSR on its corridor.

- Different effects of rail and air on each industry were estimated by the model. In Japan’s case, rail transport has a higher correlation with the economic activity level of various industrial sectors than does air transport.
- The statistical data of employment indicate that the opening of HSR has brought economic effects. For example, following the full opening of the Kyushu Shinkansen, employment in the corridor regions increased in almost all industrial sectors, which includes the sectors extracted by the model. In addition, the share of employment of the corridor regions in the whole of Japan has increased.
- Our analysis shows that opening of HSR will bring not only economic impacts but also QoL improvement to its corridor regions.
For further research, we recommend: (i) applying the model to the Mumbai-Ahmedabad HSR Corridor, (ii) incorporating economic impact into QoL enhancement, and (iii) deepening QoL analysis for various HSR corridors in India.

Hopefully, this methodology can be applied to HSR corridors not only in India but also in various countries, and will be helpful for future analyses and research.
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Planning, Power, and Deliberation: Lessons from High-Speed Rail Expansion in Spain

Ángel Aparicio

9.1 Introduction

Since the opening of the first 250-kilometer-per-hour link between Lyon and Paris by the French railways in 1981 and the subsequent call for a Europe-wide high-speed rail (HSR) network by a group of experts piloted by the Union of International Railways (UIC from its French acronym), high-speed rail has played a central role in the continent’s transport policy narratives (MVV Consulting 2009; European Commission 2009).

Although initially targeting the development of HSR in the European core (Figure 9.1), the rail lobby was quick to push for a Europe-wide HSR network, receiving strong support from the European southern periphery, not least out of fear of losing their share in the envisaged funding scheme. A political compromise was reached within a “high-level group of personal representatives of the heads of states or government” of the member states, which identified 14 priority projects, most of them referring to high speed rail infrastructure (European Commission 1995).

In time, this scheme would give way to the HSR network included in the first regulation of the trans-European transport network (TEN-T) (Decision No. 1692/96/EC of 23 July 1996 on Community Guidelines for the Development of the Trans-European Transport Network) and its subsequent revisions.

Also, at the end of the 1980s, the future Treaty of the European Union (Maastricht Treaty) was being negotiated. The treaty enshrined the principles of the common market, suppressing border controls for freight and passengers among member states, and included TEN-T.
as a European policy; it also sped up the decision-making process for the approval of transport regulations, with the goal of facilitating the future growth of freight flows among member states. The treaty entered into force in 1992, and it was soon followed by the 1992 White Paper on the Future Development of the Common Transport Policy (European Commission 1992). This white paper would be followed by others, published by the European Commission every 10 years. It designed an agenda aligned with the prevailing neoliberal principles in Europe at that time (Marshall 2014b): to encourage competition (and lower prices for consumers) in all transport modes within a common European transport market and to support the deployment of transnational transport networks in all modes, while entrusting rail with a central position for freight and passenger transport.

European researchers have dedicated considerable effort to analyze the effects of HSR, particularly from the fields of transport geography...
and transport economics. Whereas transport geography has focused on the accessibility gains in the territory provided by HSR, transport economics has generally undertaken microeconomic analysis based on consumers’ utility gains. Interestingly, there have been increasing attempts to bridge the gap between geography and economics, following the pathways of the New Economic Geography, looking for associations between accessibility gains and economic activity growth in the regions connected with HSR services, measured in terms of employment, regional gross domestic product (GDP), tax revenues, or tourist visitors among others (see Rothengatter 2017 for a review). Widely considered, these effects have been labeled as wider economic impacts (WEI). The European Commission has also addressed this topic in their periodical reports on regional development and on the progress in the deployment of TEN-T and HSR. The Court of Auditors (2018), the European watchdog of economic orthodoxy, was highly skeptical about the benefits of HSR, aligned with the conclusions issued by similar national bodies like Cour des Comptes (2014) in France or AIREF (2020) in Spain.

This chapter tries to elucidate some reasons European decision makers keep privileging HSR within their transport policy in spite of sustained criticisms from the economics field. Instead of trying to expand the realm of the potential economic benefits, like WEI studies do, the approach is to analyze the planning and decision-making procedures from a planning theory perspective, aiming at identifying the key stakeholders, their interests, and the constraints imposed on them by the political context. This approach follows the pathways of other planning theory scholars (see Marshall 2014a and 2014b for a review) and is referred to in this chapter as a public policy analysis (PPA). This PPA analysis is not intended to replace the valuable contributions from the geography and economics fields, but merely to widen the scope of the analysis. The initial hypothesis is that HSR expansion, as a key transport policy, provides a way for institutions to stabilize, reaffirming their legitimacy in the territory at times of constitutional transitions in which such legitimacy is challenged (as is the case for the still under construction European institutions or for national and regional governments following the constitutional changes leading to decentralization in European countries such as France or Spain). Secondly, transport infrastructure policies are long term by nature and therefore highly inertial and difficult to steer. Thirdly, this inertial character is strengthened by a neoliberal context in which the ability of national governments to directly intervene to support some regions is all but forbidden, narrowing regional development policies to a handful of indirect actions to gain competitiveness, of which infrastructure endowment is virtually the only one able to funnel a significant amount of resources.
This PPA is presented in this chapter as follows: It starts with an overview of the expansion of the HSR network in Spain. In spite of its peripheral position in Europe and low population density, making the economic case for HSR particularly weak, the Spanish network is the largest one in Europe (European Commission 2019). Spain was probably the country that more enthusiastically embraced the European vision of a rail-focused passenger transport system. Furthermore, initiated at the end of 1988 with the first construction work on the Madrid–Seville line, the HSR rush has proven to be resilient and able to survive through many political and territorial divides, undeterred by a deep economic and political crisis.

The second part of the chapter describes the contributions from academia to the study of HSR development in Europe and in Spain and the differences and convergences among the views of economists, geographers, and engineers. The third part provides an analytical framework for PPA based on two pillars: the general neoliberal drivers of European Union (EU) integration and the constitutional drivers of European integration and national decentralization, which jointly reinforce the historical inertia of transport infrastructure policies. The fourth part applies the PPA framework to provide a more comprehensive understanding of the planning and implementation process and explores the path forward for HSR planning and studies, as a way for academia to become more influential in shaping future policy making.

9.2 Short History of High-Speed Rail Planning and Implementation in the European Union and in Spain

This section reviews the increasing influence of European Union policies in rail planning in Spain. It provides an overview of rail infrastructure planning in Spain, followed by a description of the main drivers of the European rail policy, and concludes with an assessment of the consequences of these European drivers in the decisions adopted by the Spanish decision makers.

9.2.1 Rail Planning and Implementation in Spain

In the early 1980s, the state of the Spanish rail network reflected a decades-long lack of investments: almost two-thirds of the 11,000-kilometer (km) network was not electrified and 40% of the network remained with single track, including all the principal access from the flat central plateau where Madrid is located to the coastal cities, as the mountains
separating the plateau from the sea required costly investments and even the construction of full alternative layouts replacing the old 19th century lines. The deficit of the public rail company (Renfe) was well above €1 billion in the early 1980s (equivalent to more than €3 billion in 2020). Following the general approach of the times, the government closed down almost 20% of the existing network in 1984 and signed a contract program with Renfe to get the company back on track.

The 1980s saw the rapid modernization of the Spanish road network, with the support of the EU accelerated after the full accession of the country in 1986. The rapidly expanding motorway system provided convenient transport not only to those owning cars (the number of passenger cars per 1,000 inhabitants was already above 300), but also to those making use of a prosperous regular bus service. Train services were quickly losing any comparative advantage, and the number of passenger-km had stagnated at around 16,000 million after having peaked at almost 19,000 in the mid-1970s.

Motorway expansion was also a largely unexpected political success. It was based on the Road Infrastructure Plan (Plan General de Carreteras, PGC) informally launched in 1984 (formal approval came in 1986). The previous plan, approved in 1972 and based on concessions for the construction of toll motorways, had been a financial fiasco that left the country highly indebted to the sole benefit of the few construction companies that gained the concession contracts and seized strong guarantees and incentives from the national government, to deliver just less than 20% of the envisaged network. Not surprisingly, the new PGC first passed largely unnoticed by a skeptical public opinion but was soon generally praised as it started delivering its first results. The Ministry of Transport tried to transfer this positive experience to the much-troubled rail sector, and a Rail Infrastructure Plan (Plan de Infraestructura Ferroviaria, PIF) was approved by the government in 1987. It aimed at specializing passenger rail in high-volume long-distance corridors and metropolitan services. The upgrading of the network included a 200 km/h line linking Seville, Madrid, and Barcelona. The concept was revised in December 1988 in order to adopt an HSR design for Seville–Madrid, introducing the standard 1,435-millimeter (mm) gauge (the rest of the network would remain the traditional 1,668-mm Iberian gauge) and adopting the French TGV technology in order to start operations by 1992 target.

Shortly after opening, the line was considered a commercial success. The average monthly number of passengers carried by the line was 164,000 (or just below 2 million passengers per year). Since then, the number of passengers has steadily increased, reaching 3.3 million in 2017. This was indeed remarkable considering the population density
in Spain, but it was far from the 10 million passengers per year carried by the Paris–Lyon TGV in the 1980s or the 17 million passengers in the 1990s. Although the demand was modest compared with any other HSR line, it was significant compared to the actual demand between Seville and Madrid, reaching in 1996 41% of all the trips between Seville and Madrid, compared with just 14% in 1991, before the HSR line was operational (Inglada and Coto-Millán 2004). Furthermore, induced demand was also significant at 26% or an average annual growth of almost 5%.

These figures were seen as confirmation of wide public support and served to raise the stakes in the next infrastructure plans: the Infrastructure Master Plan 1993–2007 (Plan Director de Infraestructuras, PDI 1993) and its successor, the more detailed Rail Infrastructure Plan (PIF 1995). They expanded the main Seville–Madrid–Barcelona link further northbound to reach the French border (although they scheduled this expansion beyond the plan’s 2007 horizon); also, beyond 2007, the plans envisioned a number of additional HSR feeding lines connecting the main diagonal to other destinations, such as Valencia or the Basque country. One-third of the total investment foreseen by the plan was targeting HSR expansion, and it is worth mentioning that most of those investments (up to 65%) were expected to be covered by the private sector through public–private partnership (PPP) schemes. In fact, almost two-thirds of the total public investment envisaged in the PIF 1995 was dedicated to significant improvements ( electrification, double track, bypasses, etc.) in many sections of the existing rail network, showing that the planners paid attention to the upgrading of the whole network and not exclusively to HSR (Cruz Villalón 2017; Aparicio 2010).

This cautious approach would be abandoned in the 2000–2004 period. Although officially presented by the Ministry of Development as a new Transport Infrastructure Plan (Plan de Infraestructuras de Transporte, PIT 2000–2007), no written document was ever approved by the government or discussed at the Parliament. PIT 2000 was more a fluid political concept with simple and powerful messages in terms of the investment to be mobilized (more than €100 million) and the priority to HSR, which was to receive 46% of the total investment (the remainder going mostly to the other transport modes) in order to deploy an ever-growing tree-like network connecting all the province capitals with Madrid and reaching 7,000 km at the time the minister left office (see one of the PIT 2000 maps in Cruz Villalón 2017). No details were provided on the speed and other technical characteristics of such a network. The actual expansion of the network was modest: between 1992 and 2003, only a section of the HSR line between Madrid and Barcelona was opened, and without reaching the expected 300-km/h speed until
4 years later, due to the limitations of the then under development new European rail traffic management system, ERTMS.

Interestingly, the government was also providing key financial guidelines: the continuation of the motorway network expansion would be left to private investors (who could freely push forward proposals to complete motorway sections, for which the government would need to call for concessions) whereas HSR would be sustained mainly through public investment.

If ineffective in terms of delivery, this period would prove to have a long-term impact on the future of the Spanish HSR. It established some kind of entitlement of all Spanish cities to HSR access, a right that would prove highly resilient and politically impossible to overturn. A fatal combination of disregard for planning and an excess of political self-confidence of decision makers created a highly emotionally charged environment with all regional politicians fighting to get their promised HSR lines delivered. Particularly illustrative of the use of infrastructure planning as a poorly disguised political tool is the case of “Plan Galicia.” This was a decision by the national government to push forward and accelerate the HSR access to this northwestern region to compensate for the political unrest that followed the Prestige ecological disaster in 2003—an action that had no relationship with the causes of the problem or with its consequences (Cruz Villalón 2017).

Following the 2004 general elections and the subsequent change in the cabinet, a new plan was prepared: the Strategic Plan on Transport Infrastructure and Services (Plan Estratégico de Infraestructuras y Transporte, PEIT 2005). For the first time, the planning process had followed a regulated approval procedure, and PEIT 2005 was formally approved by the Council of Ministers. It provided a new concept, multimodality, aimed at combining the advantages of HSR with the flexibility and wider coverage of buses and conventional rail—and a new normative framework with a tiered planning scheme and a set of new regulations—to find a balance between planning and politics. The future of the rail network and, more specifically, the role of HSR was probably the most politically sensitive issue to deal with. The obvious contradictions between the political expectations of most regions and the modest demand expected in many links was negotiated through language: providing a final map of a 10,000-km network (smaller in fact than the existing rail network, suggesting the closure of some low-traffic sections) while describing that the network would include (unspecified) sections that could provide lower speeds. The plan made an honest attempt to move back to an integrated rail network where improvements in the existing network would be accompanied by a move from the Iberian gauge (1,668 mm) to the standard gauge
(1,435 mm) and most of the network would be fit for both passenger and freight traffic, while improving speeds without necessarily aiming at the 350 km/h promised by the previous government. Unsurprisingly, the increasing political polarization pushed decision makers in the most doubtful direction: keeping the whole 10,000 km network while promising that most of it would be designed with a project speed over 300 km/h whenever feasible. It was during this time that most of the current network was actually completed, including the implementation of ERTMS in Madrid–Lleida (2006, allowing for speeds over 200 km/h and 2007, for speeds over 300 km/h) and the expansion of the network to Málaga (2006), Barcelona (2008), Valencia (2010), the French border (connection completed in 2009 and full HSR upgrade in 2013), and Alicante (2013), among others.

A new change of government in 2012 was followed by a new transport infrastructure plan (Plan de Infraestructuras, Transporte y Vivienda, PITVI 2012) and a subsequent revision of the rail network. Like its predecessor, it followed a formalized approval procedure, which did not conclude until 2015. The new plan envisages a substantial decrease in public investment in transport infrastructure (from a 1.5% GDP average in PEIT 2015 to 0.9%), which was expected to be compensated for by the private sector (the construction and concession industry being considered as a strategic sector for the country, deserving support to build up know-how and prestige and effectively compete at the international level). Concerning the rail network, the plan bluntly states the disparities of an investment policy focusing on HSR: in 2012, there were 2,344 km of HSR lines and 810 km of lines somehow “adapted to HSR” (probably meaning speeds of 200 km/h) but, at the same time, only 46% of the rest of the 11,597-km rail network was electrified, 70% of it remained with single track, and only 30% allowed speeds over 160 km/h. The new plan recovered the idea of PIT 2000 of specializing the old rail network for freight and keeping the Iberian gauge while dedicating the new lines for passengers.

9.2.2 The Influence of European Policy

We need to move back to the late 1980s to find the origins of European transport policy and its interest in HSR. The rationale for HSR services in Europe came mainly from the need to increase the capacity in some congested corridors in the more densely populated areas of the continent by providing an alternative to road and air transport. Besides the well-known development of the TGV technology in France during the 1970s, other countries had made more modest attempts to provide passenger rail services with higher speeds,
such as Italy’s Direttissima connection between Rome and Florence with speeds up to 200 km/h, mostly based on train rather than infrastructure improvements, with the well-known Pendolino or the first German Intercity Express (ICE) services.

Although dauntingly expensive for the time (€4.8 million per km in 2003 currency value, not including the engineering costs for the design and manufacturing of the TGV trains) (Cour des Comptes 2014), the Paris–Lyon service proved to be successful in attracting passengers from congested motorway and air links in addition to rail corridors (serving some 10 million passengers per year shortly after opening in 1981). This empowered the European rail lobby to push for a European HSR network, primarily targeting the European core and making the case for dedicating European funds to support it. In 1986, the European Commission issued the report *Towards a European High-Speed Rail Network* (European Commission 1986). It called for an HSR targeting the most congested corridors (i.e., mostly the European core including London, Paris, Brussels, Amsterdam, and Frankfurt) and mainly financed through the European budget. This concept also provided a brilliant future to the struggling, job-intensive, and politically influential rail industry, particularly in France and Germany. It did not get the necessary support for approval, though. On the one hand, it would have given the European Commission a daunting amount of resources as well as the capacity to influence the priorities of national governments; on the other hand, the concept would concentrate the allocation of resources in the rich European core, leaving aside the poorer southern peripheral countries (Aparicio 2017).

An alternative approach gained momentum in the following years, embedding HSR expansion within the wider concept of creating transport networks covering the whole of the EU territory. The rationale of the proposal was the perceived threat of transport infrastructures soon to collapse from the growing traffic generated by the opening of the single market in 1992. In 1989, the Community of European Railways presented a “proposal for a European high-speed network,” and several working groups were put in place. A 1991 communication of the European Commission to the Council regarding a European high-speed train network (European Commission 1991) provided a sketch of what, in time, would be the HSR network included in the first regulation of TEN-T, then expected to be completed by 2010 (Decision No. 1692/96/EC of 23 July 1996 on community guidelines for the development of the trans-European transport network). The maps in the regulation distinguished between HSR lines and rail lines upgraded to HSR. In most of the EU, the second category was predominant; in France and Spain, the first category largely prevailed (see maps in European Union 1996).
TEN-T would provide the infrastructure pillar of the European transport policy. The second pillar would come from a set of regulations aimed at establishing a single European market for transport services, to be governed by fair competition among service suppliers. This was consistent with the now dominating neoliberal perspective that had been enshrined in the Treaty of the European Union (Maastricht Treaty). The Treaty entered into force in 1992, enshrining a common market and suppressing border controls for freight and passengers among member states. It included TEN-T as a European policy and new majority rules to speed up the decision-making process on, among other things, transport regulations. Soon afterward, the European Commission issued a roadmap for implementation, a White Paper on the Future Development of the Common Transport Policy (European Commission 1992). This paper designed an agenda to encourage competition (and lower prices for consumers) in all transport modes within a common European transport market and to facilitate the deployment of transnational transport networks, with a special reference to HSR.

Since then, rail traffic would experience a sustained growth in policy documents. The share of rail in passenger traffic volumes has hardly increased, and the actual expansion of rail infrastructure has been substantially lower than planned. The already ambitious HSR scheme in European Union (1996) was considerably expanded in European Commission (2009), renamed as “category I rail lines,” but the fact is that only a small part of the foreseen HSR network planned for 2020 is actually operational today, and the same can be said of the forecasts on HSR passenger demand and modal share made in those documents. The stubborn reality showed the steady decline of the rail share in passenger and freight transport in the EU. The contradiction between the expectations in policy papers and transport demand statistics did not deter the European Commission from persisting with the same rail-centered vision for almost 3 decades in the Transport White Papers published in 2001 and 2011. The last Transport White Paper (European Commission 2020) continues with the same ideas expressed in the earlier white papers and announced that by 2030 “high-speed rail traffic will double across Europe.”

Three drivers in this process are worth being described in more detail: (i) the prevailing neoliberal approach to transport as a European public policy, (ii) the sustained political influence of the European rail community, and (iii) the centrality of transport infrastructure—and particularly of HSR—in the distribution of a non-negligible share of the EU budget among member states.

**First driver (ideological): the neoliberal approach to European integration.** The Common European Transport Policy consolidates only
in the 1980s, overcoming the resistance of many countries to implement the Treaties, on the grounds of the strategic relevance of transport for national economies. At the time it was launched, this policy mainly attempted to implement the neoliberal agenda in the transport sector, aiming sequentially at air, road, and rail transport. Air transport was a low hanging fruit and was mainly implemented in the 1990s. Road transport was relevant for freight and was accelerated as a consequence of the implementation of the Common Market in 1992.

Rail transport was a different story. In the 1980s, public rail companies were drowning in debt, facing decreasing freight and passenger demand in spite of measures to protect them from road competition. The liberalization of air transport caused prices to fall and increased pressure on rail.

Rail liberalization in Europe had no clear model. Rail reform in the United States focused on freight whereas European railways had always prioritized passenger traffic. The model (Directive 91/440) was the Swedish one (separation in 1988 between infrastructure management and service operation): on-track competition inspired the EU legislation. However, the implementation of the model was subject to long delays. Full competition in passenger rail transport will not be compulsory until 2023.

This kind of market competition requires spare infrastructure capacity to operate. Infrastructure had to be improved and became a European priority. The neoliberal trends also encouraged market-driven solutions; the expectation was that private investors should be interested in investing in infrastructure that was expected to serve a growing demand.

The prevalence of the neoliberal approach led to the progressive withering of Keynesian policies, and in particular of the spatial planning tradition that had reigned in Western Europe in the postwar decades. The new regional development paradigm was based on competitiveness and rejected the direct actions of governments; regions would be empowered to compete at the European and global level through infrastructure endowment, capacity building, and—eventually—temporary fiscal incentives.

**Second driver (historical): the weight and influence of incumbent public rail companies.** The 1980s saw the incumbent rail companies in deep crisis and deficits. The companies were closing lines and reducing staff and services. The long decline of rail travel was a consequence of road competition, changing patterns in the post-1970s economy, and European railways’ inflexibility and reluctance to change.

The general narrative was that railways have to be supported in their transition toward competition by major infrastructure investments.
What remained largely untouched was the extremely high price tag of such investments, caused partially by the complexity of the rail system but also by the decades-long oligopoly of the rail industry.

A highly political narrative was built up by the rail conglomerate: There was a need for better infrastructure (HSR), as demonstrated in the Paris–Lyon project (launched in 1976 and opened in 1981 with a dedicated line, instead of just enlarging the existing capacity) and previously in Japan (with the *shinkansen* in 1964). Long-distance passengers were the strategic market to capture. And that would be a strategic choice in the ever-growing corridors at the core of Europe, liberating air space.

The view on HSR was first presented in the 1992 Transport White Paper: (COM (92) 494) within the concept of a Trans-European Transport Network (TEN_T), in which the key ambition was to substantially facilitate the physical movements- and in particular border crossing among European countries. This ambition had been shyly initiated in 1978, with the creation of a Committee on Transport Infrastructure, which since 1982 was allocated a modest fund to support the so-called transport infrastructure projects of European interest. In 1990, the European Commission convened a high-level working group, consisting of experts from government and industry as well as transport operators and users. The working group provided a report including a network for high-speed trains (European Commission 1991). The European Commission followed a similar approach for the other transport modes. All these activities were backed politically at the highest level, with the introduction of new provisions on trans-European networks in the 1992 Treaty on the European Union (Maastricht Treaty), which formed the new basis for the community action announced in the 1992 Transport White Paper.

**Third driver: regional development funds moving away from road projects.** In the early 1990s (at the time of the Spanish PDI 1995), the main motorway corridors had been financed with large support from EU funds. As the European TEN-T policy was developing, it became increasingly obvious that the funds would be supporting primarily rail in the future.

EU funding changed well-consolidated practice within the Spanish administration. The long-established reluctance toward public works spending was replaced by a frenzy to be able to properly spend and justify the increasing resources coming from Brussels. Many politicians and experts and a large part of the public considered that keeping a long list of projects in the pipeline ready for funding was a key obligation of any conscientious minister of transport.
9.2.3 Why High-Speed Rail Became So Central to Spanish Transport Policy and to Politics

The territorial conditions in Spain make this country an unlikely candidate for extensive HSR expansion. The first chapter of PDI 1993 provided a detailed spatial analysis of the country, pointing out among others, the following conditions:

- Low-density population in most of the country, much lower than in the European core. Most of the population is concentrated along the Mediterranean coast and in Madrid, with just two other inland cities, Zaragoza and Seville, with above half a million inhabitants—and Seville actually being very close to the coast and having a river port (Escudero Gómez, García González, and Martínez Navarro 2019).
- Not in a position to provide HSR technology for tracks or trains. Although in the 1980s, Spain had a significant rail equipment manufacturing industry, its competitive advantage was associated with the modernization of the existing rail system with its characteristic Iberian gauge.
- Rapidly improving quality of road and air passenger transport, based on the motorway network expansion, bus services among most cities, and air services linking the coastal cities with Madrid. Air traffic and airport capacity showed no signs of immediate congestion.
- Long distances to reach the European core. This made for a weak case for any international HSR services.

Under these circumstances, it is tempting to view the disruptive 1988 decision of the national government to build the new Seville–Madrid link with HSR characteristics and TGV technology as the result of the pressure of a European rail industry looking for new markets with the support of their governments. In fact, shortly after the Paris–Lyon opening, there was some preliminary interest in the Madrid–Barcelona link, but the long distance and the topographical conditions made the project too expensive (some €6 billion at the time). In contrast, the construction project for the new Madrid–Seville project was already ready. It was easy to upgrade to TGV standards and happened at a time of much-improved French–Spanish bilateral relations. The government seemed to be looking at the project more as a stand-alone corridor than as the seed of a rail network.
9.3 Contributions from Spanish Academia

A quick bibliographic search on high-speed rail in Spain yields hundreds of academic references since the 1990s. These contributions come not only from Spanish scholars, but also from professionals working in the construction, rail manufacturing, and rail management fields. These contributions cover a few topics that are closely aligned with those prevailing in the European conversation on high-speed rail: functional studies analyzing demand and changes in mobility behavior; microeconomic analysis of HSR lines mainly focusing on consumers’ gains, pricing, and cost-benefit analysis; and spatial impacts including regional development prospects and changes in urban patterns. In Spain, as in the rest of Europe, in the last 15 years there has been a sustained interest of some economists and geographers in bridging the gap between their two disciplines. Economists are pursuing this through the wider economic impacts (WEI) concept, while geographers are following the path of Krugman’s New Economic Geography (see Rothengatter 2017 for an overview of the history, definition, and typology of WEI).

Studies on the WEI concept can be linked to the interest of European decision makers in providing a more solid case for transport infrastructure investments since the turn of the century, as the results of traditional cost-benefit analysis of new projects yielded poor rates of return, particularly for projects considered to be more environmentally friendly. The concerns of some European ministers of transport were addressed, for example, in round tables organized by the International Transport Forum, one of them on the macroeconomic impacts of transport infrastructure investments (ITF 2006) and another one more specifically on the wider economic impacts of transport (ITF 2008). The United Kingdom (DFT 2005) was one of the first countries issuing recommendations to include WEI in the economic assessment of major transport infrastructure projects. Venables (2016) suggests three main mechanisms for WEI to materialize: changes in productivity linked to proximity and relocation; attraction of investments; and supply and demand impacts in the labor market.

Finally, it is worth pointing out that some of these scholars from both the geographic and the economics traditions have also attempted to establish links between their conclusions and the planning and decision-making processes related to HSR. Although not sufficiently consolidated yet, these contributions come closer to the planning theory studies on major infrastructure developed in Europe by scholars such as Flyvbjerg (2012, among many others); Flyvbjerg, Bruzelius, and Rothengatter (2003); Marshall (2011, 2014b); and Rothengatter (2019).
The rest of this section provides an overview of all these studies related to the Spanish HSR.

### 9.3.1 Transport Geography Studies: Accessibility Focus

The development of affordable geographic information systems (GIS) since the late 1980s allowed a much easier analysis of the accessibility changes induced by changes in the transport system. A GIS was applied to the analysis of the accessibility improvements provided by the road network envisaged in PDI 1993 (MOPT 1993; Gutiérrez Puebla and Urbano 1996); the interest in undertaking such studies increased at the turn of the 21st century. Following the government’s announcement of reaching all the provincial capitals with an HSR network, the mapping of accessibility indicators provided easy-to-communicate evidence of the fairness of a policy that provided similar mobility conditions throughout the country (e.g., see maps in Monzón de Cáceres et al. 2008). In the analysis of HSR, scholars initially focused on the reduction of travel time, following the concept of a *shrinking space* as proposed by researchers such as Spiekermann and Wegener (1994). This was the approach followed by Gutiérrez Puebla (1998) and applied subsequently by the same author to the planned HSR network in Spain (2004). This was followed by gravity-based indicators, combining travel time with the population, density of jobs, or local GDP of the cities included in the area of study. What was interesting is how accessibility indexes were increasingly presented first as indicators of regional development potential and finally of territorial equity (Monzón et al. 2008; Monzón, López, and Ortega 2019). In accordance with this approach, the expansion of HSR rail would seem all but unavoidable to prevent further spatial segregation among the Spanish regions (Monzón et al. 2008). However, the same authors also point out the potentially polarizing effects of HSR compared to motorway networks (López, Gutiérrez, and Gómez 2008). Further to the same tune, some scholars conclude from their accessibility studies that the transport infrastructure investment effort is insufficient to bridge the development gap among the northern and southern regions in Spain (e.g., Naranjo-Gómez 2016).

Cities, particularly medium-sized inland cities, receive particular attention from accessibility studies. This is consistent with the fact that such cities in the depopulated areas of inland Spain between Madrid and the coastal regions would be linked to the HSR network in accordance with the national government's announcement in 2000. The studies provided evidence of the strong gains in accessibility provided to these cities by HSR (e.g., Ureña et al. 2005; Ribalaygua et al. 2004; Ribalaygua Batalla 2005; Garmendia, Ureña, and Coronado 2011; Garmendia,
Ribalaygua, and Ureña 2012). The high expectations in the first studies were followed by more critical assessments once the factual evidence failed to show any significant changes in depopulation and economic development trends. Some scholars (e.g., Garmendia, Ribalaygua, and Ureña 2012) recommended the implementation of direct development actions by the national and regional government in these regions, but—besides these being at odds with the neoliberal approach to regional development prevalent in the EU—the synergies among such policies and HSR were difficult to find. Gaining proximity to Madrid or to other metropolitan areas did not prove to make these cities attractive for the relocation of people and jobs. Furthermore, other effects such as the relocation of residence to cheaper mid-size cities in the vicinity of Madrid and Barcelona, based on HSR-based daily commuting (Guirao, Campa, and Casado 2018), remain anecdotal.

The undelivered expectations of HSR in medium-size cities probably encouraged some scholars to explore alternative causality chains leading to economic growth in cities. Tourism has been the most studied sector, as could be expected by its strong share in the country’s GDP. The expected increase in tourism was justified on the basis of the lower travel time (compared to road) or costs (compared to air travel) and the higher quality of HSR travel (e.g., Campa et al. 2018). Bellet Sanfeliu, Alonso Logroño, and Casellas (2010) describes the strategies followed by some of these cities (usually the largest ones) to attract visitors and to position themselves as destinations for conferences, congresses, and other corporate and business events. However, HSR could also have negative impacts on a city as a destination if the passengers’ deserting air travel in favor of HSR made air companies reduce or cancel their services (Albalate and Fageda 2016). Some evidence suggests that tourism growth follows concentration patterns similar to jobs and housing. That is, it tends to benefit mostly the larger destinations, as they offer a wider variety of attractions and services (Masson and Petiot 2009).

As accessibility studies became more specific and focused on particular activities, scholars realized the relevance of service frequency and schedules. A problem that is particularly relevant for cities orienting their strategies toward same-day tourism or long-distance daily commuters: the concentration of services early in the morning and late in the afternoon would become costly for rail operators unless they are able to dedicate the idle trains to other lines outside those time periods. Moyano, Martínez Sanchez-Mateos, and Coronado (2018) developed accessibility indicators that include frequency, schedules, and ticket fares, showing how the Spanish cities linked by the HSR network enjoy vastly different accessibility conditions when all these variables are considered.
Another area of relatively recent attention refers to last-mile accessibility and, more generally, to the expansion of the area that could be efficiently covered by an HSR station. For example, Martínez et al. (2016) identified the catchment areas of six Spanish cities served by HSR, and Moyano, Moya-Gómez, and Gutiérrez-Puebla (2018) analyzed the cases of Barcelona and Madrid. Action at this micro-accessibility level (e.g., through the provision of more convenient public transport services to access HSR services) has a strong potential to expand HSR-related accessibility gains to a wider territory; however, the number of additional persons benefiting from these gains remains small—at least in medium-sized inland cities—due to the depopulation and low density of these areas.

9.3.2 Microeconomic Studies: Transport Market, Demand, and Supply

From a microeconomic perspective, Spanish scholars have developed a utility-based cost-benefit analysis (CBA) and explored the role of HSR in the long-distance passenger mobility market, as well as aspects related to affordability, fare structure, and competition with other transport modes.

According to the CBA by Coto-Millán, Inglada, and Rey (2007) for the Madrid–Seville and Barcelona–Madrid lines, most of the benefits of both HSR lines come from the savings obtained by users that were previously using other transport modes (virtually all former conventional train users and also a significant share of air transport users). This suggests that HSR has a strong ability to disrupt the transport market. Esteras González (2016) provides an excellent ex post analysis of the Spanish HSR lines, obtaining—as could be expected—a very low economic efficiency of these investments. De Rus and Inglada (1997) for Madrid–Seville and de Rus and Román (2006) for Barcelona–Madrid, among others) find low social benefits as a consequence of the intrinsic low demand that can be expected in HSR corridors, compared to the high construction costs.

As civil construction costs are significantly lower in Spain than in France and other countries (Cour des Comptes 2014; AIReF 2020), the Achilles’ heel of the Spanish HSR for these economists is the low demand, even after gaining a significant share of former rail and road passengers and inducing the surge of new travelers. Consequently, a better estimate of future travel demand and modal split has become the objective of many researchers. For example, Martín and Nombela (2007) conclude that a sustained annual HSR passenger growth (of some 1.5%) could be expected, with most of the growth (1.2%) coming
from induced travel. This conclusion opens an interesting new front for debate: whether public policies that induce mobility demand can be considered as environmentally friendly. In this sense, Ortega et al. (2016) find a high price-demand elasticity in HSR use and consider that the comparatively low passenger demand of HSR in Spain could also be a consequence of the charging policy traditionally implemented by Renfe, the public railway operator, which was based on competition with air services and did not consider seriously a more aggressive policy until 2013. However, such a policy to induce users to make additional trips raises, besides the environmental concerns just mentioned, additional ones from the perspective of fair competition with the operators of concurrent transport modes.

The scholars’ interest in rail–air competition increased after the opening of the Barcelona–Madrid corridor, as the context differed considerably from the Madrid–Seville HSR opening in 1992. In the latter, the total distance was significantly shorter, making air services less attractive, and at the time there was still limited competition in air passenger transport, so that the then incumbent public company, Iberia, had little interest in challenging HSR dominance with lower fares, all but leaving the field to unchallenged HSR dominance. On the contrary, the Barcelona–Madrid corridor was served by several air transport companies, and most of them responded to the opening of HSR services in 2007 with strategies including rescheduling of services, smaller planes, and lower fares. Gundelfinger-Casar and Coto-Millán (2017) suggest that demand for air travel has fallen due to increased competition from HSR in the Madrid–Valencia and Barcelona–Madrid corridors. Based on a sample of 1,011 travelers, Pagliara, Vassallo, and Román (2012) describe the demand response to different improvements in the level of transport services, showing that prices and service frequency were indeed relevant in users’ modal choice and also that the competitiveness of air travel was handicapped by the inconvenience of check-in and access control procedures to the airports. These scholars also stated that the HSR market share in the corridor (44% compared to 56% for air transport), although substantial, was at the time of the study (2010) lower than the 53% to 63% that had been anticipated by some ex ante studies (López Pita and Robusté 2005). This smaller market share could be due to the commercial reaction of air transport providers at a time low-cost services were blossoming in Europe.

A final area of interest has been the impact HSR can have on the affordability and social exclusion effects of long-distance passenger transport systems. For example, out of the 414 responses obtained from an internet questionnaire, Pagliara et al. (2016) found some evidence
of economic exclusion inhibiting potential travelers from using HSR services.

### 9.3.3 Approaching High-Speed Rail from Regional Development and Spatial Planning

As in the rest of Europe, the disappointing results of microeconomic assessments spurred the interest of Spanish scholars to explore the wider economic impacts of HSR along different lines. For example, in the tradition of Keynesian macroeconomics, Bellet, Alonso Logroño, and Casellas (2010) examined the ability of HSR improvements to attract new activities to cities. The scholars also examined the so-called accompanying measures that could enhance such attraction. While acknowledging the lack of any automatic causality effect on local development, they highlight, together with the new opportunities opened by HSR in terms of improved relationships with the markets and sociocultural networks of other cities, the momentum created by the new infrastructure in the local community by a shared enthusiasm, spurring local stakeholders to seize not only the new opportunities but also the renewed energies mobilized in the community.

Hernández and Jiménez (2014) put forward the potential of the spillovers on local budgets to facilitate local development through the dynamism of local governments. Their argument is that the generation of new economic activity increases public revenues. They find some evidence of this, reflecting such an increase in local economic activity and an improvement in local budgets. However, they consider that such new economic activity only happens in a limited 5-km radius from the city newly served by HSR services, and that it is likely that it corresponds more to relocations than to additional economic activity.

Feliu (2012) and Ribalaygua and Pérez-del-Caño (2019), among many others, are interested in the WEI of HSR in medium-sized cities and point out the relevance of each local context. The former considers that the local development HSR can bring to a city only materializes if local stakeholders are able to provide a constructive environment to take advantage of local endogenous resources. The local economic sectors benefiting from HSR have particular characteristics such as those related with information, communications, or entertainment. Also, the arrival of HSR tends to foster cooperation among local stakeholders, making it easier to find a compromise even in what had been until then almost intractable conflicts. The latter examine the potential HSR stations have to foster urban development and the catalytic role they can play to implement new multifunctional urban centralities. The attainment of
WEI in cities could therefore be facilitated by HSR station design well coordinated with redevelopment plans in the area.

The role of HSR stations in urban development and WEI attainment has been and continues to be a highly debated topic. Santos Ganges (2016 and 2017) provides a general overview of the approach followed by the Ministry of Transport, the Administrator of Railway Infrastructures (ADIF), and most local governments, concluding that they yield overambitious and expensive station designs and greedy commercial urban redevelopment concepts in order to finance them; furthermore, the real estate market in most Spanish cities proves unable in practice to materialize such urban development plans. The main rail station in Madrid (Chamartín) provides the most illustrative case for the critics: an urban redevelopment concept that has languished for 25 years and has been an ever-growing source of speculative maneuvering with no investment yet from the developers chosen by ADIF to carry out the project (Aparicio and Arias 2019). Bellet, Alonso, and Gutiérrez (2012) provide a more optimistic picture of the potential of HSR stations to sustain large urban development schemes that can provide substantial WEI. Bellet Sanfeliu and Jurado Rota (2014) review location patterns in different Spanish cities, concluding that decision makers have generally favored HSR station design in central or tangential locations with stronger urban development potential than peripheral stations.

9.3.4 Some Factual Evidence of the Spanish Urban System

As the WEI narrative reviewed above is focused on cities, it is worth taking a closer look at the Spanish urban system and its relationship with HSR. Escudero Gomez, García González, and Martínez Navarro (2019) provide an overview of this relationship, concluding that HSR has generally consolidated preexisting urban hierarchies. In the last 30 years, Madrid seems to have expanded its dominant role in the hierarchy, and in spite of its lower population, its metropolitan regional GDP has surpassed that of Catalonia in terms of contribution to the national GDP. Also, some large to medium-sized regional capitals (Seville, Valladolid, Zaragoza) seem to have consolidated their intermediate role in the urban hierarchy, although this seems to have happened mostly at the expense of the other cities in their respective regions, medium-sized cities that, as reviewed above, have not seen their role significantly changed, even in those cases in which the HSR network has reached the city. Overall, administrative roles prevail in the configuration of the cities’ systems, especially in the medium-size range. This helps to explain the emergence of regional capital cities
In fact, the consolidation of the urban hierarchy largely took place in the 1980s and early 1990s, prior to any significant HSR expansion, and can be better explained by the decentralization process and, eventually, the rapid expansion of the motorway network (Herrera 1998). Whereas proximity to a large metropolitan area has traditionally stimulated local population growth, Navarro-Azorín and Artal-Tur (2017) find some evidence of an opposite trend for municipalities in the vicinity of a large metropolis in which some agglomeration diseconomies may be operating. This would suggest the advantages in some cases of establishing collaborative networking strategies among neighboring cities rather than focusing on connections to the largest metropolitan areas. Precedo Ledo and Míguez Iglesias (2018) compared the relative competitiveness of Spanish cities before and after the 2007–2008 financial crisis, concluding that those cities benefiting from large public expenditures in the precrisis period (a group that includes some regional capitals) performed much more poorly after the crisis period, whereas those that enjoy structural advantages such as good local quality of life, specialized industries, or a higher degree of internationalization (all of which tend to come together) gained more competitive positions after the crisis.

Changes in the urban hierarchy can also be associated with the combined drivers of strong population growth (largely sustained by steady immigration, especially since the end of the 20th century) and by the depopulation of large parts of the rural and urban areas in inland Spain, the latter leading to “massive concentration of population, assets and services in large cities and coastal areas. Medium-sized cities, especially inland, are able to help and have to help to maintain the demographic tissue of the country. It is necessary to continue exploring the causes and reasons of the growth and prevalence of certain cities over others within the Spanish urban system” (Escudero Gomez, García González, and Martínez Navarro 2019: 12).

A review of local employment growth (Gutierrez Posada, Rubiera Morollón, and Viñuela 2018) confirms the uneven spatial distribution of economic activity since the early 1990s and the relevance of local conditions. If development policies need to be tailored at a more local level in Spain, it is not surprising that HSR deployment is showing evidence of local development only in the few cases of cities in which local conditions (in particular, those appealing to economic actors searching for agglomeration economies) were already fostering such concentration of population and economic activity—concentration that would have happened even in the absence of HSR. Holl (2018) finds that the capacities of human capital have played a much more significant role
than accessibility has in the comparative resilience of Spanish cities to the 2007–2008 financial crisis.

It is also interesting to analyze local growth in particular economic sectors. Sánchez Moral et al. (2008) do so for the relocation strategies of industrial activities, combining some deconcentration patterns with the sustained dominance of the three traditional industrial nodes (Catalonia, Madrid, and the Basque Country) in industries with high technological intensity. Mendez et al. (2012) provide a similar analysis of creative industries in Spanish cities, showing the spatial logic that determines their territorial distribution. The authors consider that this could provide some indication of progress toward a more balanced polycentric urban system in Spain; the analysis shows a strong concentration of these activities in Madrid and Barcelona, but also some relevant activity—although modest in terms of significance in the local economy—in a few cities, due to a variety of local conditions, within which there is no mention of accessibility or HSR.

It can be concluded that most studies reflect that the changes in the Spanish urban system are strongly linked to the political decentralization process undertaken in the 1980s and to specific local conditions, in which HSR does not seem to have been influential in a general sense. However, the arrival of HSR is likely to have induced in some cases more collaborative strategies among local stakeholders, eventually facilitating the implementation of disruptive strategies with positive effects on local development. This is consistent with the geographic conditions of the country, which make HSR an unlikely contributor to the integration of most Spanish cities at the European or global levels, and with the prevailing purpose of most HSR trips for tourism, leisure, and personal interaction rather than for business trips.

9.3.5 Considerations on the Decision-Making Process

The review above shows the differences and convergences among Spanish scholars from the fields of economics, geography, and transport engineering. All of them have keenly tried to establish convincing causality paths linking HSR accessibility to local development. Consistent with the particular characteristics of the Spanish urban system, they have paid particular attention to the contribution HSR could provide to support the growth of inland medium-size cities. Compared to other transport modes, and particularly to air transport, HSR provided an appealing option to link these cities together and to major metropolitan nodes. However, such an approach has failed to deliver the expected outcomes in terms of economic growth and a more balanced, polycentric system.
The scholars cited here and others have subsequently reflected on the reasons national and regional governments keep dedicating substantial resources to the expansion of the HSR network. Some of them have tried to identify biases and weaknesses in the decision-making process. For example, Castillo-Manzano, Pedregal, and Pozo-Barajas (2016) conclude that transport decision makers have not developed a consistent policy for the HSR system, from infrastructure investments to operations. Under the current system, ADIF is allowed to charge too low fares for HSR infrastructure use as a way to foster demand and remain competitive toward air services; these fares are however insufficient to cover not only the total infrastructure costs, but even the marginal costs of the HSR network. Castillo-Manzano, Pedregal, and Pozo-Barajas (2016) attribute this political decision of lowering HSR fares to an attempt to increase HSR travel demand in order to justify the sustained investment the national government was dedicating to build new HSR lines at a time of deep economic crisis and dramatic cuts in social spending. This explanation leaves unanswered the question of why the government was prioritizing HSR construction even in times of economic turmoil and social unrest.

Different answers have been provided to this question. For example, Albalate and Bel (2011) initially attribute it to a disdain for rigorous economic analysis in the selection of political priorities. The authors also highlight the lack of transparency of the national government to provide detailed information on HSR costs and demand per line, which is for them a key barrier to undertake a rigorous public debate of the HSR policy and decision-making process. Subsequently, Albalate, Bel, and Fageda (2012) sustain that investment in the HSR network (and previously in motorways) is driven by centralization strategies directing funding to the regions immediately surrounding the political capital. These authors subsequently (2015: 89) complement this view with the prevalence of political precepts that “consider an equal endowment of infrastructures (in terms of both quantity and quality) to guarantee equality between the citizens of different regions.” Additionally, they criticize what they see as a centralized system of public management that facilitates the fixing of charges in a manner not necessarily related to costs, which facilitates cross-subsidy and sheer economic inefficiency.

Interestingly, Cruz Villalón (2017) points out in quite an opposite direction that rather than a consequence of a powerful national government, the expansion of HSR can be rather explained by the national government’s institutional weakness and the sustained claims from regional governments. The political precept of “equal endowment of infrastructures” denounced by Albalate, Bel, and Fageda (2015) would be the only possible compromise in a context of increasing
decentralization, in which transport infrastructure investment is one of the few tools remaining in the hands of the national government for direct physical action in the territory.

Not surprisingly, the public works construction industry has championed HSR expansion and lobbied for ever-increasing transport infrastructure investments, either directly from the public budget or indirectly through public–private partnerships. Cruz Villalón (2017) summarizes the main arguments of the construction industry: the multiplying effects of infrastructure investment on regional GDP, jobs, and fiscal revenue (see, e.g., Herce and Sosvilla-Rivero 2002) and the users’ benefits in terms of travel time and cost. Núñez (2015) adds to this the international relevance of the Spanish construction industry, suggesting the need to consider transport infrastructure investment as a “national champions” policy to be followed in the same way other European countries promote their industrial strengths globally.

Muñoz Martínez (2018) describes the mutual political advantages that the national and the regional governments find in the current race to expand the HSR network and focuses his analysis on the limitations of the existing evaluation processes in HSR planning and the characteristics of the decision-making processes. He sees a mutual relationship that should be strengthened through adequate formalization of these activities, including increased transparency of decision-making processes in transport planning and a clearer framework for the involvement of local stakeholders (regional governments in particular). Muñoz Martínez (2018: 141, author’s translation) concludes by stating that “the root of the problem (overspending in transport infrastructure) is not that the inefficiencies exposed have not been detected by the decision-making bodies, but rather the institutional and organizational design of the managing bodies of large transport infrastructures in Spain, the short-term vision of the political actors, and the association of public management success to the completion of new projects are contrary to the revisionist theses.”

It can be concluded that a variety of public policy factors have contributed to locking what began, in the 1980s, as a generally welcome infrastructure modernization program into a situation from which regional and national decision makers are unable to find a way out. Among the factors identified by the scholars included in this review, it is worth highlighting the following ones:

- The weak and poorly formalized deliberation processes of public policies have not been strengthened in a way consistent with the ever-growing resources and political effort dedicated to transport infrastructure development and particularly to HSR.
• HSR was developed at a time when the new decentralized regime was still under construction in Spain, with national and regional governments exploring their respective competencies and roles.
• The EU financial resources dedicated to TEN-T became a powerful tool to leverage substantial public funds to transport infrastructure. In spite of its comparatively low contribution (contrary to the general perception, EU funds have covered just around 15% of total HSR infrastructure investment in Spain), EU funding provided justification for policies and strengthened the national government’s role in its negotiations with the regions.
• Many stakeholders are not fully aware of the heavy environmental burdens imposed by HSR development; this insufficient concern is facilitated by the low population density along most of the lines and the lack of sustainable development alternatives for these rural and natural areas.
• HSR brings global industrial opportunities, and the government has been willing to actively support the entry of Renfe and the Spanish rail industry into the HSR market as well as the internationalization of the Spanish construction sector.

9.4 Widening the Analytical Framework

Out of the contributions reviewed in the previous section, the reader might conclude that the implementation of HSR in Spain is just a story of political failure: decision makers unable to rectify EU arrogance imposed through TEN-T planning and financing mechanisms that do not consider the variety of local contexts, powerful industrial sectors imposing their agendas and interests, and naïf enthusiasm for technological innovation from some scholars and professionals, hailing HSR as a new game-changer transport mode and as the backbone of a continental integrated multimodal system, providing seamless environmentally friendly mobility for long-distance travel and leaving congested motorways and airports as a thing of the past.

A more nuanced perspective would rather state that economics- and accessibility-focused assessments, although relevant in their conclusions, fail to provide a convincing answer to the key question of why the Spanish government kept prioritizing HSR investments, and to a large extent continues to do so. Moreover, although Spain could justly be labeled as a particularly faithful follower of a biased European transport policy strongly encouraged from the European decision-making centers, it is certainly not the only country doing so: from the
Betuweroute in the Netherlands to Milan’s new Malpensa Airport and the French East High-Speed Line, the continent is plagued by costly priority TEN-T projects that have largely failed to reach their expected demand targets. From this perspective, the priority is to establish a broader analytical framework with some additional elements that can help to understand the continuity and good health of such policies in Spain and more generally in the European Union.

Marshall (2014b) provides some initial material to undertake this task. From his perspective, there are two key contextual drivers to consider at the European level: the prevailing neoliberal approach to integration that the European Union embraced since the late 1980s and the legitimation deficit of the EU, with institutions still largely “under construction” and therefore with difficulties to find their proper role vis-à-vis other governmental layers (mainly national governments) and the public.

Regarding the first of these drivers, it is worth recalling that the three pillars of European integration (liberalization, single market, and monetary union) were inspired by the then-prevailing neoliberalism, only shyly mitigated by the inclusion in the 1986 Single European Act of the concept of economic and social cohesion to compensate for the negative effects of completion of the internal market in less developed regions. Such an approach all but eliminated the ability of governments to directly support regional or local development through direct support to concrete companies or sectors. The new paradigm was to provide indirect support through state-supported human capacity building, infrastructure endowment, or transitional tax incentives, to cite the most frequent instruments; all these actions should increase the competitiveness of the companies in the targeted region and in this way induce economic development (Molle 2007; Colomb and Santinha 2014). Since the 2007–2008 financial crisis, this purely horizontal policy of territorial cohesion has been widely criticized. The Barca Report on the future of cohesion policy is particularly relevant (Barca 2009), as it—without much success—advocated for better contextualized and more flexible public policies in Europe, capable of adapting to the peculiar needs of each territory.

As for the second driver, the legitimation deficit of the EU, the EU has undertaken almost continuous constitutional reforms since the 1980s, and one of its key constitutional principles, subsidiarity, introduces a flexible playing field in which the actions of the European institutions are subject to permanent political scrutiny to make sure they are not invading those of the national governments. European integration has profoundly altered the previous constitutional and political arrangements. Furthermore, many European countries have
transitioned during the same period toward more decentralized state structures, with the emergence of regional governments or the expansion of their competencies (Marshall 2014b). In this evolving context, governments need to find alternative policy actions to achieve their political objectives (and particularly, economic development), interacting with the other governmental layers and trying to probe the legitimacy of such policies in front of them and the public at large.

Both conditions largely apply to Spain. The EU’s neoliberalization pressure resulted in a steady increase in mobility demand, particularly in air transport with the expansion of low-cost carrier services: since 2009, Ryanair has led the ranking of domestic passengers and flights (European Commission 2019). However, the economic crisis delayed rail passenger liberalization, with new companies getting their licenses in 2019 and planning to start operations in 2021. More interestingly, since the early 1990s, neoliberal narratives were influential in the national government’s efforts to attract private investors to transport infrastructure construction. As already mentioned, PDI 1993 considered that the private sector could provide a substantial part of the Barcelona–Madrid HSR line, and one of the reasons for the long and ever-growing list of projects included in what was called PIT 2000 was to provide potential investors with an ever-increasing number of projects ready for construction, accompanied by changes in PPP regulations to facilitate such investments: a supply-driven approach to create a prosperous market for transport infrastructure investment (López Corral and Sánchez Soliño 2003). If ineffectual in terms of mobilizing private investment (and with financial bankruptcy and high rescue costs for the public budget in the few cases private investors in which were attracted, like the Perthus HSR tunnel or the motorway concessions at the turn of the 21st century), this neoliberal vision was highly influential in the expansion of the planned HSR network established in PIT 2000.

Marshall (2014a and 2014b) links EU neoliberalism, the subsequent downgrade of traditional spatial planning in Europe, and the surge of transport infrastructure planning as a substitute. TENT and, in particular, HSR planning provides a flexible image of modernity that can accommodate a wide variety of discourses (environmental, social, efficiency, territorial equity) while largely leaving to the market, through PPP, the final decision about the feasibility of particular projects.

As for the institutional legitimization deficit, it is worth recalling that the 1978 National Constitution established a new regional governmental layer—autonomous communities—in what had been a very centralized country. Rather than providing a clear definition of the competencies for each governmental layer, the Constitution provided a flexible framework in which, besides the competencies explicitly attributed to
each layer, the national government could also transfer the management of some of its own competencies to regional governments. This created a situation of permanent transition and negotiation, with regional governments generally keen to get more competencies transferred to them. This created a highly mobile institutional framework dominated by continuous bargaining, quite similar to the European situation. In Spain, the negotiation takes place between national and regional governments; in Europe, it takes place between the EU institutions—mainly the European Commission—and national governments.

Similar to the European level, transport infrastructure planning provides an opportunity to the national government to make itself visible at the physical, territorial level. The Spanish Constitution of 1978 had defined spatial planning as a regional and local competence, leaving the national government out except for establishing the basic legislation on urban planning. Every attempt of the national government to establish some kind of coordination was rebuked by the Constitutional Court; the most complete defeat came in the 1997 sentence suppressing large parts of the 1990 Urban Planning Law. One of the few remaining options for the national government to elaborate a narrative about the Spanish territory was through transport infrastructure, as was also the case at the European level.

Such narratives cannot be limited to the utilitarian logic of supply and demand. That is why, very much like the European Commission’s approach to TEN-T, a complex legitimating narrative was created, combining considerations of the environment, people’s mobility rights, global competitiveness, and social and territorial cohesion. As the right place for most of these considerations would have been the now-forbidden old-style spatial planning, the result was an inconsistent narrative that has managed to prevail and has even been consolidated throughout Europe for three decades. This narrative, in complicity with the neoliberal views, allows blaming as inefficient those governments unable to improve the development level of their territory in spite of receiving brand-new transport infrastructure. The narrative thus increases the pressure on governments to undertake all sorts of socially unpopular structural reforms to become more competitive.

One paradox in this legitimation of the national government’s transport infrastructure policy is that it creates an unlikely coalition of all governmental levels to increase the public resources allocated to the policy as a way to support regional governments. The obvious alternative—simply transferring these resources to regional governments so that they could dedicate them to those policies they might find more suitable to support themselves—is not an option, as it would have left the national government even more diminished in its coordinating capacity.
Through their claims to receive transport infrastructure investments, regions involuntarily push to reinforce the investment capacity and territorial intervention of the national government—a paradox that is also present at the European level.

Transport infrastructure planning provides the future’s visions that can no longer be expected from spatial planning in these neoliberal times. This is a powerful political instrument for under-legitimized institutions and provides strong bonds among governmental levels at a time of pervasive constitutional transitions and rebuilding. Transport infrastructure planning provides an opportunity for consensus-building practice, which can later be translated to more controversial, short-term policies. The incumbent stakeholders’ interests amalgamate around such policies, helping to provide support, justification, and continuity and also preventing disruptive stakeholders from effectively challenging the status quo.

The neoliberal paradigm leaves few, if any, options to decision makers at all governmental levels. Most governments’ spatial planning capacities have all but disappeared and have been replaced by territorial marketing and bargaining with special interest groups. In this context, the HSR debate looks like little more than a distraction from the much more politically charged debate on the need to rebuild spatial planning. Moreover, the TEN-T and HSR experiences show how, in the absence of consistent spatial planning, transport policy is doomed to choose between the Scylla of utilitarianism and the Charybdis of a “coffee-for-all” network expansion.

Some of academia’s assessments of transport infrastructure planning, and particularly of HSR, may have contributed more to consolidate business-as-usual policies than to spur a debate on the spatial consequences of neoliberalism in Spain (and in Europe). For example, the utilitarian assessment based on an estimate of future HSR demand and the utility gains (mostly time savings and travel costs) associated with HSR compared to competing modes provides a basis to claim such utilitarian gains as rights that should in time be enjoyed by residents in cities not yet served by HSR. Cost-benefit assessments, useful to compare alternatives at the project level, are not well suited to compare among broader policy options. Furthermore, their positive consideration of induced demand as a benefit seems at odds with environmental considerations about ever-growing long-distance personal mobility. Although significant contributions have been recently made to include in the economic analysis the unlocking opportunities new transport infrastructure can provide to regional and local development (Vickerman 2017) or WEI (Rothengatter 2017; Wangsness, Røedseth, and Hansen 2017), these approaches to capture
the indirect impacts of transport infrastructure investments in the whole economic system cannot satisfactorily cover the nuances of transport infrastructure policy. This shortcoming of CBA is due, among other things, to the intrinsic difficulties to establish the causal relationships at the basis of such impacts and the consideration only of economic actors (producers, consumers, investors, workers, etc.) in the analysis of the expected influence of infrastructure endowment on their decisions.

Similarly, accessibility-focused assessments may be overstating the relevance of HSR accessibility in location decisions at a time when the existing transport networks and services are already providing reasonable accessibility levels to most if not all European regions and cities. Rather than blame regional and local stakeholders for not seizing the HSR opportunities with the implementation of accompanying measures, it would seem more fruitful to expand the policy options these stakeholders have at their disposal to spur such development, of which HSR would perhaps not be an adequate one. There is not much reason to look for comfort in the HSR impacts on second-rate economic sectors like tourism rather than looking for actions to increase the resilience and reduce the dependency of less developed regions.

A focus on the efficiency of HSR, on accessibility gains or consumers’ choices—no matter how relevant for economics, geography, and other disciplines—tends to divert the public debate toward secondary issues, whereas the essential choice of indirect spatial intervention through HSR and other transport infrastructure stays out of the scene. Scholars’ contributions have supported a de-politization of planning in the sense that they have narrowed the realm of its democratic deliberation as a public policy. They have also supported a hyper-politization of planning in the sense of providing arguments for the governments and other influential actors involved in the negotiation of future networks, project prioritization, and resource attribution. Many scholars’ focus is far away from the decision-making processes, and they can hardly contribute to making these processes more transparent. To accomplish that, it would be necessary to provide wider assessments of the quality of the decision-making process in terms of increasing democratic deliberation and transparency. It would also be necessary to answer questions such as, which are the key drivers and the key stakeholders? How do stakeholders’ strategies accommodate different contexts? The prevalence of the key stakeholders, including national governments and industries (construction, transport equipment, transport service, infrastructure managers, etc.) leaves weaker players, including not only civil society organizations but also cities and a majority of the economic sectors, with too few options to intervene in the debate or to challenge its neoliberal foundations. The strong inertia of public policies makes
it unlikely that disruptive options will be considered in the discussion without much more substantial contributions from the academia.

In the meantime, as Marshall (2014b) underlines, the forms of policy making resulting from European neoliberalism will continue being institutionalized and naturalized, establishing a plurality of policy silos—of which the HSR debate is only one example—and making genuine spatial planning debates ever more difficult.

9.5 Path Forward: Need for a Wider Public Policy Assessment of High-Speed Rail

The valuable HSR planning assessments provided from economics and geography could be fruitfully complemented by the consideration of HSR as a public policy. Besides delivering the expected outcomes (effectiveness) with the minimum necessary resources (efficiency), public policies are supposed to strengthen the political deliberative community and to provide civic education on democracy (Dewey 1927).

In this sense, public deliberations on HSR would be expected to have addressed the wider spatial challenges Spain and Europe are facing: the dubious materialization of the polycentric or “decentralized concentration” paradigm, the stubborn consolidation of ever-growing segregation among regions, the rigidity of urban hierarchies, and the accelerated concentration of directive functions in a handful of cities. Scholars’ contributions are fundamental to support the engagement in such debates of an informed citizenship. The fact that the researchers’ curiosity on HSR has expanded is highly positive, as their work provides a wider array of factual evidence and arguments. However, these contributions should not hide the need to for basic discussion of the grounds for the choice of actions such as HSR expansion for public investment, the stakeholders involved in such actions, and the procedures leading to such choices and to their implementation.

As Marshall (2014b) suggests, one promising starting point is to analyze the increasing constraints governments have for direct action in the territory. These constraints result from the combined effects of the neoliberal approach to EU integration, limiting the prospects and actions for territorial cohesion, and the difficult consolidation of a multi-layered governance system, which has weakened the legitimacy of some governments to address spatial issues. In this transitional context, governments can no longer espouse the traditional visions of a balanced and prosperous territory provided by spatial planning, and they find a dubious replacement in the images of transport infrastructure and particularly HSR.
An approach of analyzing these constraints provides the necessary perspective to differentiate among the many different levels of analysis that otherwise researchers may tend to mix together: the purely functional role HSR may play in long-distance mobility, progress in regional development, and prospects for strengthened territorial cohesion. More decisively, such an approach also could serve to undertake the public debate on the increasing weakness of transport infrastructure policies as substitutes for spatial planning. This could lead to the preservation of valuable national and local spatial planning traditions and ultimately to the emergence of a new spatial planning paradigm for our post-neoliberal times. In the 1990s, transport infrastructure became an unusual alternative to reaffirm the spatial role of troubled governments and provide a sense of direction at times of constitutional transition, and HSR added to that the illusion of innovation and modernity, creating a widely shared vision. But that vision has proven to be an illusion, and it is now high time to undertake a public discussion in search of more effective spatial policies.

In the absence of such broader analysis and the deliberation it generates, bureaucratic inertia and the dominating positions of the incumbent stakeholders ensure that public policies are continued, undeterred by functional or efficiency criticisms, as TEN-T and Spanish HSR plans show. Political parties and other civil society organizations are often entrapped by the system and, rather than challenging it, they prefer to base their criticism on the clumsiness of their rivals and lack of delivery (not fast enough, not good enough, and so on) rather than on substance (Why should this be done now? What are the objectives?). But as stated by Marshall (2011: 903), “the whole infrastructure field is caught in a powerful and tense pull of forces, making it a deeply problematic area for public action…. Planners and policy-makers generally therefore are obliged to act in subtle and adaptive ways.” Feeling unable to curb the business-as-usual trends, smart politicians at best negotiate the situation as well as they can; for example, governments have tended to slow down the flows of direct public investment, delaying administrative approvals and undertaking works at a sluggish pace, which explains the modest completion of TEN-T networks and the Spanish HSR system compared with their respective plans. This political strategy opens an attractive front for populist criticism, claiming the need for bold political leadership and weaker administrative controls to meet the desires of the people. Building a strong citizenship, strengthening and opening up the deliberative processes, and facilitating the access to information and assessments is a promising way to counteract this kind of populism.
References


Planning, Power, and Deliberation: Lessons from High-Speed Rail Expansion in Spain


PART III
Impacts of High-Speed Rail on Other Modes of Intercity Travel
Key Messages
Yoshitsugu Hayashi, KE Seetha Ram, Veronica Ern Hui Wee, and Ayushman Bhatt

Having considered the framework of transport infrastructure’s wider economic impacts and quality of life implications at the national, regional, and individual levels in Part II of this edited volume, we move ahead to the next step of considering the impacts of huge transport investments, such as in high-speed rail (HSR), on the supply and demand of various other existing transport modes. HSR development is believed to affect other transport modes in different ways as it produces major changes in the travel times and costs of intercity passenger travel. Specifically, HSR is often argued to create competition for air travel as it not only generates new passenger demand with a new service but also diverts demand from airlines and expressways and can lead to considerable changes in the multi-modal share of all modes. In the People’s Republic of China (PRC), a substantial reduction of air travel followed major HSR introduction. The magnitude of such an impact varies across distances, with the greatest impact found on short-distance routes and faster speed HSR routes (Wang et al. 2018). Similarly, Hanaoka (2020) shared findings on how the introduction of new shinkansen (bullet train) lines in Japan increased both passenger demand and the passenger share of HSR in relation to air travel where travel time was under 4 hours. Although pricing on these shorter routes and the HSR link between major cities appears to be less sensitive and has a limited effect on mode shift, the links connecting to rural areas have shown a high sensitivity to fare changes, compounded by the lack of fare options for HSR, as the introduction of low-cost airline carriers caused some shift to air travel. For trips over 4 hours, other factors, such as discounted fares, flexible seat use, or attractive designs, can be leveraged to make HSR

1 With contributions from Tae Hoon Oum (Sauder School of Business, UBC Canada) and Shinya Hanaoka (Tokyo Institute of Technology, Japan). Drawn from the deliberations and discussions held at the sessions titled “Competition and Cooperation between Air, Rail and Roads for Inter-city Travel” and “Quantifying and Simulating Quality of Life” held on 15 October and 16 October 2020, respectively, during the ADBI-Chubu University Conference (virtual) on Transport Infrastructure Development, Spillover Effects, and Quality of Life. The authors also acknowledge the contributions from the participants of these sessions.
services more competitive. Yet, Oum (2020) also highlights the potential for cooperation between airlines and HSR in integration of services. Frankfurt Airport, Deutsche Bahn, and Lufthansa offer integrated tickets, baggage handling, and coordinated schedules on the Frankfurt to Cologne Bonn route, as does the TGV-Air cooperation in France. Several Chinese airlines and Tianjin Airport also leveraged this synergy to tackle the severe congestion at Beijing Capital International Airport and reroute passengers through Tianjin Airport instead through easy air-rail connectivity.

Part III of this edited volume thus seeks to further explore the interaction between different modes of intercity travel in terms of both competition and complementarity, expanding the discussion to conventional or regional rail and road travel. Even with the implementation of HSR, other transportation modes can complement HSR by providing last-mile accessibility or a low-cost option for rural residents. Thus, HSR cannot be viewed only as a competitor; it is a piece of regional or national transport planning that must be integrated with existing options and that has the potential to bring about spatial, lifestyle, and business changes in urban areas and along the rail corridor. Three chapters, comprising this third part, are refined from the presentations of the authors of the called-for papers and invited papers who participated in the ADBI-Chubu University conference (held virtually during 12–16 October 2020).

Chapter 10 by Ren et al. examines the spillover effect of HSR development on mode choice for intercity travel. Through a survey of passengers who chose to take conventional trains in Chongqing, PRC, the study identifies factors that affect the likelihood of choosing conventional trains over HSR. Although a spillover effect is observed, the magnitude of impact is diminished where the last-mile travel time between the railway station and passenger origin or destination exceeds 2 hours. This highlights the importance of last-mile accessibility for enhancing the utilization of HSR. In addition, the likelihood of choosing conventional trains is positively correlated with age and negatively correlated with income and education, demonstrating that a degree of conventional train operations must be maintained to service certain social groups.

Chapter 11 by Chao and Vuchic thoroughly evaluates different types of HSR network planning, design, and operations associated with their urban forms through the understanding of HSR as a service business. Taking the case studies of New York and Florida, this chapter draws out key lessons in capacity, network design, operation, and decision issues. For example, the chapter recommends that planners reduce dead-end terminal operation and shift to a through-running system. The chapter
also argues that the broader strategic vision of regional and national city planning should incorporate an understanding of the roles and characteristics of regional rail and HSR, their impacts on the long-term growth of metropolitan and intercity areas, and the potential of network efficiency for generating economic value.

Chapter 12 by Le and An identifies factors that might drive a modal shift to and from current transportation modes for intercity trips in Viet Nam to provide a better understanding of the competitiveness of HSR over other modes of transport. The chapter further suggests what might be done to better position the role of HSR in providing interprovincial mobility. Feasibility studies on the HSR project in Viet Nam have indicated that the topography and passenger demand is suitable for the construction of HSR, particularly to link Ha Noi and Ho Chi Minh City. This chapter highlights the numerous potential synergies between HSR and other transportation modes and demonstrates the different social groups or journey types that various forms of transport can target. As such, planning and implementation of HSR must be integrated with existing public transport services.

However, in the related discussion during the conference, the discussants predicted that this trend in mode shifts would undergo significant changes with the increasing developments in technologies that enable further high-speed mobility, for instance the planned Maglev or ultra-HSR along the Tokaido corridor in Japan, as the increased speed combined with the high frequency of rail has the potential to eliminate air travel on Maglev routes altogether.

Competition has been further exacerbated by the coronavirus disease (COVID-19) pandemic, as discussed in Part I of this edited volume. HSR and air travel were both adversely impacted by COVID-19 and must now adjust to ensure travel is COVID-19 safe. While a globally accepted standard on COVID-19 safe air travel is yet to be established, implementing COVID-19 safety measures on HSR has been easier and less costly. Additionally, the negative economic impact of the pandemic was alleviated through alterations in HSR services as it is easy to convert some or all cars to cargo carriage if required. Passenger demand recovery for HSR also appears to be faster, as HSR traffic in the eastern coastal regions of the PRC has already rebounded to September 2019 levels (Oum 2020). Further research in this direction is hence required to continue to examine such changes in mode shifts that might occur due to the introduction of HSR.
References


10

Does High-Speed Rail Have a Spillover Effect on the Mode Shift for Intercity Travel

Xiaohong Ren, Zhenhua Chen, Ting Dan, Chunyang Wang, and Wei Wang

10.1 Introduction

The rapid development of high-speed rail (HSR) infrastructure has had a notable impact on intercity travel and modal market shares in many countries. Compared to other surface transportation modes such as private vehicles, buses, and conventional passenger rail, HSR has an overwhelming advantage in travel time savings. In addition, HSR also competes with aviation, especially for intercity travel of distances of 500–800 kilometers (km) (Chen 2017). The development of HSR in the People’s Republic of China (PRC) is even more phenomenal. With strong central government support, the PRC has developed the world’s largest HSR system which, as of the end of 2019, has a total track length of 35,000 km. The system has several unique characteristics. For instance, the scale of the system is extensive: it consists of eight east–west bound and eight north–south bound HSR trunk lines that connect 30 of the country’s 31 provincial-level administrative divisions. While the majority of the PRC’s HSR system consists of passenger dedicated lines with a maximum speed of 350 km/hour, there are also some lower-speed lines (e.g., with a maximum speed of 250 km/hour or above).

The deployment of the HSR system has substantially increased intercity travel demand in the PRC. As illustrated in Figure 10.1, HSR ridership increased exponentially as more lines went into operation. The annual ridership of HSR exceeded 2.05 billion in 2018, which accounted for 60.9% of the total passenger rail ridership that year. On the supply
side, the HSR network was also expanded considerably. For instance, the total length of railway tracks in operation reached 131,700 km by the end of 2018, including 30,000 km of HSR nationwide.

Although people have begun enjoying the benefits of HSR in the PRC, Japan, and some countries in the European Union, the lack of HSR development in other countries such as the United Kingdom, the United States, India, and Malaysia has undergone substantial debate, as it remains unclear whether the gargantuan cost of developing HSR infrastructure would be offset by the benefits the system is expected to generate. Many studies have attempted to investigate the impact of HSR on society, the environment, and the economy. However, there is still a lack of understanding of to what extent the development of HSR influences the mode shift of intercity travel. Furthermore, it is also unclear whether the development of HSR has any spillover effect on people’s mode choice for intercity travel.

This study intends to fill these research gaps by conducting an empirical investigation based on a patron survey at three railway stations in Chongqing, PRC. Based on the responses from 4,924 passengers who chose conventional trains to travel, the motivation and factors that affected their decision of mode choice are examined empirically using multinomial logit regression analysis. In particular, the spillover effect
of mode shift is examined by comparing the odds ratio of choosing conventional rail and HSR for intercity travel among different patron groups, such as by distance variation (measured in travel time) between the railway stations and their origins, and whether or not the origin of the patron is serviced by HSR.

The study provides important implications for transportation planners and policy makers to optimize the operation of HSR and thereby to improve the quality of life for intercity travel. The research findings could also help us better understand the impact of existing HSR systems in terms of spillover effects so that future decision making on investment pertaining to HSR infrastructure development could be implemented more wisely and effectively.

The rest of the chapter is organized as follows. Section 10.2 summarizes the literature review and identifies research gaps. Section 10.3 presents the data, while Section 10.4 introduces the methodology. Section 10.5 discusses the empirical findings and, lastly, Section 10.6 summarizes and concludes.

10.2 Literature Review

With the rising interest in HSR development globally, the number of studies focusing on the impact assessment of HSR infrastructure has also increased substantially in recent years. Many studies have attempted to examine the benefits of HSR with a focus on the economic effects the system generates. However, the findings are somewhat mixed. For instance, some studies indicate that HSR can positively impact the economy due to travel time savings (Rietveld 1989; Chen et al. 2016), whereas other studies suggest that the economic effects of HSR systems are negligible or, in some cases, may even be negative due to the existence of spillover (redistribution) effects (Boarnet 1996). Some studies suggest that HSR can have a negative impact on peripheral cities while benefiting major central cities (Hall 2009), while other studies, such as Chen and Haynes (2015), attempt to quantify the spillover effects of HSR on housing prices. However, it remains unclear whether or not HSR has any spillover effect on mode shift, in other words, whether the opening of HSR services also affects people’s travel behavior spatially.

In fact, the deployment of HSR has considerably promoted the evaluation of travel behavior change from a comparative perspective between HSR and other modes such as air, conventional rail, bus, and private vehicle. The impacts of HSR on aviation have received the most attention given that HSR and some short-haul air services are highly competitive due to similarities in characteristics such as speed and
which cities they serve. In general, the literature has revealed a mixed impact of HSR on air transportation.

On the one hand, some studies indicate that HSR has a negative impact on air transportation due to its substitutional effect on air, which results in reductions in air travel demand and airlines’ seat capacity (Jiménez and Betancor 2012; Wan et al. 2016; Zhang, Yang, and Wang 2017). However, the substitutional effects of HSR on air travel vary due to the influence of factors such as routes, travel distance, city type, and country of destination (Chen 2017; Chai et al. 2018; Wan et al. 2016). Some studies, such as Behrens and Pels (2012), Danapour et al. (2018), and Li and Sheng (2016), indicate that the major factors that influence HSR and air transportation competition include price, travel time, service frequency, and travel distance.

On the other hand, the development of HSR is also likely to have positive impacts on air transportation. The competition can promote the expansion of air transport networks to cover more fringe markets (Jiang and Zhang 2016), which then provides more options for passengers. In addition, the cooperation between HSR and aviation through strategies such as enhancing modal integration to allow seamless intermodal transfer is also likely to facilitate intercity travel experience and promote the growth of air transportation services (Xia and Zhang 2017). The substitution between HSR and air transportation can also generate positive impacts under disruptive events such as transportation system failures or natural disasters (Chen and Wang 2019). The development of HSR has also been found to have a positive outcome on air transportation in terms of reducing congestion at bigger airports (Takebayashi 2016). Recently, Borsati and Albalate (2020) found that HSR expansion had a slightly positive impact on motorway traffic in Italy.

Scholars have also attempted to evaluate the travel behavior change of HSR based on travel surveys. For instance, Chan and Yuan (2017) found that people prefer to ride HSR more often for tourism-related trips. Ren et al. (2019) revealed that travel demand between Chengdu and Chongqing increased by 60% after the opening of the HSR system. Furthermore, the mode choice was found to be affected by several factors, such as fare, travel habits, trip distance, and onboard amenities, which all play significant roles in whether passengers choose conventional rail over HSR (Ren et al. 2020).

Although the aforementioned studies attempted to reveal the travel behavior changes caused by the operation of HSR in the PRC, most of the studies were conducted at an aggregated level without a comparison of the change in travel demand from a shifting behavior perspective. There is also a lack of focus on the examination of to what extent the mode choice may change spatially since the introduction of HSR. Hence,
it is imperative to examine to what extent the impact of HSR may affect mode shift with a consideration of its spillover effect.

10.3 Data

To examine the spillover effect of HSR on the mode shift of intercity travel, the city of Chongqing was selected as a case study. Chongqing is one of the four municipalities in the PRC and a comprehensive transportation hub in the southwest region. The following three major rail stations were selected for conducting a passenger survey: Chongqing North Railway Station, Chongqing West Railway Station, and Chongqing Railway Station.

Our focus was on passengers riding conventional trains rather than HSR. Hence, our focus group was the passengers who took conventional train services to depart from Chongqing. There are 34 conventional trains that operate on a daily basis and they connect Chongqing with 331 cities nationwide. In addition, there are also 122 high-speed train services (with a serial number of G, D, or C) departing from Chongqing and 112 daily passing trains. In total, Chongqing was connected with 126 cities through these high-speed train services.

The residential city with the largest sample size of respondents is Chongqing, which accounts for about 41%. The city with the second largest sample is Chengdu. Among the samples, cities with HSR services account for 68.1%.

The survey was conducted from 1 May to 12 May 2019, which covered both a holiday period (1–4 May) and a non-holiday period (5–12 May). In total, we obtained 4,924 valid survey responses with an overall rate of validity at 96.57%. The summary statistics of the respondents are displayed in Table 10.1. The data have been previously applied to evaluate the impact of HSR on social equity (Ren et al. 2020). More details of the discussion of the survey respondents can be found in Ren et al. (2020).

Figure 10.2 shows the proportion of respondents with a different travel time between their origin and the departing train station. More than one-third of the passengers had a travel time of 2 hours or more, which is followed by the group with a travel time between 0.5 and 1 hour. Such a pattern suggests that most passengers who take conventional trains come from regions that are relatively far from the train stations.

Figure 10.3 shows the socioeconomic characteristics of the respondent’s origin with a variation in travel time from the railway stations in Chongqing. In particular, both GDP per capita and population density decreased as the distance of the respondents’ origin from the train stations increased.
Table 10.1: Summary Statistics of the Survey Respondents

<table>
<thead>
<tr>
<th>Category</th>
<th>Overall</th>
<th>Non-Holiday</th>
<th>Holiday</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Responses</td>
<td>Share (%)</td>
<td>No. of Responses</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Male</td>
<td>2,866</td>
<td>58.20</td>
<td>2,507</td>
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<tr>
<td>Female</td>
<td>2,058</td>
<td>41.80</td>
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</tr>
<tr>
<td><strong>Age</strong></td>
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<td></td>
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<tr>
<td>Under 18 years old</td>
<td>250</td>
<td>5.08</td>
<td>211</td>
</tr>
<tr>
<td>18–25 years old</td>
<td>2,412</td>
<td>48.98</td>
<td>2,032</td>
</tr>
<tr>
<td>26–45 years old</td>
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<td>1,548</td>
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<tr>
<td>46–60 years old</td>
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<tr>
<td>More than 60 years old</td>
<td>119</td>
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<tr>
<td><strong>Education</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Junior high school and below</td>
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<td>14.11</td>
<td>630</td>
</tr>
<tr>
<td>Technical secondary school and high school</td>
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<td>Junior college</td>
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<tr>
<td>Master's degree and above</td>
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<td><strong>Occupation</strong></td>
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<tr>
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<td>504</td>
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<tr>
<td>Retiree</td>
<td>162</td>
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<tr>
<td>Entrepreneur</td>
<td>272</td>
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<td>Individual business</td>
<td>312</td>
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<tr>
<td>Businessperson</td>
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<td>524</td>
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<td>Worker</td>
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<td>Farmer</td>
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<td>Other</td>
<td>894</td>
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<td><strong>Monthly Income</strong></td>
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<td></td>
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<td>373</td>
<td>7.58</td>
<td>330</td>
</tr>
<tr>
<td>CNY2,000–5,000</td>
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<td>CNY5,001–10,000</td>
<td>998</td>
<td>20.27</td>
<td>897</td>
</tr>
<tr>
<td>More than CNY10,000</td>
<td>320</td>
<td>6.50</td>
<td>289</td>
</tr>
</tbody>
</table>

Source: Authors’ calculation.
Figure 10.2: Proportion of Respondents with a Different Travel Time from Origin to Departing Train Station

Notes: All the values were measured in percent.
Source: Authors’ calculation.

GDP = gross domestic product.
Notes: GDP per capita is measured by CNY100 per person. Population density is measured by number of people per square kilometer.
Source: Authors’ calculation.
10.4 Methodology

To assess whether or not the intercity mode choice of people with a different travel distance from their origin to the railway stations differs, we adopted both the binary logit (BNL) and multinomial logit (MNL) models, developed by McFadden (1973). BNL and MNL are the standard approaches to determine what crucial variables affect mode choice (Wen, Wang, and Fu 2012). Specifically, in a binomial logit model, the relationship between the odds of \( y \) equals one and independent variables \( x_i \) can be expressed as:

\[
\log \left( \frac{p_i}{1-p_i} \right) = a + bx_i, \quad (1)
\]

where \( p \) indicates the probability of selecting a category \( (y_i = 1) \). The odds can be calculated from the probability, which could be denoted as:

\[
\text{odds} = \frac{p_i}{1-p_i} = \frac{p(y_i = 1)}{p(y_i = 0)} = \frac{p(y_i = 1)}{1 - p(y_i = 1)}. \quad (2)
\]

In the case where the independent variable \( x \) is also a binary variable, the odds ratio can be used to express a ratio between two groups of odds that an individual chooses a certain category. For instance, assuming that \( y = 1 \) and \( x = 1 \), the odds ratio can be expressed as:

\[
\text{odds ratio} = \frac{\text{odds}(x_i = 1)}{\text{odds}(x_i = 0)} = \frac{\exp(a + b)}{\exp(a)} = \exp(b) \quad (3)
\]

The MNL model, which is derived from the extension of the binary logit model, is essentially an estimation of a set of binary logit models. Assuming that there are \( n \) categories of dependent variables, we can then assign values of different categories as \( 1, 2, \ldots, n \). With the first category treated as the reference case, the basic equation of the MNL model can be expressed as:

\[
\log \left[ \frac{p(y_i = 2)}{p(y_i = 1)} \right] = a_i + b_i x_i \quad (4)
\]
To examine which factors prohibited passengers from choosing HSR as their primary mode of intercity travel, we conducted a statistical regression analysis based on the passengers’ decision to utilize conventional trains after the opening of HSR. As illustrated in Table 10.2, two dependent variables were adopted: the first one measures mode choice after the opening of HSR, while the second one measures preference of HSR if the price is not a concern. The former is a categorical variable that represents the category of different transportation modes, including conventional trains, high-speed trains, and other modes (including bus, shuttle, private vehicle, taxi, and aircraft). The latter is a binary variable that represents whether passengers prefer to travel by HSR if the price is not a concern. The independent variables consist of several factors, including the motivation for choosing conventional trains after the establishment of HSR. In addition, other variables representing the socioeconomic attributes of respondents, such as gender, age, education, occupation, and income, are also included. The third type of factor includes the attitude of respondents, for instance, whether a direct connection to the respondent’s destination by HSR was available, and whether the respondents perceived a reduction in train service frequency after the establishment of HSR. In addition, a correlation analysis was conducted to examine the collinearity of all the variables. As summarized in Appendix 10.1, the results show that the correlation of all the independent variables is relatively low, which suggests that collinearity is not a concern in this analysis.
Table 10.2: Description of the Key Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Variable Type</th>
<th>Variable Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent variable</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selected mode after the opening of HSR ((Y_1))</td>
<td>Unordered</td>
<td>HSR = 1, Conventional train = 2, Other modes (including bus, shuttle, private vehicle, taxi, and aircraft) = 0</td>
</tr>
<tr>
<td>Do you prefer to travel by HSR if the price is not a concern ((Y_2))</td>
<td>Unordered</td>
<td>Yes = 1, No = 0</td>
</tr>
<tr>
<td><strong>Independent variable</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender ((X_1))</td>
<td>Unordered</td>
<td>Male = 1, Female = 0</td>
</tr>
<tr>
<td>Age ((X_2))</td>
<td>Ordered</td>
<td>Under 18 years old = 1, 18–25 years old = 2, 26–45 years old = 3, 46–60 years old = 4, More than 60 years old = 5</td>
</tr>
<tr>
<td>Education ((X_3))</td>
<td>Ordered</td>
<td>Junior high school and below = 1, Technical secondary school and high school = 2, Junior college = 3, Bachelor’s degree = 4, Master’s degree and above = 5</td>
</tr>
<tr>
<td>Occupation ((X_4))</td>
<td>Ordered</td>
<td>Other = 0, Farmer = 1, Student = 2, Worker = 3, Businessperson = 4, Business owner = 5, Entrepreneur = 6, Retiree = 7, Civil servant = 8</td>
</tr>
<tr>
<td>Monthly income ((X_5))</td>
<td>Ordered</td>
<td>No income = 1, Less than CNY2,000 = 2, CNY2,000–CNY5,000 = 3, CNY5,001–CNY10,000 = 4, More than CNY10,000 = 5</td>
</tr>
<tr>
<td>Can HSR directly reach the destination city ((X_6))</td>
<td>Unordered</td>
<td>Yes = 1, No = 0</td>
</tr>
<tr>
<td>After the opening of HSR, respondent perceived a reduction in conventional train shifts going to the destination ((X_7))</td>
<td>Unordered</td>
<td>Yes = 1, No = 0</td>
</tr>
<tr>
<td>Distance ((X_8))</td>
<td>-</td>
<td>Distance from respondent’s destination to the Chongqing departure station</td>
</tr>
<tr>
<td>Travel time between respondent’s origin and the departing train station ((X_9))</td>
<td>Ordered</td>
<td>Within 0.5 hours = 1, 0.5 hour to 1 hour = 2, 1 hour to 1.5 hours = 3, 1.5 hours to 2 hours = 4, 2 hours and more = 5</td>
</tr>
<tr>
<td>Distance from respondent’s residential city to the Chongqing departure station ((X_{10}))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*continued on next page*
Table 10.2  

<table>
<thead>
<tr>
<th>Variable</th>
<th>Variable Type</th>
<th>Variable Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Why not take HSR after the opening of HSR</td>
<td>Unordered</td>
<td>Yes = 1, No = 0</td>
</tr>
<tr>
<td>There is no HSR at the destination (C₁)</td>
<td>Yes = 1, No = 0</td>
<td></td>
</tr>
<tr>
<td>The transfer is not convenient (C₂)</td>
<td>Yes = 1, No = 0</td>
<td></td>
</tr>
<tr>
<td>HSR fare is higher (C₃)</td>
<td>Yes = 1, No = 0</td>
<td></td>
</tr>
<tr>
<td>No need to save time (C₄)</td>
<td>Yes = 1, No = 0</td>
<td></td>
</tr>
<tr>
<td>There is no night train (C₅)</td>
<td>Yes = 1, No = 0</td>
<td></td>
</tr>
<tr>
<td>Saving accommodation costs (C₆)</td>
<td>Yes = 1, No = 0</td>
<td></td>
</tr>
<tr>
<td>No smoking on HSR (C₇)</td>
<td>Yes = 1, No = 0</td>
<td></td>
</tr>
<tr>
<td>HSR catering is expensive (C₈)</td>
<td>Yes = 1, No = 0</td>
<td></td>
</tr>
<tr>
<td>Habit (C₉)</td>
<td>Yes = 1, No = 0</td>
<td></td>
</tr>
<tr>
<td>It is more comfortable to take a sleeper on conventional trains during long-distance travel (C₁₀)</td>
<td>Yes = 1, No = 0</td>
<td></td>
</tr>
</tbody>
</table>

HSR = high-speed rail.
Source: Authors’ compilation.

10.5 Results

This chapter addresses the following specific questions. Was direct access to the final destination of respondents available by HSR (Table 10.3)? Was an HSR service available at the origin of the respondent (Table 10.4)? To what extent was the mode choice affected by the distance range from the origin of a respondent to the train station (Tables 10.5 and 10.6)? In particular, we examined the spillover effect of HSR as to the extent to which the mode choice of passengers varies...
spatially as a response to the introduction of HSR, given the concern of
the different distances between the train station and one’s origin. Hence,
the spillover effects were primarily examined in the third part of the
analysis.

The statistical analysis was conducted using a multinomial logit
regression in two groups. The first group evaluates the factors affecting
passengers’ choice of the conventional train as opposed to other
transportation modes (including bus, shuttle, private vehicle, taxi, and
aircraft) after the introduction of HSR. The second group evaluates the
factors affecting passengers’ choice of conventional trains over HSR.

As shown in Table 10.3, in the case of whether direct access to
the final destination was available by HSR, several variables, such as
fare, age, education level, and income, were found to have statistically
significant influences on mode choice. Specifically, when other modes
of transportation (model 1) and HSR (model 2) were treated as the
reference group, a one-unit higher fare of HSR was associated with
an increase of the odds of choosing conventional trains by 210.2% and
144.9%, respectively. On the contrary (shown in models 3 and 4), the
odds of selecting conventional trains increased by 61.6% and 84.8%,
respectively, if direct access to the final destination by HSR was not
available. The results suggest that the mode choice of those who
have direct access to their destinations by HSR is sensitive to the fare
change.

Table 10.3: Result Comparison Based on Respondents’ Responses
to Whether a Direct High-Speed Rail is Available for Their Trip

<table>
<thead>
<tr>
<th>Whether a Direct HSR is Available</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td></td>
<td>Conventional train = 1</td>
<td>Conventional train = 1</td>
</tr>
<tr>
<td></td>
<td>Other modes = 0</td>
<td>HSR = 0</td>
</tr>
<tr>
<td>Gender (X₁)</td>
<td>1.158 (0.241)</td>
<td>1.326** (0.155)</td>
</tr>
<tr>
<td>Age (X₂)</td>
<td>1.707*** (0.221)</td>
<td>1.410*** (0.103)</td>
</tr>
<tr>
<td>Education (X₃)</td>
<td>0.845** (0.073)</td>
<td>0.832*** (0.043)</td>
</tr>
<tr>
<td>Occupation (X₄)</td>
<td>1.007 (0.041)</td>
<td>0.978 (0.025)</td>
</tr>
<tr>
<td>Monthly income (X₅)</td>
<td>0.658*** (0.059)</td>
<td>0.831*** (0.045)</td>
</tr>
</tbody>
</table>

continued on next page
### Table 10.3 continued

<table>
<thead>
<tr>
<th>Whether a Direct HSR is Available</th>
<th>Yes</th>
<th>Model 1</th>
<th>No</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conventional train = 1</td>
<td>Other modes = 0</td>
<td>Conventional train = 1</td>
<td>Other modes = 0</td>
</tr>
<tr>
<td></td>
<td>HSR = 0</td>
<td></td>
<td>HSR = 0</td>
<td></td>
</tr>
<tr>
<td>Variables</td>
<td>Model 2</td>
<td>Model 3</td>
<td>Model 4</td>
<td></td>
</tr>
<tr>
<td>Habit (C_9)</td>
<td>1.019</td>
<td>1.095</td>
<td>0.930</td>
<td>1.809***</td>
</tr>
<tr>
<td></td>
<td>(0.362)</td>
<td>(0.225)</td>
<td>(0.315)</td>
<td>(0.396)</td>
</tr>
<tr>
<td>It is more comfortable to take a</td>
<td>1.057</td>
<td>1.424**</td>
<td>0.922</td>
<td>1.023</td>
</tr>
<tr>
<td>sleeper on conventional trains</td>
<td>(0.246)</td>
<td>(0.205)</td>
<td>(0.344)</td>
<td>(0.234)</td>
</tr>
<tr>
<td>during long distance travel (C_9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance (X_8)</td>
<td>0.631***</td>
<td>1.485***</td>
<td>0.914</td>
<td>1.153*</td>
</tr>
<tr>
<td></td>
<td>(0.104)</td>
<td>(0.145)</td>
<td>(0.113)</td>
<td>(0.091)</td>
</tr>
<tr>
<td>HSR fare is higher (C_3)</td>
<td>3.102***</td>
<td>2.449***</td>
<td>1.616*</td>
<td>1.848***</td>
</tr>
<tr>
<td></td>
<td>(0.635)</td>
<td>(0.281)</td>
<td>(0.416)</td>
<td>(0.269)</td>
</tr>
<tr>
<td>There is no HSR to the destination (C_1)</td>
<td>1.536</td>
<td>0.639***</td>
<td>1.008</td>
<td>0.701**</td>
</tr>
<tr>
<td></td>
<td>(0.429)</td>
<td>(0.094)</td>
<td>(0.243)</td>
<td>(0.098)</td>
</tr>
<tr>
<td>After the opening of HSR,</td>
<td>0.931</td>
<td>0.783**</td>
<td>1.001</td>
<td>0.558***</td>
</tr>
<tr>
<td>respondent perceived a reduction in frequency of conventional trains (X_7)</td>
<td>(0.192)</td>
<td>(0.093)</td>
<td>(0.272)</td>
<td>(0.086)</td>
</tr>
<tr>
<td>Saving accommodation costs (C_6)</td>
<td>1.174</td>
<td>1.272</td>
<td>1.394</td>
<td>1.731*</td>
</tr>
<tr>
<td></td>
<td>(0.419)</td>
<td>(0.242)</td>
<td>(0.737)</td>
<td>(0.513)</td>
</tr>
<tr>
<td>The transfer is not convenient (C_2)</td>
<td>0.702</td>
<td>1.121</td>
<td>1.845*</td>
<td>1.415*</td>
</tr>
<tr>
<td></td>
<td>(0.184)</td>
<td>(0.194)</td>
<td>(0.663)</td>
<td>(0.264)</td>
</tr>
<tr>
<td>No need to save time (C_4)</td>
<td>1.540**</td>
<td>1.173</td>
<td>1.507</td>
<td>1.149</td>
</tr>
<tr>
<td></td>
<td>(0.316)</td>
<td>(0.133)</td>
<td>(0.419)</td>
<td>(0.177)</td>
</tr>
<tr>
<td>There is no night train (C_5)</td>
<td>1.261</td>
<td>0.914</td>
<td>0.652</td>
<td>0.549**</td>
</tr>
<tr>
<td></td>
<td>(0.453)</td>
<td>(0.189)</td>
<td>(0.300)</td>
<td>(0.160)</td>
</tr>
<tr>
<td>No smoking on HSR (C_7)</td>
<td>0.707</td>
<td>0.757</td>
<td>0.537</td>
<td>0.821</td>
</tr>
<tr>
<td></td>
<td>(0.268)</td>
<td>(0.193)</td>
<td>(0.280)</td>
<td>(0.305)</td>
</tr>
<tr>
<td>HSR catering is expensive (C_8)</td>
<td>1.165</td>
<td>1.758**</td>
<td>0.670</td>
<td>0.458*</td>
</tr>
<tr>
<td></td>
<td>(0.497)</td>
<td>(0.442)</td>
<td>(0.471)</td>
<td>(0.184)</td>
</tr>
<tr>
<td>Travel time from respondent's origin to the departing station (X_9)</td>
<td>1.053</td>
<td>1.051</td>
<td>1.136*</td>
<td>1.140***</td>
</tr>
<tr>
<td></td>
<td>(0.065)</td>
<td>(0.038)</td>
<td>(0.086)</td>
<td>(0.051)</td>
</tr>
<tr>
<td>Constant</td>
<td>2.297</td>
<td>0.143***</td>
<td>2.825</td>
<td>0.877</td>
</tr>
<tr>
<td></td>
<td>(1.300)</td>
<td>(0.048)</td>
<td>(1.810)</td>
<td>(0.337)</td>
</tr>
<tr>
<td>No. of observations</td>
<td>2,090</td>
<td>2,090</td>
<td>1,532</td>
<td>1,532</td>
</tr>
<tr>
<td>Pseudo R-squared</td>
<td>0.086</td>
<td>0.086</td>
<td>0.092</td>
<td>0.092</td>
</tr>
</tbody>
</table>

HSR = high-speed rail.

Notes: Standard errors are displayed in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1.
Source: Authors’ calculation.
The results also show that if the age of the respondent increased by one unit, the odds of them choosing conventional trains over HSR and other modes increased by 41.0%–70.7% if there was direct HSR to their destination. Conversely, the odds would increase by 22.9%–100.7% if there was no direct HSR to the destination. In general, a higher fare for high-speed train services and a higher age is associated with an increase in the odds of choosing a conventional train instead of other modes.

However, the negative statistical association was confirmed with other variables, such as education and income. For instance, the results show that when there was direct HSR to the destination, a higher education level was associated with a decline in the odds of choosing conventional trains by 15.5% and 16.8% when the reference groups were specified as other modes and HSR, respectively. Similarly, when a direct HSR connection to the destination was not available, the odds of choosing conventional rail were observed to decrease by 25.8% and 33.6%, respectively, as the level of education increased. Such results suggest that when a direct HSR service to one’s destination is not available, the change in preference of HSR over other transportation modes for an intercity trip is likely to be more substantially influenced by factors such as education and income.

Because of the increase in distance from respondents’ destinations to the station, when there was a direct HSR connection to the destination, the odds of passengers choosing conventional trains rather than other transportation modes decreased by 36.9% and the odds of choosing conventional trains instead of HSR increased by 48.5% (but only 15.3% if there was no direct HSR to the destination).

If the destination city provided no HSR service, the odds of passengers choosing conventional trains instead of HSR declined by 36.1% and 29.9%, respectively. If the transfer was not convenient when there was no direct HSR to the destination, the odds of choosing to travel by conventional train increased by 84.5% and 41.5%, respectively.

The travel time between the respondent’s origins and the train station had a significant influence on the increase in the odds of passengers choosing conventional trains to travel only when there was no direct HSR to their destination. This result indicates that people in more remote areas are more inclined to ride on conventional trains in such a case.

Table 10.4 summarizes the results based on whether the respondent’s residential city provided an HSR service. The results show that regardless of whether their residential city provided HSR, the high fares of HSR were a common factor that increased the odds of passengers choosing conventional trains by 139.2%, 119.5%, 193.2%, and 104.2% in Models 1–4, respectively, which reveals that passengers’ choice of the
Table 10.4: Comparison Based on the Availability of High-Speed Rail Services at the Respondent’s Origin

<table>
<thead>
<tr>
<th>Whether an HSR Service is Available</th>
<th>Yes</th>
<th>No</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender ( (X_1) )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.885 (0.173)</td>
<td>1.126 (0.120)</td>
<td>1.718** (0.471)</td>
<td>1.716*** (0.286)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age ( (X_2) )</td>
<td>1.801*** (0.226)</td>
<td>1.384*** (0.094)</td>
<td>1.836*** (0.341)</td>
<td>1.161 (0.124)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education ( (X_3) )</td>
<td>0.774*** (0.064)</td>
<td>0.767*** (0.037)</td>
<td>0.929 (0.116)</td>
<td>0.730*** (0.055)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupation ( (X_4) )</td>
<td>0.991 (0.037)</td>
<td>0.989 (0.022)</td>
<td>0.940 (0.053)</td>
<td>0.971 (0.034)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monthly income ( (X_5) )</td>
<td>0.604*** (0.051)</td>
<td>0.799*** (0.040)</td>
<td>0.713** (0.094)</td>
<td>0.671*** (0.055)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habit ( (C_9) )</td>
<td>0.954 (0.300)</td>
<td>1.206 (0.223)</td>
<td>1.183 (0.459)</td>
<td>1.805** (0.460)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is more comfortable to take a sleeper on conventional trains during long distance travel ( (C_{10}) )</td>
<td>0.866 (0.199)</td>
<td>1.322* (0.192)</td>
<td>1.439 (0.542)</td>
<td>1.472* (0.325)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance ( (X_8) )</td>
<td>0.804* (0.092)</td>
<td>1.278*** (0.095)</td>
<td>0.848 (0.141)</td>
<td>1.294*** (0.140)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSR fare is higher ( (C_3) )</td>
<td>2.392*** (0.466)</td>
<td>2.195*** (0.235)</td>
<td>2.932*** (0.847)</td>
<td>2.042*** (0.337)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>There is no HSR at the destination ( (C_7) )</td>
<td>1.162 (0.253)</td>
<td>0.649*** (0.080)</td>
<td>1.591 (0.495)</td>
<td>0.694** (0.123)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can HSR directly reach the destination city ( (X_6) )</td>
<td>0.893 (0.172)</td>
<td>0.803** (0.090)</td>
<td>0.688 (0.186)</td>
<td>0.818 (0.133)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After the opening of HSR, respondent perceived a reduction in conventional train shifts going to the destination ( (X_7) )</td>
<td>1.050 (0.204)</td>
<td>0.739*** (0.082)</td>
<td>0.809 (0.251)</td>
<td>0.527*** (0.095)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saving accommodation costs ( (C_6) )</td>
<td>1.019 (0.356)</td>
<td>1.401* (0.277)</td>
<td>1.604 (0.923)</td>
<td>1.052 (0.302)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The transfer is not convenient ( (C_5) )</td>
<td>0.945 (0.230)</td>
<td>1.267 (0.190)</td>
<td>1.135 (0.444)</td>
<td>1.120 (0.263)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No need to save time ( (C_4) )</td>
<td>1.749*** (0.357)</td>
<td>1.167 (0.127)</td>
<td>1.204 (0.346)</td>
<td>1.167 (0.198)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>There is no night train ( (C_5) )</td>
<td>1.131 (0.387)</td>
<td>0.760 (0.155)</td>
<td>1.042 (0.522)</td>
<td>0.803 (0.231)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

continued on next page
conventional train is more sensitive to the fares when compared with other modes than when compared with HSR. The increase in monthly income also can decrease the odds of passengers choosing conventional trains by 39.6%, 20.1%, 28.7%, and 32.9% in Models 1–4, respectively.

The influence of other factors has greater heterogeneity. Specifically, when there was no HSR service in the respondent’s residential city, male passengers were more likely than female passengers to choose conventional trains with an increase in odds of 71.8% and 71.6%, respectively.

When there was an HSR service available in their residential city, the higher the education level of the respondent, the lower the odds of choosing conventional trains. When other transportation modes and high-speed rail were used as reference groups, the odds decreased by 22.6% and 23.3%, respectively.

With an increase in the distance from the departure station to the destination, when there is an HSR service in the respondent’s residential city, the odds of passengers choosing conventional trains over other modes decreased by 19.6%, whereas the odds of passengers choosing conventional trains increased by 27.8%. Conversely, if a respondent’s hometown provided no HSR service, the odds of them choosing conventional trains rather than HSR increased by 29.4%. This means

<table>
<thead>
<tr>
<th>Whether an HSR Service is Available</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td>Conventional train = 1 Other modes = 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No smoking on HSR ($C_7$)</td>
<td>0.717</td>
<td>0.780</td>
</tr>
<tr>
<td>(0.262)</td>
<td>(0.193)</td>
<td>(0.313)</td>
</tr>
<tr>
<td>HSR catering is expensive ($C_8$)</td>
<td>1.163</td>
<td>1.168</td>
</tr>
<tr>
<td>(0.559)</td>
<td>(0.301)</td>
<td>(0.534)</td>
</tr>
<tr>
<td>Travel time between respondent’s origin and the departing train station ($X_9$)</td>
<td>1.094</td>
<td>1.074**</td>
</tr>
<tr>
<td>(0.063)</td>
<td>(0.036)</td>
<td>(0.093)</td>
</tr>
<tr>
<td>Constant</td>
<td>3.657***</td>
<td>0.318***</td>
</tr>
<tr>
<td>(1.918)</td>
<td>(0.096)</td>
<td>(0.722)</td>
</tr>
<tr>
<td>No. of observations</td>
<td>2,497</td>
<td>2,497</td>
</tr>
<tr>
<td>Pseudo R-squared</td>
<td>0.080</td>
<td>0.080</td>
</tr>
</tbody>
</table>

HSR = high-speed rail.

Notes: Standard errors are displayed in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1.
Source: Authors’ calculation.
that the longer respondents’ trips were, the higher the increase in odds that they would choose conventional trains instead of HSR and other modes. Travel time between respondents’ origins and the departing train station had a positive effect on passengers’ choice of conventional rail. Specifically, the increase in odds was 7.4% when there was an HSR service available in their city of residence, whereas the increase was 10.7% when there was not.

The comparison of different respondent groups with varying distances between their residence and the train station with the consideration of price factors is summarized in Table 10.5. Higher age was found to be associated with an increase in odds of a passenger’s choice of conventional trains of 22.9%–161.8%, as observed in Models 1–6. Table 10.5 also shows that the age factor of those who lived within a 2-hour trip to the train station had a more considerable influence on their travel behavior than those who lived more than 2 hours away.

In addition, a relatively high fare was associated with an increase in the odds of choosing conventional rail by 72.7%–133.9%, which suggests a more significant impact of higher HSR fares on the travel behavior of those who lived more than 2 hours away from the train station than on those within a 2-hour trip. This finding suggests that those who live farther from a train station are more likely to choose conventional trains.

In terms of the influence of income, the odds of choosing conventional trains were found to be associated with a decrease of 25.2%–51.8% as income level increased.

The influence of other factors presents great heterogeneity based on different transportation modes and distance ranges. In particular, the improvement of education had a significant negative impact on passengers’ choice of a conventional train if their origin was outside a 2-hour range from the station. If there was no HSR at their destination, it significantly affected the odds of passengers choosing conventional trains, and the odds decreased by 28.1% when passengers lived within an hour of the train station and decreased by 40.8% when passengers lived more than 2 hours away.

If HSR could directly reach the destination city, the odds of passengers choosing conventional trains decreased by 23.9% when passengers lived more than 2 hours from the station. After the opening of HSR, whether respondents perceived the frequency of conventional trains reducing significantly affected the odds of them choosing conventional trains, with the odds decreasing by 25.6% if respondents perceived a significant reduction and 39.6% if they did not. If the transfer was inconvenient, taking the high-speed rail as the reference group, the odds of choosing conventional trains increased by 41.4% when the travel time from the passenger’s home to the station was greater than 2 hours.
<table>
<thead>
<tr>
<th>Respondent Group (Based on Distance between Residential Locations and the Train Stations)</th>
<th>Within 1-Hour Range</th>
<th>Within 2-Hour Range</th>
<th>Outside 2-Hour Range</th>
<th>All Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 3</td>
<td>Model 4</td>
</tr>
<tr>
<td><strong>Dependent Variable</strong></td>
<td>Conventional train = 1 Other modes = 0</td>
<td>Conventional train = 1 HSR = 0</td>
<td>Conventional train = 1 Other modes = 0</td>
<td>Conventional train = 1 HSR = 0</td>
</tr>
<tr>
<td>Gender (X$_1$)</td>
<td>1.298*** (0.366)</td>
<td>1.137*** (0.184)</td>
<td>1.125*** (0.287)</td>
<td>1.090*** (0.152)</td>
</tr>
<tr>
<td>Age (X$_2$)</td>
<td>2.618*** (0.524)</td>
<td>1.438*** (0.148)</td>
<td>2.617*** (0.469)</td>
<td>1.487*** (0.132)</td>
</tr>
<tr>
<td>Education (X$_3$)</td>
<td>0.882*** (0.107)</td>
<td>0.702*** (0.050)</td>
<td>0.844*** (0.094)</td>
<td>0.696*** (0.044)</td>
</tr>
<tr>
<td>Occupation (X$_4$)</td>
<td>1.034*** (0.058)</td>
<td>1.036*** (0.035)</td>
<td>1.000*** (0.050)</td>
<td>0.991*** (0.029)</td>
</tr>
<tr>
<td>Monthly income (X$_5$)</td>
<td>0.482*** (0.063)</td>
<td>0.748*** (0.058)</td>
<td>0.512*** (0.060)</td>
<td>0.785*** (0.052)</td>
</tr>
<tr>
<td>Habit (C$_9$)</td>
<td>1.177*** (0.559)</td>
<td>1.210*** (0.321)</td>
<td>1.351*** (0.613)</td>
<td>1.330*** (0.258)</td>
</tr>
<tr>
<td>It is more comfortable to take a sleeper on conventional trains during long-distance travel (C$_{10}$)</td>
<td>0.622*** (0.226)</td>
<td>1.156*** (0.276)</td>
<td>0.672*** (0.218)</td>
<td>1.269*** (0.262)</td>
</tr>
<tr>
<td>HSR fare is higher (C$_3$)</td>
<td>1.847** (0.542)</td>
<td>1.898*** (0.311)</td>
<td>1.727*** (0.449)</td>
<td>1.922*** (0.277)</td>
</tr>
<tr>
<td>There is no HSR at the destination (C$_1$)</td>
<td>1.153*** (0.355)</td>
<td>0.779*** (0.130)</td>
<td>1.241*** (0.341)</td>
<td>0.794*** (0.123)</td>
</tr>
<tr>
<td>Can HSR directly reach the destination city (X$_6$)</td>
<td>0.836*** (0.238)</td>
<td>0.907*** (0.153)</td>
<td>0.822*** (0.209)</td>
<td>0.820*** (0.118)</td>
</tr>
<tr>
<td>After the opening of HSR, respondent perceived a reduction in conventional train shifts going to the destination (X$_7$)</td>
<td>0.934** (0.259)</td>
<td>0.771*** (0.125)</td>
<td>0.926*** (0.234)</td>
<td>0.744** (0.107)</td>
</tr>
</tbody>
</table>

continued on next page
Table 10.5  continued

<table>
<thead>
<tr>
<th>Respondent Group (Based on Distance between Residential Locations and the Train Stations)</th>
<th>Within 1-Hour Range</th>
<th>Within 2-Hour Range</th>
<th>Outside 2-Hour Range</th>
<th>All Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 3</td>
<td>Model 4</td>
</tr>
<tr>
<td>Dependent Variable</td>
<td>Conventional train = 1 Other modes = 0</td>
<td>Conventional train = 1 Other modes = 0</td>
<td>Conventional train = 1 Other modes = 0</td>
<td>Conventional train = 1 Other modes = 0</td>
</tr>
<tr>
<td>Saving accommodation costs ($C_6$)</td>
<td>1.133 (0.628)</td>
<td>1.432 (0.454)</td>
<td>0.846 (0.404)</td>
<td>1.392 (0.400)</td>
</tr>
<tr>
<td>The transfer is not convenient ($C_2$)</td>
<td>0.736 (0.262)</td>
<td>1.092 (0.247)</td>
<td>0.711 (0.228)</td>
<td>1.009 (0.201)</td>
</tr>
<tr>
<td>No need to save time ($C_4$)</td>
<td>2.124** (0.680)</td>
<td>0.974 (0.163)</td>
<td>2.133*** (0.609)</td>
<td>1.098 (0.160)</td>
</tr>
<tr>
<td>There is no night train ($C_5$)</td>
<td>1.343 (0.747)</td>
<td>0.834 (0.261)</td>
<td>0.927 (0.428)</td>
<td>0.823 (0.232)</td>
</tr>
<tr>
<td>No smoking on HSR ($C_7$)</td>
<td>1.022 (0.561)</td>
<td>1.060 (0.372)</td>
<td>1.145 (0.597)</td>
<td>0.998 (0.302)</td>
</tr>
<tr>
<td>HSR catering is expensive ($C_8$)</td>
<td>1.760 (1.420)</td>
<td>1.200 (0.456)</td>
<td>1.647 (1.093)</td>
<td>1.183 (0.376)</td>
</tr>
<tr>
<td>Distance from respondent's city to the Chongqing departing train station ($X_{10}$)</td>
<td>26.230 (58.985)</td>
<td>0.285 (0.360)</td>
<td>1.924* (0.691)</td>
<td>0.842 (0.144)</td>
</tr>
<tr>
<td>Constant</td>
<td>1.172 (0.842)</td>
<td>0.719 (0.303)</td>
<td>1.764 (1.200)</td>
<td>0.625 (0.226)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No. of observations</th>
<th>1,093</th>
<th>1,093</th>
<th>1,415</th>
<th>1,415</th>
<th>2,181</th>
<th>2,181</th>
<th>3,596</th>
<th>3,596</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudo R-squared</td>
<td>0.081</td>
<td>0.081</td>
<td>0.079</td>
<td>0.079</td>
<td>0.089</td>
<td>0.089</td>
<td>0.073</td>
<td>0.073</td>
</tr>
</tbody>
</table>

HSR = high-speed rail.
Notes: Standard errors are displayed in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1.
Source: Authors' calculation.
Travel time from a respondent’s home to the departing train station increased the odds of them choosing conventional trains over other modes by 92.4% within a 2-hour range and over HSR only 4% outside a 2-hour range. This reveals that the impact of HSR on mode shift varies with travel time from the respondent’s residential city to the train station and that the magnitude of the impact is likely to diminish after the travel time exceeds 2 hours.

Table 10.6: Result Comparison Based on Respondents Whose Residential Location and the Train Station are at Different Distance Ranges (without the Consideration of Price Scenario)

<table>
<thead>
<tr>
<th>Respondent Group (Based on Distance between Residential Locations and the Train Stations)</th>
<th>Within 1-Hour Range</th>
<th>Within 2-Hour Range</th>
<th>Outside 2-Hour Range</th>
<th>All Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Variable (Do you prefer to travel by HSR if the price is not a concern)</td>
<td>Yes = 1, No = 0</td>
<td>Yes = 1, No = 0</td>
<td>Yes = 1, No = 0</td>
<td>Yes = 1, No = 0</td>
</tr>
<tr>
<td>Gender ($X_1$)</td>
<td>0.796</td>
<td>0.816</td>
<td>0.880</td>
<td>0.845</td>
</tr>
<tr>
<td>(0.171)</td>
<td>(0.156)</td>
<td>(0.139)</td>
<td>(0.102)</td>
<td></td>
</tr>
<tr>
<td>Age ($X_2$)</td>
<td>0.933</td>
<td>0.937</td>
<td>0.968</td>
<td>0.961</td>
</tr>
<tr>
<td>(0.117)</td>
<td>(0.105)</td>
<td>(0.093)</td>
<td>(0.069)</td>
<td></td>
</tr>
<tr>
<td>Education ($X_3$)</td>
<td>1.513***</td>
<td>1.465***</td>
<td>1.282***</td>
<td>1.357***</td>
</tr>
<tr>
<td>(0.141)</td>
<td>(0.124)</td>
<td>(0.087)</td>
<td>(0.071)</td>
<td></td>
</tr>
<tr>
<td>Occupation ($X_4$)</td>
<td>0.939</td>
<td>0.935*</td>
<td>1.019</td>
<td>0.982</td>
</tr>
<tr>
<td>(0.041)</td>
<td>(0.036)</td>
<td>(0.033)</td>
<td>(0.024)</td>
<td></td>
</tr>
<tr>
<td>Monthly income ($X_5$)</td>
<td>1.124</td>
<td>1.203**</td>
<td>1.019</td>
<td>1.084</td>
</tr>
<tr>
<td>(0.109)</td>
<td>(0.106)</td>
<td>(0.072)</td>
<td>(0.059)</td>
<td></td>
</tr>
<tr>
<td>Can HSR directly reach the destination city ($X_6$)</td>
<td>0.684*</td>
<td>0.789</td>
<td>0.908</td>
<td>0.840</td>
</tr>
<tr>
<td>(0.146)</td>
<td>(0.147)</td>
<td>(0.138)</td>
<td>(0.097)</td>
<td></td>
</tr>
<tr>
<td>After the opening of HSR, respondent perceived a reduction in conventional train shifts going to the destination ($X_7$)</td>
<td>1.426</td>
<td>1.271</td>
<td>1.528**</td>
<td>1.399***</td>
</tr>
<tr>
<td>(0.312)</td>
<td>(0.249)</td>
<td>(0.266)</td>
<td>(0.179)</td>
<td></td>
</tr>
<tr>
<td>Distance from respondent’s residential city to the Chongqing departing train station ($X_{10}$)</td>
<td>1.445</td>
<td>1.575*</td>
<td>0.981*</td>
<td>0.989</td>
</tr>
<tr>
<td>(2.422)</td>
<td>(0.398)</td>
<td>(0.011)</td>
<td>(0.009)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>3.587***</td>
<td>3.064***</td>
<td>5.412***</td>
<td>4.416***</td>
</tr>
<tr>
<td>(1.834)</td>
<td>(1.379)</td>
<td>(1.921)</td>
<td>(1.181)</td>
<td></td>
</tr>
<tr>
<td>No. of observations</td>
<td>1,086</td>
<td>1,406</td>
<td>2,153</td>
<td>3,623</td>
</tr>
<tr>
<td>Pseudo R-squared</td>
<td>0.045</td>
<td>0.035</td>
<td>0.020</td>
<td>0.023</td>
</tr>
</tbody>
</table>

HSR = high-speed rail.
Notes: Standard errors are displayed in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1.
Source: Authors’ calculation.
Table 10.6 summarizes passengers’ preference in travel mode with a variation in distance range between their origins and the train stations (also called origin and destination, or OD). Different from the previous results, the analyses here examine passengers’ mode choice without consideration of price factor. In general, the results show that the higher the education level, the greater the odds of a passenger using HSR, ceteris paribus. For instance, the odds were found to increase by 51.3%, 46.5%, and 28.2 %, if the travel time between OD is within 1 hour, 2 hours, and more than 2 hours, respectively. The results also show that the odds ratio of passengers choosing HSR for intercity travel decreased as the distance between their origins and the train stations increased. In addition, an increase in income was found to be significantly associated with an increase in the odds of selecting HSR by 20.3% if the travel time between OD was within a 2-hour range.

In addition, the results show that the mode choice preference was significantly influenced by the distance from the respondent’s residence to the train station. In particular, the odds of passengers choosing HSR increased by 57.5% if the travel time between OD was within a 2-hour range. However, the odds decreased by 1.9% when passengers lived more than 2 hours away from the station.

This assessment reveals that the odds ratio of choosing HSR generally decreased as the distance between a passenger’s origin and the train station increased. In particular, the odds of passengers choosing a high-speed train increased significantly if the distance between their origin and the train station was within 2 hours. However, the odds were found to be significantly lower if the distance measured by travel time was over 2 hours. In sum, the results suggest that HSR does have a spillover effect on people’s mode choice. However, the effect decreases as the distance between the passenger’s origin and the train station increases.

10.6 Conclusion

The key research findings can be summarized as follows. In general, intercity mode choice was found to be significantly affected by several factors, such as whether a high-speed train that provides direct access to the passenger’s destination was available, whether an HSR service was also available at the respondent’s residential origin, and the distance between the passenger’s origin and the railway station.

Price was also a key factor that affected mode choice. Specifically, the higher fare of high-speed trains led to increased odds of respondents choosing conventional trains. The assessment also showed that passengers were more likely to use conventional trains rather than
high-speed trains if the following conditions were met: the trip involves long-distance travel (with a travel time of more than 6 hours), a transfer was difficult, or the travel time from the passenger’s origin to the train station was relatively long. In addition, older people were found to be more likely to choose conventional trains for intercity travel as opposed to other modes of transportation, including HSR. Conversely, higher education and income were found to be associated with lower odds of choosing conventional trains.

The study also found that the odds ratio of choosing conventional rail is relatively higher if the travel time between a respondent’s origin and the departing rail station is longer. In particular, passengers who lived more than 2 hours away from the train stations in Chongqing were found to be more willing to travel by conventional train instead of HSR. This result suggests that although HSR does have a spillover effect on mode shift, the magnitude of the effect is likely to be diminished after the distance exceeds a 2-hour travel time.

The study provides at least the following two implications for transportation planners and policy makers. Firstly, planning and investment for the development of HSR infrastructure should be conducted more carefully, with consideration of its impact on mode choice. Given that certain social groups (e.g., those with lower incomes, lower education levels, higher age, or residence relatively far from major cities) are less likely to be able to afford HSR, it is important to maintain a certain amount of conventional train operations. These strategies can help to ensure transportation equity and improve the quality of life for those utilizing conventional rail for intercity travel. Secondly, given that the spillover effects of the HSR system on mode choice are limited to a certain geographic scale, more attention should be paid to improving the “last mile” of accessibility. Strategies include offering accessible public transit or shuttle services to the residents who live relatively far from railway stations. These should be implemented so that the utilization of HSR can be further increased.
References


### Appendix 10.1: Correlation Matrix of All the Variables

| Variable | X1     | X2     | X3     | X4     | X5     | X6     | X7     | X8     | X9     | X10    | C1     | C2     | C3     | C4     | C5     | C6     | C7     | C8     | C9     | C10    |
|----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| X1       | 1.000  |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| X2       | 0.141  | 1.000  |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| X3       | -0.112 | -0.214 | 1.000  |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| X4       | 0.055  | 0.282  | 0.088  | 1.000  |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| X5       | 0.277  | 0.431  | -0.189 | 0.360  | 1.000  |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| X6       | 0.030  | 0.292  | 0.062  | -0.006 | -0.076 | 1.000  |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| X7       | 0.062  | 0.045  | 0.031  | 0.056  | 0.079  | 0.039  | 1.000  |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| X8       | 0.111  | 0.133  | -0.124 | 0.012  | 0.109  | 0.086  | -0.054 | 1.000  |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
| X9       | 0.001  | 0.003  | -0.120 | -0.058 | -0.001 | -0.086 | -0.029 | 0.098  | 1.000  |        |        |        |        |        |        |        |        |        |        |        |        |        |
| X10      | 0.028  | 0.097  | 0.074  | 0.083  | 0.057  | 0.108  | -0.058 | 0.315  | -0.028 | 1.000  |        |        |        |        |        |        |        |        |        |        |        |        |
| C1       | -0.030 | -0.036 | -0.043 | 0.025  | 0.043  | -0.300 | 0.030  | -0.081 | 0.024  | -0.098 | 1.000  |        |        |        |        |        |        |        |        |        |        |        |
| C2       | 0.024  | 0.022  | -0.054 | 0.035  | 0.012  | -0.012 | 0.017  | 0.018  | 0.008  | -0.034 | -0.002 | 1.000  |        |        |        |        |        |        |        |        |        |        |        |
| C3       | -0.024 | 0.002  | 0.090  | -0.072 | -0.157 | 0.156  | 0.002  | 0.059  | -0.015 | 0.060  | -0.294 | -0.092 | 1.000  |        |        |        |        |        |        |        |        |        |        |
| C4       | -0.016 | -0.075 | 0.054  | -0.063 | -0.084 | 0.137  | 0.012  | -0.018 | 0.039  | -0.006 | -0.220 | -0.106 | 0.150  | 1.000  |        |        |        |        |        |        |        |        |        |        |
| C5       | 0.002  | -0.001 | 0.084  | 0.028  | 0.043  | 0.009  | 0.045  | 0.002  | -0.041 | 0.028  | -0.025 | -0.031 | -0.038 | -0.040 | 1.000  |        |        |        |        |        |        |        |        |        |
| C6       | -0.005 | -0.006 | 0.028  | -0.027 | -0.060 | 0.066  | 0.010  | 0.005  | 0.041  | 0.019  | -0.083 | 0.022  | 0.080  | 0.058  | 0.052  | 1.000  |        |        |        |        |        |        |        |        |
| C7       | 0.130  | 0.008  | -0.075 | -0.002 | 0.074  | 0.051  | 0.000  | 0.031  | -0.008 | 0.010  | 0.040  | 0.015  | 0.052  | -0.028 | 0.014  | 0.022  | 1.000  |        |        |        |        |        |        |        |        |
| C8       | 0.028  | 0.035  | -0.021 | 0.002  | 0.010  | 0.012  | 0.052  | 0.004  | -0.006 | 0.009  | -0.011 | -0.003 | 0.075  | -0.061 | 0.021  | 0.050  | 0.067  | 1.000  |        |        |        |        |        |        |        |
| C9       | -0.013 | -0.064 | -0.022 | -0.021 | -0.061 | -0.027 | -0.013 | -0.030 | -0.002 | 0.054  | -0.079 | -0.009 | 0.077  | 0.021  | -0.058 | -0.004 | 0.027  | -0.007 | 1.000  |        |        |        |        |        |        |        |
| C10      | 0.030  | 0.097  | 0.036  | 0.051  | 0.074  | 0.101  | 0.024  | 0.133  | -0.042 | 0.142  | -0.082 | 0.005  | -0.027 | 0.001  | 0.072  | 0.052  | 0.028  | 0.027  | -0.040 | 1.000  |        |        |        |

Source: Authors.
11

Sine Qua Non: High-Speed Rail Forms and Roles in Intercity and Urban Areas

Eugene Chao and Vukan R. Vuchic

11.1 The Importance of Rail Systems in Cities

Rail systems with cable traction and then electric propulsion were the revolutionary invention around 1890 that introduced motorized transportation into cities. With greater speed, comfort, and reliability than walking and biking, the cities grew from compact walking cities to transit cities and developed suburbs. Schematic engineering and technical planning resulted in the rapid construction of trams and streetcars followed in the 1920s by buses and trolleybuses, broadening the family of transit modes. The next significant change came during 1930–1960 as the rapid growth of car ownership offered greater mobility and created chronic congestion and externalities. Responses to the pressures of unlimited car use varied in different cities. One extreme followed by most cities in the United States (US) was encouraging the use of cars by building extensive highway networks and parking facilities while neglecting public transport, pedestrians, and other modes. These policies created auto-based cities with severe problems of car dependency and low environmental quality. Most European cities gave considerable attention to the problem of the “collision of cities and cars” and gradually developed policies that led to the creation of “intermodal” cities. In all medium and large cities, rail systems play a crucial role in enhancing livability and sustainability.

Livability refers to the quality of life in a city, comprising economic vitality, socially sound relations, and the quality of the natural and human environment. Sustainability represents a stable condition that can last through generations without depletion of resources and degradation of the natural and human environment or quality of life (Vuchic 1999).
### Table 11.1: System Performance for Different Generic Classes of Transit Modes

<table>
<thead>
<tr>
<th>Generic Class</th>
<th>Private Auto on</th>
<th>Street Transit</th>
<th>Semirapid Transit</th>
<th>Rapid Transit</th>
<th>Intercity Transit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unit</td>
<td>Street</td>
<td>Freeway</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transit Unit Capacity</td>
<td>sps/TU</td>
<td>12–2.0</td>
<td>40–300</td>
<td>40–600</td>
<td>140–2,000</td>
</tr>
<tr>
<td>Max. Frequency, ( f_{\text{max}} )</td>
<td>TU/hr</td>
<td>600–800</td>
<td>1,500–2,000</td>
<td>60–120</td>
<td>40–90</td>
</tr>
<tr>
<td>Line Capacity, ( C )</td>
<td>sps/hr</td>
<td>720–1,050</td>
<td>1,800–2,600</td>
<td>2,400–15,000</td>
<td>4,000–20,000</td>
</tr>
<tr>
<td>Operating Speed, ( V_o )</td>
<td>km/hr</td>
<td>20–50</td>
<td>60–90</td>
<td>5–20</td>
<td>15–45</td>
</tr>
<tr>
<td>Productive Capacity, ( P_c )</td>
<td>10(^3) sp-km/hr</td>
<td>10–25</td>
<td>50–120</td>
<td>20–150</td>
<td>75–600</td>
</tr>
<tr>
<td>Investment Cost per Pair of Lanes, MM</td>
<td>10(^6) $/km</td>
<td>0.2–2.0</td>
<td>2.0–15.0</td>
<td>0.1–2.0</td>
<td>3.0–12.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Typical Systems</th>
<th>System “a”</th>
<th>System “f”</th>
<th>RB-1</th>
<th>RB-2</th>
<th>SCR</th>
<th>BRT</th>
<th>LRT-1</th>
<th>LRT-2</th>
<th>RRT-1</th>
<th>RRT-2</th>
<th>RGR</th>
<th>HSR-US</th>
<th>HSR-A abroad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit Unit Capacity</td>
<td>sps/TU</td>
<td>1.3</td>
<td>1.3</td>
<td>65</td>
<td>75</td>
<td>140</td>
<td>100</td>
<td>180</td>
<td>430</td>
<td>800</td>
<td>1,100</td>
<td>1,000</td>
<td>1,200</td>
</tr>
<tr>
<td>Max. Frequency, ( f_{\text{max}} )</td>
<td>TU/hr</td>
<td>700</td>
<td>1,800</td>
<td>12.0</td>
<td>90</td>
<td>90</td>
<td>100</td>
<td>90</td>
<td>40</td>
<td>30</td>
<td>35</td>
<td>28</td>
<td>75</td>
</tr>
<tr>
<td>Line Capacity, ( C )</td>
<td>sps/hr</td>
<td>910</td>
<td>2,340</td>
<td>1,800</td>
<td>6,750</td>
<td>10,000</td>
<td>10,000</td>
<td>16,200</td>
<td>17,200</td>
<td>24,000</td>
<td>38,300</td>
<td>28,000</td>
<td>90,000</td>
</tr>
<tr>
<td>Normal Operating Speed, ( V_o )</td>
<td>km/hr</td>
<td>35</td>
<td>80</td>
<td>20</td>
<td>18</td>
<td>26</td>
<td>26</td>
<td>30</td>
<td>33</td>
<td>38</td>
<td>36</td>
<td>50</td>
<td>160</td>
</tr>
<tr>
<td>Operating Speed at Capacity, ( V_{oc} )</td>
<td>km/hr</td>
<td>20</td>
<td>40</td>
<td>10</td>
<td>12</td>
<td>18</td>
<td>18</td>
<td>23</td>
<td>25</td>
<td>38</td>
<td>34</td>
<td>48</td>
<td>120</td>
</tr>
<tr>
<td>Productive Capacity, ( P_c )</td>
<td>10(^3) sp-km/hr</td>
<td>18.2</td>
<td>93.6</td>
<td>78</td>
<td>81</td>
<td>180</td>
<td>180</td>
<td>370</td>
<td>430</td>
<td>912</td>
<td>1,309</td>
<td>1,394</td>
<td>2,000</td>
</tr>
<tr>
<td>Investment Cost per Pair of Lanes, MM</td>
<td>10(^6) $/km</td>
<td>0.6</td>
<td>8.0</td>
<td>0.2</td>
<td>0.3</td>
<td>7.0</td>
<td>7.0</td>
<td>8.0</td>
<td>9.0</td>
<td>12.0</td>
<td>20.0</td>
<td>18.0</td>
<td>30.0</td>
</tr>
</tbody>
</table>

BRT = bus rapid transit, hr = hour, HSR = high-speed rail, km = kilometer, LRT = light rail transit, RB = regular bus, RGR = regional rail, RRT = rapid rail transit, sps = spaces, TU = transit unit, US = United States.

Source: Authors.
Many changes in rail systems have occurred the introduction of the first motorized vehicles. Since their invention about 120 years ago, electric rail systems have remained the most lasting mode of urban and intercity transportation. While requiring substantial investment and encompassing several modes, rail systems represent the backbone of a high-capacity, reliable, and economical transport mode influencing land use development and shaping the quality of life in people-oriented cities. Large cities in developed countries, such as Tokyo, New York, and Moscow, could not function or even exist without their extensive rail networks. Similarly, most cities with populations from half a million to 2 or 3 million that are known for their pedestrian orientation and livability, like Munich, Vienna, and Toronto, have a high quality of life enabled by extensive use of various modes of rail systems. Table 11.1 represents system performance for different generic classes of rail transit modes.

11.2 Review of High-Speed Rail

The first high-speed rail (HSR) line opened in the world, from Tokyo to Osaka in Japan in 1964, revealed that rail technology is not limited to speeds below 200 kilometers per hour (km/hr); HSR could provide highly reliable, safe, and comfortable travel at 210 km/h or above. Despite its excellent public acceptance, HSR expanded only in Japan until France opened its first TGV line—Paris to Lyon—in 1981 with a maximum speed of 270 km/hr. The development of HSR has accelerated and spread to many countries during the last 40 years. With these high-quality transportation services, European countries have evolved from individual HSR lines (e.g., France, Germany, and Spain) to an international network offering much faster and more comfortable travel than the highway or air travel could offer among numerous cities, such as Madrid, Marseille, Zurich, Berlin, Stockholm, and London. Brussels, the capital of Europe, was in an ideal geographical position to use HSR to shorten travel times to surrounding countries, primarily to France, Luxembourg, Germany, the Netherlands, and the United Kingdom. Today, HSR is not limited to Japan, France, Germany, and Spain. Another dozen economies, including the Republic of Korea; Taipei, China; the Russian Federation; Belgium; and Italy, now operate single or multiple HSR lines. In recent years, the People’s Republic of China has started rapid construction of a national HSR network (Lawrence, Bullock, and Liu 2019). In contrast, the United States (US) is lagging far behind this effort (Fernandez 2019; CRS 2019; NCRRP 2016).

A review of the worldwide development shows that the construction of single lines along major population corridors in Japan, France, Spain, and a few other countries has grown into planning and construction of
major national and international networks (Leboeuf 2018). HSR is not just a passenger transportation system faster than conventional rail, but it is a new mode of passenger transportation that fills the gap between auto travel on the highway at cruising speeds of 100–120 km/hr and air travel at 600–800 km/hr. HSR has developed cruising speeds in the 300–350 km/hr range, outperforming automobiles. HSR offers two to three times faster travel than cars. Its competitiveness with air travel results from shorter access and departure terminal times, which compensates for HSR’s lower maximum speeds and provides shorter total travel times up to the range of 400–1,000 km (250–650 miles) (Chao, Vuchic, and Vashchukov 2019).

HSR is a complex system comprising interdependent elements such as rolling stock, rights-of-way, and stations. While highways can accommodate a variety of vehicles, rail systems have highly technical coordination between their tracks and rights-of-way, line alignment geometry, vehicle profile, axle loads, signals, etc. Conventional rail lines allow diversity in the rolling stock physical standards and performance characteristics. In contrast, HSR systems are more sophisticated and custom-made. The design limits their interchangeability and reduces

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**Figure 11.1: Relationship Between Capacity, Investment Cost, and Passenger Attraction of Different Generic Classes of Transit Modes**

BRT = bus rapid transit, HSR = high-speed rail, LRT = light rail transit.

Source: Authors.
possibilities for operating different rolling stock and selling vehicles among different HSR lines and networks.

HSR lines in Japan and Spain have conventional rail lines with non-standard gauges (narrow and broad, respectively). Most European countries design their systems for the exclusive use of HSR passenger services. Still, in many cases, these special HSR trains branch out to sections of conventional rail lines (e.g., freight and regional rail) that are used by both types of trains: conventional and high-speed on certain sections. HSR in the US cannot be categorized as HSR based on its peers’ standards because it does not have all the high-performance attributes (e.g., speed, exclusive use for rights-of-way) of the peers’ HSR systems. In some instances in the US, the regional rail plays a larger role than the HSR in defining and shaping the urban and intercity areas. The socioeconomic effect of HSR is to unify the region and strengthen the corridor. The US example brings up a technical question: Can US regional rail services connect or even operate as HSR to push the system performance boundaries without compromising ridership? Figure 11.1 compares the performance attributes of different modes, emphasizing the attributes of HSR.

11.3 The Essential Concepts of Network Planning and Design

How do the HSR network and performance attributes shape the urban forms? Could the HSR trains leverage track sharing activities with the conventional trains and regional rails in individual sections to increase service frequency and area coverage? How can the HSR system integrate its routes and networks to produce the maximum throughput to stimulate regional growth? Is there a definitive mechanism to extract the maximum synergy between network design and operation strategy? This section distills critical answers from the existing networks to address the common predicaments in the network planning, design, and operation phases.

11.3.1 Trunk and Branch Lines

Passenger transfers among lines involve some resistance because a transfer may cause delays and require passenger reorientation between mezzanines and platforms on different lines. Thus, transfers are seen as less desirable. However, it is a mistake to design rail systems with only independent trunk lines without branches based on the misbelief that the network should not have any merging or
diverging movements. In fact, networks with more transfer options offer passengers more route selections than lines with no transferring, as shown in Figure 11.2. Integrated networks with transfer platforms collectively create efficient passenger circulation, train operation, and overall throughput. When transfers are designed correctly, the benefit of line alignment, scheduling, and service efficiency outweighs passenger resistance. The importance of transfers has been demonstrated by the most successful large rail networks in Moscow; Munich; San Francisco; Washington, DC; and New York. These systems rely on extensive intermodal and intramodal transfers. Networks that have at least two branches are superior in both respects: each branch provides additional area coverage and offers only one-half of the trunk line capacity, resulting in higher utilization. Network and services integration through transfers includes functional design of lines, optimal layout of transfer stations, and coordinated scheduling and information (Vuchic and Musso 1992).

To comprehend the relationship between transfers and network efficiency, it is important to explain the characteristics of trunk and branch (i.e., feeder) lines and how these two are shaping the geometric forms of cities and suburbs:

- Trunk line: overlapping sections are used by more than one line, usually in the center of cities.
- Branch line: separates from the trunk as single lines operate toward the suburbs.
In network planning and transfer design, independent lines and an integrated network have these differences:

- **Independent line**: each line operates by itself between two terminals.
- **Integrated network**: where lines overlap, they have joint sections or branches.

An independent line with all trains running between the terminals has its own fleet and depot. It is the simplest to operate, allowing high service reliability and short headways. An integrated network has lines with branches that diverge, merge, and overlap among different sections. These lines are more complicated to operate because of the merging and diverging, which may cause delays. In contrast, an integrated network allows different train capacities in various sections and requires fewer passenger transfers.

Although independent lines offer direct services, each line does not have to operate independently. Independent lines are more costly to build and may not necessarily translate to lower operation and maintenance (O&M) costs (Lehner 1969). Integrated networks (e.g., regional unified networks) include merging, diverging, and overlapping lines and often have branches leaving the city center toward the suburbs. Integrated networks offer greater area coverage, connectivity, and access to a defined region (Lee 1998; Venturi 2017). As branches increase area coverage, they become more valuable in suburban areas where radial lines diverge and single lines cannot serve well in large areas (Korea Trains 2020). With greater area coverage, the network attracts more passengers. Branches are often designed with an economic intention to stimulate new growth areas, as shown in the example in Figure 11.3. Trunk lines usually have regular headways. When a single trunk line divides into two branches, the trunk maintains its service frequency with coordinated headways. As branches increase total ridership on the line, offered line capacity increases, kilometers of empty space decrease, and the operating ratio (used capacity divided by total capacity) increases, as plotted in Figure 11.4.

In shaping a city’s form and functionality, integrated networks compared to independent lines have the following advantages. Integrated networks offer more direct trips, reduce transfers, shorten station dwell times (i.e., deadhead) due to fewer passengers boarding/alighting, and allow scheduling to better match passenger loads (i.e., volumes) on individual network sections. Rolling stock is interchangeable and able to switch among lines to increase fleet utilization. Routes and lines are more responsive to incidental changes when demand suddenly escalates due to seasonal activities (e.g., sports, concerts, parades). Interoperating
Figure 11.3: High-Speed Rail Connects Major Center Cities via Rail Radial and Tangential Lines to New Growth Areas

HSR = high-speed rail.
Source: Authors.

Figure 11.4: Area Coverage, Load Section, Capacity, and Passenger Profile: Trunk Line with Two Branches

Source: Authors.
rolling stock on an integrated network also has the benefit of consolidating various operational facilities (e.g., maintenance yards, control towers, and command centers). The operational consolidation creates greater economies of scale, thereby reducing O&M costs and headcount expenses.

Despite the services and operation benefits, integrated networks have two main disadvantages: (i) they are more complicated to operate due to interactions among lines and (ii) a delay on one line is likely to extend to other lines and reduce service reliability.

The primary decision to build independent or integrated lines or a large-scale regional unified network depends on the collaborative incumbents’ decisions. Some transit agencies favor the simpler operations of independent lines. Others put more weight on passengers’ convenience and shorter cycle times. Passenger-centric decisions will create value for hundreds of thousands of passengers every day for many decades. The benefit to passengers exceeds the benefit to transit operators and service supervisors.

11.3.2 Geometric Types of Rail Lines and Network

Rail lines and networks play a long-term and significant role in a city’s formation and functionality. Their geometric forms can be classified into common types of lines and networks alongside their inherent characteristics in connecting cities and urban areas as shown in Figure 11.5. The analyses are better carried out in the planning stage. Some of these common types of lines and networks are more frequently found in a regional rail or metro system; others may be found in the track-sharing sections between regional rail and HSR. The purpose of dissecting the geometric forms of lines and networks is to understand their variety and distinctive character in planning and designing networks associated with the city’s form and functionality.

Radial lines go from the center city radially outward to suburban areas. Radial lines are often the most frequently traveled corridors in urban areas. Their passenger loads are the highest where lines leave the center city, then decrease outward toward the suburbs. Trunk radial lines with branches represent a logical solution to increase efficiency by splitting the trunk section into two or more branches. As the utilization of capacity on the trunk line decreases toward the suburbs, the trunk radial divides into several branches, each one receiving a fraction of offered capacity and using it for new passengers from additional coverage.

Diametrical lines connect different suburbs through the center city. They provide a better distribution, a greater area coverage, and more transfer options to other lines in the center city than radials do.
On diametrical lines with branches, the sum of passenger loads on each section should be similar so that in line-pairing (i.e., pairing the services from one side to another), it is desirable to have similar loads among the branches on each side to operate similar train lengths and headways on the merging lines. There are two common types of diametrical lines. L-shaped lines often have a positive feature in which one or several similar lines can provide intersecting points, allowing transfer stations with other lines, which is impossible if lines are parallel. U-shaped lines are formed to match passenger loads between two corridors on the same side from the center city. This form satisfies the operating efficiency requirements, but it is unable to serve trips between the two radial sections. The U-shaped lines make longer travel times for passengers who plan to cross between two outlying segments of the same line. In most cases, such trips take much longer than a direct journey by bus or car to cross the outlying segments.

In shaping the city’s formation, diametricals compared with radials have the following attributes. Diametrical lines distribute passengers better in the center cities and offer greater network connectivity and operation efficiency. Diametrical lines do not require terminals to be located in the most expensive land area—the center city. However, diametrical lines must connect two or more corridors with relatively balanced passenger loads on each side.

Figure 11.5: Geometric Types of Rail Lines and Network

Source: Authors.
Tangential and circumferential lines operate in major cities with grid street patterns, such as the regional rail systems in Toronto, Philadelphia, and Washington, DC. They serve major tangential corridors around the center city. They distribute or interconnect radial lines. Their volumes tend to be lower than on the radial lines, but they are less peaked in distance and time, so they are more uniformly utilized.

Circle or ring lines are avoided by individual cities where planners worry about the technical minutiae of recovering from delays. Detractors of this type of line or network say that they should not exist because of two operational problems. First, when a delay occurs, it is difficult to recover from it because circle lines do not have end stations with terminal times that can be positioned for recovery. Second, circle lines can run only with headways in integer fractions of their cycle times, limiting selection of operating headways. Supporters of circle lines use these two countermeasures to recover from delays. First, two to three points can be designed where reserve trains wait to be called into service when a delay occurs. Such a design has been adopted on Tokyo’s Yamanote circle line, which carries more than 1 million passengers per day. Second, London’s Circle Line and Berlin’s S-Bahn, both circle lines, have connections with radials; therefore, each train makes one or two circles and then goes to the radial line’s terminal for delay recovery. Moscow solved the delays and technical obstacles and maintained strong reliability to become an exemplar of circle lines in its regional rail systems with two distinct roles in shaping city form. The circle line serves larger travel volumes around the center city and connects adjacent landmasses. Second, the circle line interconnects with the radials, integrating the entire network and shortening many non-center-oriented trips. The circles tend to appear in the urban environments, not in an intercity scale. Circle lines thus play a significant role in the central circles of Tokyo, Seoul, Berlin, Beijing, and Moscow with three distinct performance attributes:

(i) Circle lines have transfer stations with all radial lines and nicely integrate their radial-dominated network.

(ii) Circle lines have three functions: First, they serve circumferential trips in the ring area. Second, they serve as collector-distributors for radial lines. Third, they interconnect radials by shorter routing than by radials in and out of the center city.

(iii) Unlike the radials with heavy passenger volumes weighted toward the center city, circle lines more evenly distribute passenger loads along the line and throughout the day. Circle lines provide useful links for passengers and are efficient in operation due to high capacity utilization rates.
To summarize, circles lines serve many trips in the ring around the center city and collect and distribute better for radial lines. As connectors among radial lines, circle lines reduce travel to and from city center. The passenger load patterns are more evenly distributed along the line and through hours of the day than on radials. Nonetheless, circle lines need to operate with certain fractional integer headways. Since there are no terminals, recovery from delays is difficult and must be handled with special operational measures. Operationally, circle lines need careful planning to solve these operational issues. Still, in many cities, particularly those with mostly radially oriented lines (e.g., Moscow), circle lines can play a crucial role in shaping and enhancing socioeconomic activities.

11.3.3 Through-Running Stations and Dead-End Terminals

A through-running station allows trains to pass through the station with a minimal headway ($h_{min}$). A dead-end station does not allow trains to pass through, functioning as a terminal. Figure 11.6 visually compares two types of throughput design in a rail system. The dead-end terminal doubles the minimal headway ($2 \times h_{min}$) due to the train’s turnback activities. In train operation, shorter minimal headway means lower deadhead. In contrast, if a system embraces a longer headway, the system inevitably encounters more nonoperating periods (i.e., periods of train operation that are unable to generate revenue).

![Figure 11.6: Visual Comparison of Dead-End Terminal vs. Through-Running Station](image-url)

Panel A. Separate Terminals with Radial Lines
Panel B. Connected Terminals with Diametrical Lines

Source: Authors.
The trade-off between fixed tracks with lower investment but higher O&M cost vs. flexible tracks with higher investment but lower O&M cost has a direct impact on the overall throughput elements: frequency and capacity. Figure 11.7 shows three scenarios of a through-running station that allows trains to bypass each other, resulting in an increase of service frequency on a single line. Figure 11.8 represents a superior operating performance with the through-running operations, favoring the operator, passenger, and city in various aspects (Vuchic 2005).
11.4 Network Design and Operation Strategy

Rail infrastructure serves as a strong element to bind a city’s transport network. HSR unites multiple cities along major corridors, and its service efficiency relies on two decisive factors: network design and operation strategy. The first factor shapes the city’s formation; the second defines the city’s efficiency and functionality. This section examines methodologies for extracting the maximum synergy between network design and operation strategy, using case-study methods to distill the dynamic performance attributes of the high-performance HSR system. The US HSR cases reflect the US HSR concept, which may not be categorized as an HSR system based on other countries’ HSR standards, as explained earlier. Too often, the US regional rail plays a larger role and provides more functionality than the US HSR does in defining and shaping the urban and intercity areas. The US rail system has gone through many booms and busts (Briginshaw 2014; NCRRP 2016). Nowadays, it is still suffering from making the kind of compelling progress its peers did.

In recent years, one of the motivating stories—perhaps the most illuminating one in the US HSR development—is that the Brightline was
funded solely by a private equity investor, operating from Miami to West Palm Beach with an intermediate stop in Ft. Lauderdale. The Brightline case emphasizes the existing operational challenges, showcases the decision process, and introduces corresponding measures to tackle the fundamentals. Another case is the New York government initiative of the HSR development led by Governor Andrew Cuomo (Cuomo 2019). The proposal reflects his ambitious goal in developing an innovative strategy to build HSR in New York. The New York case highlights the advantages of the through-running network design by comparing plausible cases in US peer cities. Then, the innovative strategy: the Bigger Apple Plan, looking beyond the growth of New York, includes the growing economies and populations of Newark and Long Island (Venturi 2017). The plan develops a transformative approach to boost the regional long-term competitiveness and quality of life by strengthening rail connectivity and performance as a foundation to generate a virtuous cycle to tackle the outstanding socioeconomic issues in this “Bigger Apple region.” The New York case analyzes the sophisticated relationship between city and transportation, particularly with the rail and HSR system, and examines the interdependent socioeconomic attributes.

11.4.1 Brightline: Too Long to Drive, Too Short to Fly

Florida, like many US states, once had a glorious passenger rail history from the late 19th to mid-20th century. The rise and fall of the passenger rail in Florida is tied to an incredible industrialist, Henry Flagler, known as the founding father of Miami and Palm Beach. He was the founder of Standard Oil and the Florida East Coast Railway, extending his business along the East Coast and covering lucrative grounds across territory including Ohio, New York, and Florida (Florida East Coast Railway n.d.). In the early 20th century, the Florida East Coast Railway ran its passenger and freight services for 500 miles north from Key West to Miami through West Palm Beach to Cocoa and terminating in Jacksonville. In a heavily regulated and unionized industry, passenger services ceded operation in July 1968 because of the escalation of a nonoperating union issue. After the incident, passenger services were abandoned and tracks have been used solely for freight purposes (HNTB 2019, 2020; US SEC 2019).

The shutdown of Floridian passenger rail services contributed to congestion in the southeast sections of the interstate highways I-95 and I-75 when the Floridian population and the regional economy were growing. Floridian leaders acknowledged the severity and inconvenience due to the lack of mobility choice and the significant travel cost and time. Although numerous state government agencies tried to revitalize the
legacy of passenger rail services between West Palm Beach and Miami, the funding remained a major obstacle (CPCS 2018).

Lack of funding continued to prevent progress until 2012, when the revitalization started taking off led by a private equity firm, Fortress Investment Group (Leonard 2020). Fortress acquired 99% of Florida East Coast Industries (FECI, renamed from Florida East Coast Railway as the business diversified). FECI wholly owned the All Aboard Florida LLC (US SEC 2019). FECI is now a transportation, infrastructure, and real estate development company based in Miami, Florida. FECI began to reestablish passenger rail by upgrading the existing freight routes and tracks and gradually acquired lands from state-owned properties along the I-95 highway corridor (Florida East Coast Railway n.d.). The procuring process encountered fewer restrictions on the controversial eminent domain and “not in my back yard” (NIMBY) issues thanks to the simple land ownership of the FEC and state properties (Florida East Coast Railway n.d.; Property Rights Law Firm 2020). FECI named this revitalizing project Brightline in November 2015 with a business slogan of “Too Long to Drive, Too Short to Fly” (Levine 2018).

In phase one, the project development team planned to reintroduce the passenger rail services between West Palm Beach and Miami with an intermediate stop in Fort Lauderdale (Leonard 2020; US SEC 2019) as shown in Virgin Trains USA (US SEC 2019). The project hired Skidmore, Owings & Merrill to lead architectural design, the Rockwell Group for planning and designing stations and public amenities, and the Walsh Group for constructing (Porritt 2018) and procuring semidiesel rolling stocks (10 locomotives and 20 coaches) from Siemens (Siemens Mobility 2019). The project’s communication and signaling system was from Alstom (US SEC 2019). The FEC acted as the primary investor, project owner, and developer for the entire project with a total cost of $4 billion, but terms and details were undisclosed, as is typical for private equity investors (ITE 2018; Department of the Treasury 2019). Based on publicly available information, the tax-exempt private activity bond has been used for financing the project. The United States Internal Revenue Service provision of the 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users established a grants tax exemption for privately owned intercity HSR facilities with a volume cap of 25% of the bond (Maguire and Hughes 2018; Department of the Treasury 2019). The bond measure gave the private equity investor and real estate developer a strong incentive; however, the Fortress Cofounder and Brightline leading investor Wes Edens exercised a greater incentive with real estate development activities in and around the three station areas (Newman, Davies-Slate,
and Jones 2018; Thomas 2019). Other revenue sources were farebox and ancillary services (e.g., food and beverage, parking, naming rights, sponsorships and partnerships, merchandise, advertisement, and fee-related earnings), and the mix-used transit-oriented development consolidated existing transit services alongside commercial, retail, and residential values. For example, MiamiCentral Station was the masterpiece of Brightline's intermodal outcome seamlessly connecting with the Metrorail and Metromover. MiamiCentral became a new hub to revitalize Miami's central business district. In January 2018, Brightline began the operation. The train was supposed to travel at speeds from 125 to 200 km/hr, but it was traveling at an average speed of 55 km/hr due to a 180 at-grade crossings along the route (HNTB 2019). As for passenger fees, a one-way ticket has two options: $23 for a coach car or $38 for a business car with complimentary food and beverages (Louis Berger 2018; Brightline 2020).

Brightline, besides its goal to reinstate passenger rail services, acted as a catalyst to reinvigorate the long-neglected Miami Overtown neighborhood, which had been marginalized during the establishment of the new interstate system in the 1970s (SPEEDLINES 2018). Brightline reopened options for dining, attractions, recreation, and events for Floridians. For example, fans of the Miami HEAT National Basketball Association team can now travel from Palm Beach and Fort Lauderdale to MiamiCentral Station for 6 p.m. game times (HNTB 2019).

In the third quarter of 2018, only a few months after the reopening of Florida passenger rail services, Brightline announced a strategic partnership and licensing agreement with the Virgin Group. After the ownership transition, Virgin Group, led by the billionaire Richard Branson, owned Brightline and rebranded it as Virgin Trains USA in the first quarter of 2019 (Helfman 2020; Larsen 2018; US SEC 2019).

Although it remained unknown whether this acquisition was a situation of buying from a forced seller or selling to a forced buyer, the deal in Branson’s mind took advantage of the strong business headwind of increasing mobility and frequency of travel, the growing highway congestion in the region, the emerging new options for local first- and last-mile rideshare options, the increasing traveler dependence on mobile devices, and the growing attention to the environmental footprint of travel (US SEC 2019). These attractive factors favored the passenger rail business going forward and the acquisition strengthened his Virgin brand in the North America market (Bloomberg 2019).

In the second quarter of 2019, Virgin Trains USA announced its phase two plan to extend the project from the Miami–West Palm Beach section to Tampa with two major intermediate stops in Disney and Orlando and various conditional intermediate stops along the
West Palm Beach–Orlando section (e.g., Jupiter, Stuart, Vero Beach, Melbourne, and Cocoa) (Brightline 2018; GoBrightline 2019). Despite the applause and successes, two counties (Indian River and Jupiter) from 2012 to 2017 spent over $7 million taxpayer dollars to oppose the project, preventing it from reviving passenger services in the growing state. In January 2018, the two counties filed their ninth legal action against this project. They had been unsuccessful in their eight previous actions (Goddard 2018; Rodriguez 2019). In February 2020, Indian River has dropped its appeal (BISNOW 2020). While awaiting the court decisions for the last appeal, Virgin Trains USA has been examining the trade-offs between station density, passenger travel time, and area coverage, and has been exploring means to accelerate services and increase line capacity in each direction of the West Palm Beach–Tampa route (Roberts 2019).

In phase two, the project has been investigating whether to build an intermediate stop at Disney World. Changes in the vicinity of any lines and network often involve the creation of additional stations. The decision involves substantial investment and affects not only passengers but regional travel patterns. The decision process requires a comprehensive evaluation of direct and indirect consequences as well as collateral damages (e.g., areas not served, cause célèbre issues). Figure 11.9 represents the assessment of whether to add a new station to the existing network. The analyses divided the beneficiaries and affecting parties into three groups: passenger, operator, and community with their possible reactions to various events.

Although adding a station to an existing line may translate into more ridership and new coverage, it may slow the travel speed. When this happens, the corresponding strategy is to run skip-stop or express operations (Vuchic and Newell 1968; Vuchic 1969).

Skip-stop is the only service that provides increased speed on two-track lines while maintaining high frequency and line capacity. As shown in Figure 11.10, skip-stop has three types of stations: AB, A, and B. Some trains stop at AB and A stations and others stop at AB and B stations. Thus, by each train not stopping at A or B stations, skip-stop trains travel faster than all-local trains. Skip-stop is often used during peak hours with short headways or substantial passenger loads on both origination and destination. This operation even doubles headways at A and B stations. Higher speed attracts passengers. If the cycle speed were to reduce, the number of trains traveling on the line would decrease. Accordingly, it would reduce investment and operating costs. Another alternative service option is to run express services. Express services better operate on two tracks, allowing expresses to overtake locals. The most efficient express-local service is operated on a pair of tracks for
each direction with no overlapping sections on its express and local services (Vuchic 1973, 1967, 2020).

Phase one of the project is serving the West Palm Beach to Miami section with only one track for each direction. If the train plans to operate as skip-stop or express services, the rail infrastructure must carry a pair of tracks in each direction. Despite the debating of whether to install intermediate stations at Jupiter, Stuart, Vero Beach, Melbourne, and Cocoa within the West Palm Beach–Orlando section, one suggestion is to build two tracks in each direction to prepare for future requests for express or skip-stop operations. Although tracks and platforms are more costly to build, this preserves room for future customized operation when the line reaches its capacity. Figure 11.11 maps out the operation decisions behind the skip-stop and standard operations with pros and cons of five scenarios.

---

### Figure 11.9: Effects of Adding a Station to an Existing Line

<table>
<thead>
<tr>
<th>Event</th>
<th>Consequences by incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Passenger</td>
</tr>
<tr>
<td>Construction of station</td>
<td>Investment cost of stations and amenities</td>
</tr>
<tr>
<td></td>
<td>Disturbances to the community</td>
</tr>
<tr>
<td>Station operation</td>
<td>Costs of added personnel and utilities</td>
</tr>
<tr>
<td></td>
<td>Local congestion</td>
</tr>
<tr>
<td>Additional train stopping</td>
<td>Lost passengers (revenue)</td>
</tr>
<tr>
<td></td>
<td>Increased auto travel*</td>
</tr>
<tr>
<td>Diversion from automobile</td>
<td>Increased mobility and convenience</td>
</tr>
<tr>
<td></td>
<td>Additional passengers (revenue)</td>
</tr>
<tr>
<td></td>
<td>Reduced auto travel</td>
</tr>
<tr>
<td>Newly generated trips at new</td>
<td>Reduced congestion</td>
</tr>
<tr>
<td>and adjacent stations</td>
<td>around adjacent stations</td>
</tr>
<tr>
<td>Diversion of trips from</td>
<td>Increased mobility; decreased costs; higher land values</td>
</tr>
<tr>
<td>adjacent stations</td>
<td></td>
</tr>
</tbody>
</table>

* Community effects (e.g., congestion, noise, air pollution, and energy consumption) are proportional to traffic volume.

Source: Authors.
**Figure 11.10: Types of Accelerated Operations**

- **A. Express/local operation**
  - Express train
  - Local train

- **B. Skip-stop operation**

  Train A
  - A
  - AB
  - A
  - B

  Train B
  - A
  - AB
  - A
  - B

**TU** = transit unit.

Source: Authors.

---

**Figure 11.11: Comparative Analyses of Skip-Stop and Standard Operations**

<table>
<thead>
<tr>
<th>Differences</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>Higher operating speed</td>
<td>Fewer stops/km</td>
<td>Longer headways at A, B</td>
<td>No direct A-B connection</td>
<td>More complicated service</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>Reduced headways at AB</td>
<td>Reduced fleet size</td>
<td>Increased waiting time</td>
<td>Inconvenience and delay</td>
<td>Passenger confusion</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Saved travel time</td>
<td>Saved operating costs</td>
<td>Increased passenger comfort</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>Reduced waiting time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>More TU-km higher operating costs</td>
<td>Increased line capacity</td>
<td></td>
<td></td>
<td>Cost of public information</td>
</tr>
</tbody>
</table>

**TU** = transit unit.

Source: Authors.
11.4.2 New York High-Speed Rail: High Performing Through-Routes and Transformative Strategy to the Bigger Apple

In rail operation, minimal headway ($h_{\text{min}}$), determines the maximum frequency of transit units on the line. The headway is determined by the relationship between two transit units following each other at a station. A high-performance rail system tends to minimize headway to maximize throughput. To examine the usefulness of the through-running operation capability, this section investigates three US cities and compares them with and without the through-running capability for their rail systems associated with their city’s functionality.

The first example, Philadelphia’s SEPTA Jefferson Station located on Market Street between 10th and 12th Streets is the only through-running station in a US metropolitan area. Before 1979, one side of the dead-end operations had six independent lines; another had seven. The metropolitan areas were disconnected. Economic productivity was low because of the disjointed development that caused challenges in getting in, out, and around the city. Connecting these two areas into a single central business district by building a direct through-running tunnel and unifying these 13 lines to further consolidate throughputs and increase network efficiency became a preeminent goal to bolster Philadelphia’s long-term economic growth. Schematic track redesign and reengineering efforts were made (Corazza and Musso 1981; Musso and Vuchic 1988). Line pairing procedures were meticulously reexamined (Vuchic and Kikuchi 1984, 1985, 1987, 1994). The city converged on a four-track connecting trunk line shown as the thick trunk line in Figure 11.12 (ReThink Studio 2017). The design results in a shorter headway on the joint section. Peak volumes were handled by retaining the same minimal headway, but trains were lengthened. SEPTA former General Manager Jeffrey D. Kneppel said in an interview in 2016: “The Jefferson tunnel has a positive economic impact on the city’s long-term competitiveness.” Philadelphia used to have five transit agencies controlling different transit modes in the metropolitan area. To reduce the administrative burden and managerial redundancy and increase the entire system’s network efficiency, these five entities have been consolidated into a single entity—SEPTA.

As a second example, Boston is served by two regional isolated rail systems throughout Massachusetts, New England, and the Northeast Corridor. The current network is disjointed, as shown in Figure 11.13. The lines are far from connecting and none fully link to the subway;
meanwhile, highway congestion is severe. The dead-end operation squanders the potential of the existing transportation network and hobbles the regional economy, particularly in the north and west of the city (North South Rail Link 2017).

The third example, New York City’s transit system, is facing a capacity challenge because the offered capacity cannot catch up with the pace of ridership growth. For most New Yorkers, clogged buses and crowded trains have become their main or even only choice of modes. A dead-end terminal, Pennsylvania (Penn) Station, is located in the heart of Manhattan. Amtrak (i.e., intercity rail), New Jersey Transit, Long Island Rail Road, and Metro-North Railroad (regional rails) carry millions of daily passengers across the Big Apple. But Penn Station lacks operating flexibility, continuity of lines, and transfer design. Train movement is inefficient due to the dead-end operation and inflexible track alignments, decimating fleet utilization. Geographically, Penn Station is disconnected from Grand Central Station and therefore unable to seamlessly link to the northeastern part of the US. Can buses
be reliable? Buses in New York face more delays. The recent bus lane and signal prioritization can ease some delays, but the root problem is the incidental stopping of trucks and cars on the dedicated bus lanes, forcing unnecessary deceleration and stopping. Manhattan is already facing serious congestion, but the New York Port Authority is planning to continue bringing commuters through the already heavily congested Lincoln Tunnel to the downtown Manhattan bus terminal instead of using high-capacity rail transit through the trans-Hudson gateway tunnel to Penn Station. This decision forces the already heavily congested single core (i.e., Manhattan) to take in all the prospective growth, as shown in Figure 11.14. Growth is good, but how long can a city sustain its growth without efficient public transportation?

In New York (i.e., the Big Apple), a chronic housing shortage, overcrowded transportation, and social inequity have diminished the city’s long-term competitiveness and quality of life mainly because the rapid growth of the economy and the population over the last 2 decades outpaced infrastructure investment. After the latest economic crisis
in 2009, technology conglomerates and startups have been expanding to the New York region (i.e., the Bigger Apple, here referring to New York City, Newark, and Long Island) for its concentrated pool of skilled workers and diverse talent. New York stands at a crossroad and needs a strategy to uplift its growth. To thrive well, the Bigger Apple needs to optimize its budgetary platform and maximize private investment to manufacture synergistic outcomes. The Bigger Apple Plan offers an approach to transform the downfall into maturity. The plan leverages economic opportunities and major infrastructure proposals to solve the unmet social needs—access to quality housing, mass transit, and education—and prepare the Bigger Apple region, not just the Big Apple, to compete in the 21st-century global marketplace.

The Bigger Apple Plan connects the New York region with a regional unified network (RUN), transforming it into a multicore agglomeration alongside multiple central business districts, historical areas, and developing neighborhoods. The RUN will tackle the existing rail bottlenecks and develop better regional and HSR systems as attractive elements for a virtuous cycle of reinvestment opportunities across office and commercial spaces, housing, educational facilities, and hospitals in the region. The new cores will serve as strong suppliers to balance the outstanding demand shortages for residential and commercial spaces, educational facilities, and hospitals, as shown in Figure 11.15. With the increase of connectivity and the higher quality of life, the region will start to attract and retain more skilled workers and diverse talent.

In the 21st century, companies respond well to market conditions. To gain access to the pool of workers and diverse talent, their offices...
and corporate campuses tend to geographically collocate or locate near them. With the RUN and new cores, the Bigger Apple will become a region of choice for millennials and future generations, as shown in Figure 11.16. Competitive knowledge and innovation-driven companies and entrepreneurs follow the growth pattern. Quality commercial space in the new cores will accommodate industries, further diversifying the regional economy. Research and technology companies and universities specializing in science, technology, engineering, and mathematics (STEM) will start to develop a new industry and dilute the dependence on financial services to reduce the systematic risk of the next economic turmoil.

As time goes on, the regional tax base will grow incrementally with the region’s reputation for innovation, livability, and productivity gain. A broader tax base will lessen the individual burden and generate new sources of reinvested capital. The virtuous cycle of growth and reinvestment will serve as a solid foundation for long-term regional competitiveness and equitable development.

The Bigger Apple Plan leverages Governor Cuomo’s HSR initiative. The plan repositions growth by thinking beyond Manhattan and establishing a virtuous mechanism to consolidate the performance of regional rail and HSR in shaping the landmass to further improve the socioeconomic outlook (Venturi 2017). Figure 11.17 represents the innovative strategy for unifying the regional and HSR networks (i.e., RUN 34 and 42) across the urban and intercity areas in the Bigger Apple.
Figure 11.16: The Bigger Apple Plan: Roadmap for the Virtuous Growth Cycle

Figure 11.17: The Bigger Apple Plan: Through-Running Trunk Lines (RUN 34 and 42) for the Multicore Development

Source: ReThink Studio.
11.5 Conclusion

The function of transportation is an element in a broader process of human activities. It is used for going between activities including work, leisure, home, and business meetings. In several prosperous cities, rail services intertwine with human activities and the results and benefits from it include more than a simple count of passengers or passenger-kilometers carried. A high-performance system benefits productivity, business, and industry activities and affects the quality of life and human settlements beyond decades. For this reason, many infrastructure projects are justified by an improved economy, society, and environment, rather than the quality of the ride or real estate value around stations.

Cities’ diversity across history, culture, society, and strategic geolocation dictates the complexity of transportation problems and urban issues. It is difficult to transfer solutions directly from one city to another, but fundamental policies and guiding principles are similar. Sharing our experiences offers valuable practices for tackling the puzzling issues faced by our peers.

Cities are transitioning. Network integration is a great economic tool to conglomerate various metropolitan areas (i.e., the Northeast Corridor in the US, Jing–Jin–Ji regional corridor in the People’s Republic of China, and the corridor across Saint Petersburg–Moscow–Kazan–Yekaterinburg in the Russian Federation) to extract synergistic values among the regions, thereby facilitating passenger travel and reducing travel time. A network with operation flexibility can generate more economic value. Reengineering efforts from a dead-end terminal operation to a through-running system results in a more efficient regional unified network for the regional rail and HSR operations. This chapter has given some strategies to increase operation performance. Encouraging through-running stations and discouraging dead-end terminals are examples that have been discussed. A broader strategic vision starts with the city-transportation relationship and understanding the type of city people want. Planning with a definite economic purpose, government leaders need to determine the framework of a multimodal system and leverage regional unified networks and high-performance HSR systems to boost the long-term economic outlook across the massive landmass of the US.
References


12

Transportation Mode Choice in Viet Nam Intercity Trips

Le Thu Huyen and An Minh Ngoc

12.1 General Overview of Viet Nam’s Transportation System

Viet Nam’s economic growth in recent years has stabilized, with an economic growth rate of 7.02% in 2019, on a par with high growth countries in the region (Asia Perspective 2019). Transportation plays an important role in sustaining national economic growth. Common modes of transport in Viet Nam include roads, railways, waterways, and airways. In 2018, inland waterway transport accounted for more than 17% of domestic freight, road transport made up about 77%, and coastal shipping constituted 5% (Blancas et al. 2014).

While the development of the transport industry is essential to promote economic growth, transport industry vehicles emit carbon dioxide (CO$_2$) which causes air pollution. Transport sector emissions are the third largest after energy and agriculture, accounting for 18.38% of total greenhouse gas (GHG) emissions (Oh et al. 2019). It is also estimated that transportation emissions amounted to 47.7 million tons of CO$_2$ in 2020, and are forecasted to reach 89.1 million tons in 2030. Road transport was estimated to cover 79.4% of emissions in 2020 and 80.4% in 2030.

Viet Nam’s transport industry in recent years has been developing in the wrong direction. Despite the country’s strengths in its coastal and inland waterways transport, 77% of inland freight volume is transported via roads, a mode of transport associated with high logistics costs and GHG emissions. Therefore, to reduce logistics and environmental costs, Viet Nam needs to carefully analyze and replan its road freight area (Ministry of Transport 2016). Waterway transportation must become the main mode of transport.
Though the inland waterway network also plays a key role and transports a huge volume of goods, accounting for nearly 20% of total cargo traffic, it is currently in need of investment. Due to this lack of investment, road transport dominates passenger mobility (more than 90%) and cargo transport (more than 70%) in the whole country.

In recent decades, high-speed rail (HSR) has been the most modern means of passenger transport. It satisfies the needs of passengers, transporting a large number of people quickly, safely, and with less harm to the environment than other modes of transport. As pointed out by Jehanno (2011), HSR has a lower impact on climate and the environment than all other transport modes. In countries that developed their subway systems early (before 1940), HSR developed rapidly. This is especially in countries with a high population density.

Globally, Viet Nam ranks 15th in population and 49th in population density, so metro and HSR systems should have been developed decades ago. However, HSR has not been developed, and this has led to serious congestion in urban areas (especially Ha Noi and Ho Chi Minh City). Due to insufficient infrastructure, the expansion of the city in the form of “oil slicks” led to the collapse of infrastructure and a serious imbalance between transportation demand and supply. Although the government has been aware of this turmoil, it has not been able to manage urban development to meet the increasing demands of populations and socioeconomic development.

In addition to the characteristics of populations concentrated in two large cities, Ha Noi and Ho Chi Minh City, it is also necessary to mention the psychology and cultural habits of the people of Viet Nam, where everyone wants to have their own means of transportation. In the past few years, the number of cars has increased dramatically. Road infrastructure investment has been huge, but its development lags behind the growth of the number of vehicles on the road. Traffic accidents are worrying and CO$_2$ emissions are serious. These pressing issues mean that investment in metro and HSR lines must not be delayed.

12.2 Method

We conducted a study in 2018 with a goal to understand travelers’ behaviors, explore their transport preferences, and the likelihood of using high-speed trains for their intercity trips. Two types of interviews were organized in big cities in Viet Nam: (i) focus group interviews and (ii) traveler interviews, where we used a questionnaire-based survey.

A focus group is a professionally led small group discussion used to identify participant concerns, needs, wants, and expectations. In discussing the future of HSR in Viet Nam’s transport system, focus
groups indicated that the quality of alternative transport modes will substantially influence their willingness to use modes other than their current private mode of transport.

Traveler interviews were conducted at bus stations, railway stations, and airports in four cities: Ha Noi, Vinh, Da Nang, and Ho Chi Minh City. A total of 3,000 questionnaires were distributed, 2,713 of which were collected. The survey provided an indirect way to ascertain respondents’ views and collect data for a large sample that covered a balanced representation of the community. In our sampling, we tried to ensure that a minimum number of smaller socioeconomic groups were included in order to ensure we could identify the effects of various socioeconomic factors.

More than half the passengers interviewed were male, and the ratio of male to female interviewees was 1.2:1.0. In general, respondents were relatively young with an average age of 36.2 years. Road users tended to be younger than rail and air passengers with average ages of 35, 35.9, and 38.8 years, respectively. The majority of the interviewees were professionals, technical workers, students, or business owners (about 71%). A few were unemployed. One-third had an average income of D2 million–D8 million per month (about $86–$345). Average income was D4 million per month (about $172). The ability to pay for transport was reflected in the choice of mode of transport. Road and rail users had an average income of about D3 million, half that of air travelers. Passengers traveling by air more often had access to vehicles such as private cars, company cars, and motorcycles compared to passengers traveling by road and rail (see Table 12.1). However, in the interviews, majority of passengers (about 82%–95%) had access to motorcycles, and this factor was not relevant to their vehicle choice.

<table>
<thead>
<tr>
<th>Accessibility</th>
<th>Road Travelers</th>
<th>Railway Travelers</th>
<th>Airline Travelers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Car</td>
<td>3.0%</td>
<td>5.4%</td>
<td>24.6%</td>
</tr>
<tr>
<td>Company Cars</td>
<td>3.3%</td>
<td>1.5%</td>
<td>15.1%</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>81.9%</td>
<td>83.2%</td>
<td>95.3%</td>
</tr>
</tbody>
</table>

Source: Authors’ survey results.

Based on the interviews, passengers conduct an average of 8 intercity trips annually. Airline travelers traveled more regularly than others
road travelers took 9 trips per year, and railway travelers made the fewest trips at 5.3 per year. The largest group of interviewees (about 42%) revealed that at the time of the interview, they were traveling for personal reasons. Other reasons for road and railway trips were studying or working, while the main purpose of airline travel (more than 56%) was business.

To evaluate the accessibility of different modes of transport, we primarily considered (i) time and cost for accessing bus stations, rail stations, and airports, and (ii) waiting time at those terminals.

The cost of access to bus stations was the cheapest (about $1.1/trip). The cost of access to railway stations was almost double the cost of access to bus stations (about $2/trip). Meanwhile, the cost of access to airports was much higher (about $9/trip).

The average time to access buses, trains, and airlines was 27 minutes, 32 minutes, and 50 minutes, respectively. Waiting time at a railway station was 47 minutes, more than double the waiting time at a bus station (about 20 minutes). Waiting time at the airport was the longest at an average of 52 minutes.

We used the stated preference methodology to evaluate other quantitative factors influencing the use of various transportation modes. This included travel time, time to get to public transport stops and terminals, willingness to pay, vehicle operating cost, and transport fares for private cars, interprovincial buses, rails (normal and high speed), and airlines. The second part of the questionnaire asked about travelers’ views of the relative importance of the vehicles’ attributes and the quality of transport services.

### 12.3 Results

#### 12.3.1 Role of High-Speed Rail in Viet Nam’s Transport System

From the focus group interviews, some features of HSR stood out as advantages over current modes of transportation.

(i) **Efficient for certain lengths of passenger trips.** HSR will be effective and highly profitable in places where there is a large number of passengers traveling a distance of 300–600 kilometers (km). In areas where HSR passes through, it will greatly reduce the number of road vehicles. For example, if the Ha Noi–Vinh HSR has a speed of 350 km/hour, all passengers on this route going to the center of Ha Noi will be attracted by HSR. As a result, the number of intercity buses
will decrease by 70% and cars on the route will be reduced by at least 50%. Traffic will be safer, more economical, and more environmentally friendly.

HSR will, however, not be able to compete with aviation when the distance is 600 km or more, but is extremely beneficial for bringing passengers within a radius of 100–200 km of the airport. In developed countries, HSR or subway systems always develop along with the aviation industry. HSR is also not suitable for freight transport. With 2,000 km of coast and many rivers, Viet Nam’s waterways are ideal for transporting goods between north and south. Thus, the development of HSR could fundamentally change the transport industry and rationalize the utilization of the different modes of transport.

(ii) **Can reduce the load borne by aviation and roads.** HSR is fast and efficient so riders can save time, energy, and money. HSR is extremely reliable and operates in all weather conditions. HSR is not subject to traffic congestion, so it operates on schedule every day without delay—especially during rush hour and peak travel times.

(iii) **Can facilitate development of satellite cities for Ha Noi and Ho Chi Minh.** HSR technology can be an effective tool for helping the two cities solve population problems and traffic congestion (which lead to more traffic accidents and increased emissions). About 100–200 km from both Ha Noi and Ho Chi Minh, there are many plots of land that could be exploited to form large-scale satellite cities. These satellite cities would be about an hour’s trip away from Ha Noi and Ho Chi Minh via HSR, which would be acceptable to riders.

Viet Nam needs to develop satellite cities using modern infrastructure to meet the needs of its population. Financial services, banking, telecommunications, education, health, culture, and entertainment, together with the most modern technical infrastructure will be needed. HSR is a reasonable solution to promote socioeconomic development for the two central economic capitals, as well as for the economy of the whole country.

(iv) **Can greatly reduce traffic congestion with low effects on the environment.** HSR has the potential for high-density transport along specific corridors. For example, a double-decker E4 Series *shinkansen* (bullet train) can carry 1,634 seated
passengers, which is double the capacity of an Airbus A380 in an all-class passenger arrangement. The *shinkansen* can carry even more if standing passengers are allowed on trains. Therefore, HSR has the potential to reduce traffic congestion and relieve an overburdened transportation system. Well-designed HSR systems in use today are more environmentally friendly than road, marine, and air transport. This is because HSR systems (i) reduce usage of modes of transport that are more harmful to the environment, (ii) consume less fuel per passenger and/or freight per km, and (iii) reduce land use for a given capacity compared to road transport.

12.3.2 Road Users’ Attitudes toward Different Transport Modes

The survey provided evidence on travelers’ attitudes to the different attributes of various modes of transport. Road users’ sensitivity, purpose of their trip, income, gender, and the various attributes of different transport modes were measured. Though respondents had varied feedback regarding these attributes, the survey results provided reliable information that can be used to identify, evaluate, and apply the best initiatives to achieve objectives.

The survey proved travelers’ preference for road transport (including both buses and private cars) over airports and trains. Reasons include (i) flexibility, accessibility, convenience, and relatively low operating cost (e.g., fares in case of buses); (ii) the lack of convenient and comfortable trains; and (iii) expensive and inaccessible airlines.

The survey revealed that the length of time and cost of the trip are usually the most important factors for intercity trips. Respondents’ attitudes differed depending on whether the trip was in urban areas, towns, or cities. The trip distance may also affect travelers’ attitudes or behaviors.

Figure 12.1 shows respondents’ evaluation of each type of transport mode according to travel time, fare, network coverage, service hours, frequency, punctuality, accessibility, convenience of transfers, safety, comfort, security, staff behavior, and conditions of yards and stations. Air transport is rated higher than rail and road in almost every respect. Next is road transport, which is rated higher than rail except for punctuality, safety, comfort, security, and staff behavior. Overall, respondents’ preferences were clearest regarding safety, comfort, and security.
The results indicate that persuading large numbers of people to opt for transit vehicles such as trains, rather than cars, will be more challenging in Viet Nam than in other countries. This result should not be especially surprising. Viet Nam’s railways have been around for centuries, using a single-track system with a small gauge only 1,000 millimeters wide.

Two broad strategies may be employed. One is applying significant pressure on road users to change their travel choices. The other is using a mix of complementary measures drawing on the insights from the abovementioned analysis. This second strategy will require examining the characteristics of the different modes of transport quantitatively and qualitatively.

The results of the survey on the relative importance of the qualitative factors concerning transportation mode choice in intercity trips indicate that:

- In intercity trips, the most important factors influencing transport mode choice differ among the traveler groups (i.e., road, railway, and airline travelers). The reason may be the difference in their willingness to pay, which is a result of income and length of time.
• Road safety and users’ security are considered the most important factors for urban trips but not for intercity trips. However, these factors still have strong impacts on the choice of a particular transportation mode. Road travelers are more worried about road safety than railway and airline travelers are for rail and air travel safety.

• When purchasing and using cars, people consider vehicle safety to be the most important factor. However, many travelers still drive dangerously with such behavior as failing to observe traffic signals, speeding, excessive lane changing, careless passing, and using mobile phones while driving.

• Mode choice for urban trips is heavily influenced by travel conditions, but not for intercity trips. Trip distance and trip purpose are normally the most important factors influencing mode choice for intercity trips.

• Bus and train users are influenced by a range of transportation services. Attributes affecting decisions to select a bus or railway that gained an above average score include travel time, reliability, accessibility, safety, personal comfort and security, convenience, and flexibility.

• Airline travelers are not overly concerned by fares and costs while road and railway travelers consider costs highly important. This finding may seem to be an anomaly given the common negative response to increases in fares.

• For motorcyclists and bus users, the environmental benefits of their respective modes is considered only moderately important. This suggests that encouraging people to change from motorcycle to public transport for environmental reasons might not be very effective.

• People traveling for education and shopping are more concerned with travel costs than are people traveling for other purposes. However, this result may reflect not only the influence of trip purpose but the income effect as well.

• The survey revealed preference for road transport because of flexibility regarding travel location, travel time, household travel arrangements, moderate investment costs, and low vehicle operation costs. Road transport does have factors that make it unattractive. This includes safety issues, and unhealthy and uncomfortable environment, which are especially unpleasant on long trips. Even so, when interviewed, travelers showed little interest in changing transportation modes in the near future. To them, other modes of transport could not
match the positive attributes of cars, and were not sufficiently attractive to overcome the unappealing attributes of road transport.

Along with vehicle ownership, opinions on vehicle usage generally did not substantially differ with other socioeconomic characteristics. The survey also indicated that men and women share similar opinions, as did people of various ages and people coming from households with or without children. The principal variations were between people from low-income households who were more concerned with transport operating cost, and people from high-income households who were concerned with road safety.

12.3.3 Traveler Awareness and Behavior in Selecting High-Speed Trains

The reasons for choosing specific transportation methods are shown in Figure 12.2. Both rail and air users were influenced by similar reasons: safety, comfort, and convenience. Air travelers were influenced by speed (or “fast” travel time) but they also used roads because of convenience and cheap fares.

In the revealed preference interview, many interviewees expressed that they chose public transport for some specific routes. The survey results according to the length of journey are shown in Figure 12.3.

Besides aviation, rail was also a relatively preferred means of travel between Ha Noi and Ho Chi Minh City (in the distance of more than 1,500 km). For rail and road users (in Ha Noi, it is 39% and 63% respectively; in Ho Chi Minh City, it is 23% and 25%, respectively), roads are only suitable for short journeys.
Figure 12.2: Reasons for Different Mode Choice (share of respondents)

### Road Travelers’ Choice

<table>
<thead>
<tr>
<th>Reason</th>
<th>No (%)</th>
<th>Partly (%)</th>
<th>Yes (%)</th>
<th>No answer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel time</td>
<td>13%</td>
<td>64%</td>
<td>18%</td>
<td>5%</td>
</tr>
<tr>
<td>Fare level/VOC</td>
<td>9%</td>
<td>54%</td>
<td>35%</td>
<td>2%</td>
</tr>
<tr>
<td>Convenience</td>
<td>3%</td>
<td>56%</td>
<td>38%</td>
<td>1%</td>
</tr>
<tr>
<td>Safety and security</td>
<td>18%</td>
<td>61%</td>
<td>19%</td>
<td>2%</td>
</tr>
<tr>
<td>Comfort</td>
<td>16%</td>
<td>60%</td>
<td>21%</td>
<td>3%</td>
</tr>
<tr>
<td>No other option</td>
<td>30%</td>
<td>39%</td>
<td>25%</td>
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</table>

### Railway Travelers’ Choice

<table>
<thead>
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<th>No answer (%)</th>
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</thead>
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<tr>
<td>Travel time</td>
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<td>65%</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>Fare level/VOC</td>
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<td></td>
</tr>
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<td>Convenience</td>
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<td>53%</td>
<td>43%</td>
<td></td>
</tr>
<tr>
<td>Safety and security</td>
<td>3%</td>
<td>35%</td>
<td>64%</td>
<td></td>
</tr>
<tr>
<td>Comfort</td>
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<td>48%</td>
<td>49%</td>
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<tr>
<td>No other option</td>
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### Airline Travelers’ Choice

<table>
<thead>
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<td>Fare level/VOC</td>
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<td>Safety and security</td>
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<td>Comfort</td>
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<tr>
<td>No other option</td>
<td>43%</td>
<td>30%</td>
<td>23%</td>
<td>4%</td>
</tr>
</tbody>
</table>

VOC = vehicle operation cost.

Source: Authors’ survey results.
Figure 12.3: Mode Choice in Different Journeys (Real Preference Interview) (share of respondents)

Source: Authors’ survey results.
We also interviewed passengers to investigate their willingness to pay to shorten travel time by 30 minutes, 1 hour, 2 hours, and 3 hours (Table 12.2). Passengers using air routes were willing to pay the most and those using roads were willing to pay the least.

**Table 12.2: Willingness to Pay**

<table>
<thead>
<tr>
<th>Transport Modes</th>
<th>D per hour</th>
<th>$ per Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airline</td>
<td>41.450</td>
<td>1.78</td>
</tr>
<tr>
<td>Road</td>
<td>11.544</td>
<td>0.50</td>
</tr>
<tr>
<td>Railway</td>
<td>31.351</td>
<td>1.35</td>
</tr>
</tbody>
</table>

Source: Authors’ survey results.

We conducted interviews on the selection of modes on specific routes, based on some assumption of future conditions such as travel time and fare level. For ticket price option A, HSR fare level is assumed to be half of airfare. For ticket price B, it is equivalent to the air ticket price. For ticket price C, it is assumed to be 1.5 times higher than the current plane ticket price. Travel time is assumed to be 80 km/hour via road, 110 km/hour via railway, 300 km/hour via HSR, and air travel is same as current levels.

Interview results are shown in Figure 12.4. Passengers prefer air transport in the case of Ticket B on the Ha Noi–Ho Chi Minh City route (1,570 km long), while in the cases of Ticket A and Ticket C, HSR is preferred over air travel.

The stated preference survey also asked customers’ their expectations of HSR’s operation characteristics. As shown in Figure 12.5, safety is the biggest concern, followed by comfort and affordability of fare. In addition, for air passengers, high speed is also a major desired factor from HSR.
Figure 12.4: Passenger Selection of Mode for Specific Routes (share of respondents)

Road Travelers

<table>
<thead>
<tr>
<th>Trip of 1,570 km (option A)</th>
<th>Trip of 1,570 km (option B)</th>
<th>Trip of 1,570 km (option C)</th>
<th>Trip of 1,290 km (option A)</th>
<th>Trip of 1,290 km (option B)</th>
<th>Trip of 1,290 km (option C)</th>
<th>Trip of 870 km (option A)</th>
<th>Trip of 870 km (option B)</th>
<th>Trip of 870 km (option C)</th>
<th>Trip of 370 km (option A)</th>
<th>Trip of 370 km (option B)</th>
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Railway Travelers

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<th>Trip of 1,570 km (option C)</th>
<th>Trip of 1,290 km (option A)</th>
<th>Trip of 1,290 km (option B)</th>
<th>Trip of 1,290 km (option C)</th>
<th>Trip of 870 km (option A)</th>
<th>Trip of 870 km (option B)</th>
<th>Trip of 870 km (option C)</th>
<th>Trip of 370 km (option A)</th>
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Airline Travelers

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<th>Trip of 1,570 km (option A)</th>
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<th>Trip of 1,570 km (option C)</th>
<th>Trip of 1,290 km (option A)</th>
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<th>Trip of 870 km (option C)</th>
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</tr>
</tbody>
</table>

HSR = high-speed rail, km = kilometer.

Source: Authors’ survey results.
Figure 12.5: Expectations for High-Speed Rail Operation
(share of respondents)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Road Travelers</th>
<th>Railway Travelers</th>
<th>Airline Travelers</th>
</tr>
</thead>
<tbody>
<tr>
<td>High speed</td>
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<tr>
<td>Reasonable price</td>
<td>6%</td>
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</tr>
<tr>
<td>Frequency</td>
<td>7%</td>
<td>3%</td>
<td>44%</td>
</tr>
<tr>
<td>Punctuality</td>
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<tr>
<td>Accessibility</td>
<td>6%</td>
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<td>49%</td>
</tr>
<tr>
<td>Traffic safety</td>
<td>2%</td>
<td>4%</td>
<td>35%</td>
</tr>
<tr>
<td>Onboard comfort</td>
<td>0%</td>
<td>8%</td>
<td>59%</td>
</tr>
</tbody>
</table>

Source: Authors’ survey results.
12.4 Conclusion and Recommendations

In the pre-feasibility study report for the HSR project on the north-south axis, Viet Nam’s Ministry of Transport described the country’s topographic characteristics stretching from north to south as one consisting of two cities in broad areas, a narrow middle section, and limited land resources because of the Truong Son mountain range in the west (Ministry of Transport 2013). The remaining coastal strip is very narrow, so it is impossible to develop many road axes instead of longitudinal axes. This suggests favorable conditions for developing HSR as a type of high-volume, high-speed transport that occupies less land.

In addition, looking at Viet Nam’s geographic position, natural conditions, population distribution, and economic development, we see that 85% of the population, which creates 90% of the total domestic product, is concentrated on the two ends of the country but are separated by 1,500 km. Therefore, connecting these two areas with HSR is necessary to ensure the fastest transport and coordination of people between the two major economic hubs.

According to one feasibility study, the construction of HSR could contribute to saving travel time worth about $2 billion for passengers. At the same time, it will reduce travel costs for Viet Nam’s economy by $6.5 billion by 2050. The Ministry of Transport has also said that by 2030, passenger demand in the north-south transport corridor will be 534,000 passengers per day, equivalent to 195 million passengers per year (only for interprovincial trips). The average annual growth rate of passengers in this corridor is 6.59%. Without HSR construction, the total capacity of all modes of transport in the north-south transport corridor (road, air, and sea) by 2030 will be around only 138 million passengers per year. Thus, the demand for passenger transport in the corridor by 2030 will exceed the capacity of the transport types by 57 million passengers per year, equivalent to about 156,000 passengers per day. With superior advantages in capacity and speed, HSR can solve this problem.

Developing HSR in the current context requires a change in awareness. People need to be encouraged to choose different modes of transportation. Understanding attitudes toward different transportation modes as well as people’s awareness and behavior in using cars and private vehicles will help in proposing solutions and policies for traffic management.
References


PART IV

Transport–Urban Development Interactions
The studies included in the previous parts of this edited volume extensively discussed and presented various evidence of the effects of large transport investments in impacting development at the national and regional scales. Extending these discussions, it is also important to understand the effects on urban development through the lens of transit-oriented development (TOD) policies. While many Asian megacities are planning and implementing extensive investment in mass transit networks following the TOD principles, others are reaching an automobile-oriented saturation level and struggling to overcome increasing congestion problems. TOD policies, being a critical pillar of the future regional and urban development plans of Asian megacities, must be carefully considered. Urban development using railways has been an important theme in TOD policy as it can generate benefits for urban transportation, socioeconomic development, and well-being.

Following up on this phenomenon of integrating sustainable transportation development into urban development planning and TOD policies, Part IV presents studies and evidence that illustrate this interaction. A wide range of aspects in relation to TOD planning are covered through various case studies from Asia and the Pacific, providing valuable takeaways for envisaging the high-speed rail (HSR) development in these countries in the future. Six chapters, comprising this fourth part, are refined from the presentations of authors of the called-for papers and invited papers who participated in the ADBI-Chubu University conference (held virtually during 12–16 October 2020).

Chapter 13 by Hanni, Bansal, and Rao identifies the factors that influence ridership and quantifies the enhancement in ridership due to these factors for Pune Metro Line 3. In order to tackle the decline of public transport ridership and the increased traffic congestion in Pune, a network of mass transit systems, including metro rail, with exclusive right-of-way was proposed. This study supports the proposed metro rail

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1 Partly drawn from the deliberations and discussions held at the session titled “Transport and Urban Development Interactions” held on 15 October 2020 during the ADBI-Chubu University Conference (virtual) on Transport Infrastructure Development, Spillover Effects, and Quality of Life. The authors also acknowledge the contributions from the participants of this session.
by identifying key factors to attract the maximum ridership to maintain effectiveness and sustainability. Through surveys of users, the factors with the highest influence on enhancing metro ridership are found to be land-use development and last mile connectivity. Accordingly, the regulation of land-use developments through promoting commercialization, increasing the floor space index around the planned stations, and providing an effective last mile connectivity service are recommended for consideration in the planning and implementation of the metro rail systems.

Chapter 14 by Sato seeks to capture the value of TOD and demonstrate its effects in the case study of the North–South Commuter Extension Project to encourage investment in TOD. The chapter highlights the use of the land value capture mechanism as a possible funding source of TOD development. Using the hedonic approach, the future increased land value raised from railway implementation is estimated to be 1.84 times the railway investment cost. These findings were utilized in policy dialogues to motivate key decision makers to leverage increased land values for further TOD developments and land conversion projects to increase accessibility, which further compounded the positive effects of TOD.

Chapter 15 by Paul and Sen examines the impacts of transportation strategies on community livability in the Kolkata Urban Agglomeration and develops a policy framework for identifying the major components of the livable community based on transportation strategies. Variables related to transportation strategies are drawn from existing literature and narrowed down through confirmatory factor analysis to four factors for the assessment of community livability. From the four factors, standard of neighborhood was dominant in assessing community livability, followed by degree of safety and extent of transportation options. Overall, favorable factors in transport options were some of the key considerations in determining community livability and well-being.

Chapter 16 by Roy, Maji, and Sahu demonstrates a model that integrates study area information, desirable indicators, and existing network-based analysis to identify feasible station locations for HSR planning. Taking the case study of the Mumbai–Ahmedabad HSR corridor, this study uses a geographic information system-based analytical model to quantify the utility of planned stations at four major cities and visually compare them with results of other potential locations across these cities. This model builds on previous studies to go beyond a simple buffer analysis to consider the actual service area of an existing transport network depending on the existing road and transit network, which provides a more realistic analysis of accessibility to improve station location selection.

Chapter 17 by Mia analyzes the effect of transport infrastructure on the livability index of countries. Based on regression over 5 years of a
panel data set from nine Asian countries, the study finds that transport investment has a mixed but largely insignificant effect on overall quality of life. However, transport investment is found to improve the traffic commute index (i.e., better-quality transportation for residents) and enhance the safety of residents while also increasing the pollution index and regressing the health care index. These interactions are important to note in order to be clear on the benefits and drawbacks of investment, particularly in light of the increase in mega-infrastructure projects in developing countries over the last 2 decades.

Chapter 18 by Khan and Gonzalez highlights the challenges and opportunities in the urban transportation sector in Pacific developing member countries and suggests sustainable solutions. Pacific island countries lag behind in transportation infrastructure growth compared to countries in the Caribbean due to geography, poor institutional governance, and lack of investment. Due to a rapid increase in population in urban areas, there is a high dependence on the public transport system, so it is crucial for governments to provide equal accessibility for urban dwellers. The chapter also demonstrates the Sustainable Urban Transport Index by using it to compare the performance of the urban transport systems in Suva, Fiji, and in Port Moresby, Papua New Guinea, and identify specific policy interventions.

HSR station planning must be well integrated with urban development and TOD plans that include urban transport. Japan, for example, has long utilized HSR development for effective land use planning and for boosting the value of land, especially around stations. In a related presentation during the conference, Kudo (2020) demonstrated that the land-use impacts of HSR can be positively captured through proper urban planning. At the same time, the non-fare-box revenue of HSR can be enhanced through real estate development around a newly built station by establishing appropriate urban planning regulations and enhancing public–private partnerships for improving the connectivity of stations and the surrounding area (Takeshima 2020). Further discussions during the virtual session of the conference also highlighted that the impacts of HSR extend beyond the immediate urban area. The discussants opined that HSR can both promote the centralization of activities in bigger urban areas and distribute activities to smaller towns and cities, as both have been observed to some degree. This brings an additional challenging regional dimension for planners and TOD policy makers, who must adapt to the changes in demands and induced demands generated through HSR development. Another consideration raised was, in light of the ongoing pandemic, that urban planners must note the importance of providing open spaces in the implementation of TOD to meet public health standards.
References


13
Factors Influencing the Ridership of a Proposed Metro Rail System

Chetan Kumar Hanni, Mayank Bansal, and K. V. Krishna Rao

13.1 Introduction

Rapid urbanization coupled with economic growth has increased the share of private vehicle transport in most cities across the world. Previously, the share of public transport was significant in urban commuting. Recent modal share for transport in some of the cities in India is shown in Figure 13.1. Delhi, Mumbai, Kolkata, Bangalore, and Chennai have a public transport share of more than 30%, while the remaining cities (Ahmedabad, Pune, Surat, and Vijayawada) have a far smaller public transport share. Before rapid urbanization and high economic growth, public transport share was significant, and buses were the major mode of public transport in these cities where public transport and even the bicycle share has recently declined. The growth of private vehicle transport has become rampant, with urban travel dominated by two-wheelers, and followed by cars. To reduce private vehicle transport and promote public transport, the Ministry of Housing and Urban Affairs, Government of India has advised the planning and implementation of mass rapid transit systems (metro rail) in all cities with populations over 3 million. For less populous cities, the bus rapid transit system (BRTS) and other such modes of public transport have been recommended.

The authors would like to thank Pune IT City Metro Rail Limited for taking up this project in collaboration with the Indian Institute of Technology Bombay. They would also like to express gratitude for the support provided by Pune Metropolitan Region Development Authority, Tata Consultancy Services, Infosys, Savitribai Phule Pune University, and D. Y. Patil College of Engineering, Akurdi, Pune.
Pune is the second largest city (next to Mumbai) in the state of Maharashtra, India. Due to high growth in population and employment, coupled with growth in the automobile industry and of information technology hubs, urban sprawl has developed in Pune in the last two decades. This, accompanied by the rising incomes of people, has resulted in a tremendous growth of private vehicles, mostly two-wheelers, and followed by cars. Figure 13.2 shows that the percentage of private vehicles grows as income level increases. Prior to high growth in the use of private vehicles, the city had a significant public transport share that primarily consisted of buses. However, with the increase in private vehicles, public transport saw reduced demand and an increase in the fuel consumption rate due to traffic congestion. The heterogeneous mix of traffic composition in Pune aggravated the problem of traffic congestion with journey speeds of about 12 to 17 kilometers per hour during peak hours. To balance out the operating costs, Pune’s public transport operator was forced to increase fares and reduce the frequency of operations. Thus, private vehicles became even more attractive, which has led to the decline of public transport. In order to break this vicious cycle of continuous decline in public transport and the private vehicle transport becoming increasingly attractive in Pune, Maharashtra Metro Rail Corporation Limited proposed a network of mass transit systems such as metro rail in 2008. The metro rail systems with an exclusive right-of-way will augment public transport with an affordable, equitable, and sustainable mode of transport, and will thereby reduce traffic congestion.
In order to attract the maximum ridership for the proposed metro rail systems in Pune, we need to identify the various factors influencing ridership. We have conducted this study considering Pune Metro Line 3 (Civil Court to Megapolis Circle) to identify and quantify the influence of those factors that will help in enhancing the metro ridership. This will aid urban planners in taking proactive measures before and after the start of operation of these metro systems to make them effective and sustainable.

13.2 Review of Factors Influencing the Ridership of Mass Transit Systems

For any mass rapid transit system, it is crucial to identify the various factors that influence its ridership. Identifying these factors will enable policymakers to make the required timely decisions both before and after these mass transit systems become operational, to ensure they are effective and sustainable.

Mass transit ridership is generally forecasted based on utility theories. However, various complexities are involved as the perceived utility of transit trips varies from person to person, so we need to investigate the determinants of public transport ridership. Numerous studies have been conducted by various researchers around the world.
We review these studies to identify the factors that affect mass transit ridership. These factors are broadly classified as land-use factors, socioeconomic factors, last mile connectivity and accessibility factors, and mass transit system characteristics.

In order to assess the impact of different factors on mass transit ridership, researchers have used different tools. Sohn and Shim (2010) developed multiple regression models and a structural equation model (SEM) using metro station boardings as a dependent variable in the Seoul metropolitan area. They showed that the factors of employment, office floor area, number of transfers, commercial floor area, net population density, and number of feeder bus lines significantly influenced station boardings. Built environment factors are reported to affect mass transit ridership in various studies. The effect of built-environment factors including street density, land-use mix, and presence of feeder modes on station level ridership of the Madrid metro system was identified by Gutiérrez, Cardozo, and García-Palomares (2011). The built environment factors can be used in different forms; for example, factors of office floor area, shopping centers, and recreational venues near metro stations were reported to be associated with metro ridership in Nanjing, People’s Republic of China, by Zhao et al. (2013). In a similar study carried out by An et al. (2019) in Shanghai, built-environment factors such as shopping centers, hotels, and educational centers near the stations were studied for their effect on metro ridership.

In the Seoul metropolitan area, Choi et al. (2012) found built-environment factors, population-related factors, and employment-related factors accountable for affecting the metro ridership. The authors also claimed that population related factors were more accountable for affecting the ridership of origin stations and employment-related factors prevailed in affecting the ridership of destination stations. Another study conducted by Jun et al. (2015) for the same Seoul metropolitan area finds a positive association of land-use mix diversity, intermodal connectivity, employment, and population densities with subway ridership. In a study conducted by Ingvardson and Nielsen (2018) of 48 European metropolitan areas, it is again found that factors like employment densities were positively associated with public transport ridership. Looking at transport modes other than the metro rail transit system, a study conducted for bus transit in 25 North American cities by Boisjoly et al. (2018) identified the relationship between public transport ridership and the factors of car ownership, average fare, population density, and gasoline prices. In a similar study conducted for bus rapid transit ridership in Australia, Liu, Wang, and Xie (2019) again reported the association between population density, accessibility, and distance to central business district with public transport ridership.
From an extensive literature review of the factors affecting transit ridership, the significant factors identified by numerous studies are summarized in Table 13.1.

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Physical integration with other public transport modes</td>
</tr>
<tr>
<td>2</td>
<td>Operational integration with other public transport modes</td>
</tr>
<tr>
<td>3</td>
<td>Last mile connectivity</td>
</tr>
<tr>
<td>4</td>
<td>Level of service of mass transit</td>
</tr>
<tr>
<td>5</td>
<td>Fare system employed</td>
</tr>
<tr>
<td>6</td>
<td>Station area development</td>
</tr>
<tr>
<td>7</td>
<td>Land use</td>
</tr>
<tr>
<td>8</td>
<td>Walkability index</td>
</tr>
<tr>
<td>9</td>
<td>Vehicle Ownership</td>
</tr>
</tbody>
</table>

As mentioned in Section 13.1, to attract more riders and make metro systems effective and sustainable, the various factors that influence ridership need to be identified and understood. All the factors listed in Table 13.1, except walkability index and vehicle ownership, are considered for analyzing and quantifying their influence on the ridership of Pune Metro Line 3. The following section provides the details of the study area, Pune Metro Line 3, and the methodology used for this study.

**13.3 Study Area and Methodology**

This study considers Pune Metropolitan Region, India, as the study area. It comprises Pune Municipal Corporation, Pimpri–Chinchwad Municipal Corporation, Hinjewadi area, and the abutting areas of the Mumbai–Pune Expressway (from Pune to Lonavala). Pune Municipal Corporation has 144 traffic analysis zones (TAZs), Pimpri–Chinchwad Municipal Corporation has 105, Hinjewadi area has 16, and the remaining study area has 110, totaling 375 internal zones. The population in the study area was about 7.5 million for the year 2020.
Various metro lines have been proposed in the study area. The construction of some of them is almost near completion. The master plan of metro lines proposed in the study area is shown in Figure 13.3. For the present study, the proposed Pune Metro Line 3 with terminals at Civil Court and Megapolis Circle is considered for the analysis of factors influencing its ridership. The construction of this metro line started in 2019, and the line is likely to be operational by 2023. There are 23 metro stations proposed on this line (Figure 13.4).

The methodology adopted for the study has four steps. First, we identify various factors that influence the ridership of metro systems. Second, we collect data through primary surveys (user perception and stated preference surveys) and derive various parameters from the data collected. Third, we digitize the existing land-use data for a circular buffer zone of 800 meters around each of the proposed metro stations of Pune Metro Line 3. Finally, we apply a four-stage travel demand model to quantify the influence of the various factors identified on the ridership of Pune Metro Line 3. The travel demand model was developed by the Indian Institute of Technology Bombay. It has been used previously for estimating the ridership of proposed metro corridors in Pune.

From the data collected through primary surveys, we derive various subjective values of parameters by developing different logit models.
Using these derived parameters as inputs to the four-stage travel demand model and also carrying out the required changes in the highway and public transport network, we obtain the change in ridership of Pune Metro Line 3. The network changes include coding of new feeder bus routes and rerouting of currently operational bus routes to complement the metro rail. For the analysis of the land-use factors, we consider an increased floor space index (FSI) scenario around the proposed metro stations. This scenario is created by redistribution of planning variables (population and employment) in the trip generation step of the travel demand model. Thereafter, the complete travel demand model is applied to obtain the change in ridership. The data set used for obtaining the change in ridership for various factors is discussed in detail in the following section.

13.4 Data Set

The data set can be broadly classified into three groups. The first one is the data obtained from user perception and stated preference (SP) surveys. The second one relates to the four-stage travel demand model considered for this study. The third one is the existing land-use data surrounding the proposed metro stations.
Completely web-based survey forms were created for the user perception and SP surveys using 123formbuilder.com. We conducted pilot surveys initially and then made the required changes in the survey design. The face-to-face surveys were administered by a team of well-trained graduate students in civil engineering using tablet computers. In the user perception survey, initially, residence details, socio-economic characteristics, and current travel characteristics of potential metro users were collected. For collecting travel characteristics, we used an automatic Google powered address search bar that captures the exact start and end location of each trip. Then, we also collected their current trip frequencies and the likely number of additional trips, if the proposed metro stations are developed as commercial complexes. Trip frequencies with respect to shopping and recreation, and in particular restaurant trips, were considered. Questions related to trip frequencies mentioned in the survey are shown in Figure 13.5. A photo depicting the proposed metro station with commercial complexes was shown to the survey respondents for their ease of perception when they were answering the questions shown in Figure 13.5.

<table>
<thead>
<tr>
<th>Figure 13.5: Questions Related to Trip Frequencies for Station Area Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Number of shopping trips per month?</td>
</tr>
<tr>
<td>2. Number of recreational trips per month?</td>
</tr>
<tr>
<td>3. How many of recreational trips are restaurant trips?</td>
</tr>
<tr>
<td>If the proposed metro station houses commercial complexes, then</td>
</tr>
<tr>
<td>1. Number of additional shopping trips per month?</td>
</tr>
<tr>
<td>2. Number of additional recreational trips per month?</td>
</tr>
<tr>
<td>3. Monthly frequency of visit to restaurants with family and friends?</td>
</tr>
</tbody>
</table>

Source: Authors.

For the SP survey, we considered two sets of attributes and levels with respect to the level of service and last mile connectivity factors. The set related to level of service is shown in Table 13.2. The travel time and travel cost values shown to a respondent were calculated based on the travel details provided in the earlier part of the survey form. These values were linked internally so that multiplying factors (0.5 or 1.5) were applied and the resulting values appeared in the SP card.
For last mile connectivity, we considered three types of services: two-wheeler park and ride, bus feeder service, and walkway and walkalator (moving walkway) service. Considering the attributes and levels of travel time, travel cost, waiting time, and all types of last mile connectivity services in one set resulted in a large full factorial design. Even the fractional factorial design yielded too large a number of SP cards for conducting the survey without fatiguing the respondents. To address this problem, utilizing the advantage of having common attributes, the last mile connectivity was dealt in three subsets. In these subsets, the first three attributes and levels are common, while the fourth one varies as shown in Tables 13.3, 13.4, and 13.5. To allow a respondent to visualize the availability of a type of last mile connectivity service, an image depicting that service was shown during the survey.

Table 13.2: Stated Preference Attributes and Levels for Level of Service

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Attributes</th>
<th>Levels</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Travel time</td>
<td>2</td>
<td>0.5, 1.5 times existing</td>
</tr>
<tr>
<td>2</td>
<td>Travel cost</td>
<td>2</td>
<td>0.5, 1.5 times existing</td>
</tr>
<tr>
<td>3</td>
<td>Delay from scheduled time</td>
<td>2</td>
<td>5, 8 minutes</td>
</tr>
<tr>
<td>4</td>
<td>Comfort and crowding inside the metro</td>
<td>3</td>
<td>AC sitting, AC standing, AC standing in crowd</td>
</tr>
<tr>
<td>5</td>
<td>Wi-Fi availability inside the metro</td>
<td>2</td>
<td>Yes/No</td>
</tr>
</tbody>
</table>

AC = air conditioning.
Source: Authors.

Table 13.3: Stated Preference Attributes and Levels for Last Mile Connectivity (Two-Wheeler Park and Ride Availability)

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Attributes</th>
<th>Levels</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Travel time</td>
<td>2</td>
<td>0.5, 1.5 times existing</td>
</tr>
<tr>
<td>2</td>
<td>Travel cost</td>
<td>2</td>
<td>0.5, 1.5 times existing</td>
</tr>
<tr>
<td>3</td>
<td>Waiting time</td>
<td>2</td>
<td>High (15 minutes), Low (8 minutes)</td>
</tr>
<tr>
<td>4</td>
<td>Two-wheeler park and ride availability</td>
<td>2</td>
<td>Yes/No</td>
</tr>
</tbody>
</table>

Source: Authors.
### Table 13.4: Stated Preference Attributes and Levels for Last Mile Connectivity (Bus Feeder Service Availability)

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Attributes</th>
<th>Levels</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Travel time</td>
<td>2</td>
<td>0.5, 1.5 times existing</td>
</tr>
<tr>
<td>2</td>
<td>Travel cost</td>
<td>2</td>
<td>0.5, 1.5 times existing</td>
</tr>
<tr>
<td>3</td>
<td>Waiting time</td>
<td>2</td>
<td>High (15 minutes), Low (8 minutes)</td>
</tr>
<tr>
<td>4</td>
<td>Bus feeder service availability</td>
<td>2</td>
<td>Yes/No</td>
</tr>
</tbody>
</table>

Source: Authors.

### Table 13.5: Stated Preference Attributes and Levels for Last Mile Connectivity (Walkway and Walkalator Availability)

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Attributes</th>
<th>Levels</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Travel time</td>
<td>2</td>
<td>0.5, 1.5 times existing</td>
</tr>
<tr>
<td>2</td>
<td>Travel cost</td>
<td>2</td>
<td>0.5, 1.5 times existing</td>
</tr>
<tr>
<td>3</td>
<td>Waiting time</td>
<td>2</td>
<td>High (15 minutes), Low (8 minutes)</td>
</tr>
<tr>
<td>4</td>
<td>Walkway and walkalator availability</td>
<td>2</td>
<td>Yes/No</td>
</tr>
</tbody>
</table>

Source: Authors.

A typical SP card shown to a respondent contained two hypothetical metro systems with the difference in characteristics generated using the attributes and levels discussed previously. Two typical SP cards, one related to the level of service and the other related to last mile connectivity, are shown in Figures 13.6 and 13.7.

Each respondent was shown two sets of SP cards: one related to the level of service and the other containing any one type of last mile connectivity option. The survey was designed to facilitate a balance in the number of samples with respect to different types of last mile connectivity options.

As mentioned earlier, along with the survey data collected, a four-stage travel demand model was used for finding out the influence of various factors on the ridership of Pune Metro Line 3. The model developed by the Indian Institute of Technology Bombay and used for ridership estimates of proposed Pune metro corridors comprises a number of calibrated parameters. These parameters that were used at different stages of the model are shown in Figure 13.8.
### Figure 13.6: Typical Stated Preference Card with Respect to Level of Service Factors

<table>
<thead>
<tr>
<th>Metro System 1</th>
<th>Metro System 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel time</td>
<td>15 minutes</td>
</tr>
<tr>
<td>Travel cost</td>
<td>₹30</td>
</tr>
<tr>
<td>Delay from scheduled time</td>
<td>8 minutes</td>
</tr>
<tr>
<td>Comfort and crowding inside the metro</td>
<td>AC sitting</td>
</tr>
<tr>
<td>Wi-Fi availability inside the metro</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Please indicate your preference**

<table>
<thead>
<tr>
<th>Definitely</th>
<th>Maybe</th>
<th>Can't say</th>
<th>Definitely</th>
<th>Maybe</th>
<th>Definitively</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metro System 1</td>
<td></td>
<td></td>
<td>Metro System 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Metro System 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AC = air conditioning.
Source: Authors.

---

### Figure 13.7: Typical Stated Preference Card with Respect to Last Mile Connectivity Factor

<table>
<thead>
<tr>
<th>Metro System 1</th>
<th>Metro System 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel time</td>
<td>15 minutes</td>
</tr>
<tr>
<td>Travel cost</td>
<td>₹30</td>
</tr>
<tr>
<td>Waiting time</td>
<td>15 minutes</td>
</tr>
<tr>
<td>Bus feeder service availability</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Please indicate your preference**

<table>
<thead>
<tr>
<th>Definitely</th>
<th>Maybe</th>
<th>Can't say</th>
<th>Definitely</th>
<th>Maybe</th>
<th>Definitively</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metro System 1</td>
<td></td>
<td></td>
<td>Metro System 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Metro System 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Authors.
### Figure 13.8: Calibrated Parameters of Four-Stage Travel Demand Model

<table>
<thead>
<tr>
<th>Income Group</th>
<th>Trip Generation</th>
<th>Trip Attractions</th>
<th>$\alpha$</th>
<th>$\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car owning group</td>
<td>0.72 * POP</td>
<td>1.45<em>EMP + 0.12</em>STEN</td>
<td>-2.09557</td>
<td>-0.0001819</td>
</tr>
<tr>
<td>Two-wheeler owning group</td>
<td></td>
<td>1.28<em>EMP + 0.1</em>STEN</td>
<td>-1.07986</td>
<td>-0.0236587</td>
</tr>
<tr>
<td>No vehicle owning group</td>
<td></td>
<td>1.18*EMP</td>
<td>-0.897392</td>
<td>-0.0255572</td>
</tr>
</tbody>
</table>

EMP = employment of a zone, POP = population of a zone, STEN = student enrollment of a zone.

### Modal Split (Utility Equations)

#### For Pune Metropolitan Region
- Car owning group
  - $U_{car} = -0.2754*TT - 0.04918*TC + 0.2327$
  - $U_{2W} = -0.2754*TT - 0.04918*TC - 1.2181$
  - $U_{PT} = -0.2754*TT - 0.04918*TC - 0.1102*AT$

#### For Hinjewadi area
- Car owning group
  - $U_{car} = -0.10887*TT - 0.07258*TC + 1$
  - $U_{2W} = -0.10887*TT - 0.07258*TC - 2.733$
  - $U_{PT} = -0.10887*TT - 0.07258*TC - 0.05039*WT - 0.008715*AT$

- Two-wheeler owning group
  - $U_{2W} = -0.2255*TT - 0.1574*TC - 3.111$
  - $U_{PT} = -0.2255*TT - 0.1574*TC - 0.0770*WT - 0.1214*AT$

AT = access time, TC = travel cost, TT = travel time, WT = waiting time.

### Trip Assignment

<table>
<thead>
<tr>
<th></th>
<th>Public Transport</th>
<th>Two-Wheeler</th>
<th>Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of time (₹/hour)</td>
<td>54</td>
<td>68</td>
<td>218</td>
</tr>
</tbody>
</table>

Existing land-use data was needed to calculate the current floor space index (FSI) and examine the scenario of an increased FSI around the proposed metro stations. The relevant land-use data was digitized using online resources (Google Maps, Google Earth) and the open source QGIS software. It contained information on the height of buildings and the land-use type (residential, commercial, educational, recreational) of the built-up area. The mix of land uses within a building is also captured in this data. A ground verification exercise was carried out to validate the digitized data.

With the data set discussed above, the analysis to quantify the influence of various factors on the ridership of Pune Metro Line 3 was carried out. A detailed discussion of this analysis is provided in the following section.

13.5 Analysis, Results, and Discussion

The following five sub-sections provide the results and discussion on the analysis carried out. First, exploratory analysis of the data collected is provided. Second, the analysis of user responses for station area development is discussed. Then, the analysis and results related to the influence of last mile connectivity (including multimodal integration and level of service) and land-use on the ridership of Pune Metro Line 3 are provided. Last, the summary of percentage change in ridership with respect to various influencing factors is discussed.

13.5.1 Exploratory Analysis of Survey Data Collected

Survey data was collected from 1,197 individuals who were identified as potential metro users of Pune Metro Line 3 based on their work locations. The mode choice, age, and income distributions of the data collected are shown in Figure 13.9.

As shown in Figure 13.9, two-wheelers have the highest mode share (35%), followed by buses (including company buses) (31%). The survey data contains the highest proportion of individuals in the age group 18–25 years (47.9%), followed by the age group 25–35 years (41.2%). The average monthly income of the individuals from the data collected is ₹46,282.
13.5.2 Station Area Development

As is evident from the review of factors influencing mass transit ridership, the development of station areas as commercial and recreational complexes can increase the ridership of metro systems. To assess the impact of this factor, trip behavior of individuals with and without station area development was obtained from user perception surveys (Figure 13.10). However, even though station area development is identified as a separate factor influencing ridership, it is actually a
land-use factor. The influence of station area development on commuter trips is shown in Figure 13.10. The responses of potential metro users show that the number of trips (shopping and recreational) is likely to doubled with station area development, as compared to the scenario without.

13.5.3 Last Mile Connectivity

The influence of last mile connectivity on the ridership of the proposed Pune Metro Line 3 was analyzed with respect to three types of trip access and egress services: two-wheeler park and ride, bus feeder service, and walkway and walkalator service. The related user responses obtained from the SP survey were used to develop different binary logit models. The subjective values of the parameters derived from these logit models (shown in Table 13.6) were used in the travel demand model and the percentage change in ridership was estimated. In addition to using the parameters shown in Table 13.6, the changes required in highway and public transport network of the model were carried out. This included rerouting of currently operational bus routes to complement the metro rail, merging of existing bus stops with proposed metro stations if they are
nearby, and coding of various feeder service routes after the identification of trip production and trip attraction hotspots. The hotspots are those TAZs falling within a circular buffer zone of 5 kilometers around the proposed metro stations and having a high number of trips from and to the metro station zones (an origin-destination matrix was used to identify the higher trip numbers). Also, the walkway and walkalator services were considered by coding direct links and connectors from some of the proposed metro stations to the nearby high employment centers in the travel demand model. For instance, at one of the proposed metro stations located in front of information technology giant Infosys in Hinjewadi area, a direct link between the metro station and the office location was coded in the network. The network changes and the derived subjective values of parameters discussed above were also used to assess the influence of physical and operational integration (referred to as multimodal integration) and the level of service factors.

An increase in ridership of 11% was estimated for integration with other public transit modes. An increase in ridership of 5%, 9%, and 4% was obtained for the last mile connectivity services through two-wheeler park and ride, bus feeder, and walkway and walkalator, respectively. Availability of bus feeder services at the proposed metro stations had the highest influence on the ridership among the three last mile connectivity options for Pune Metro Line 3. Lastly, a 5.92% increase in ridership was obtained for the level of service factor.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Subjective Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of Travel Time (₹/hour)</td>
<td>152.66</td>
</tr>
<tr>
<td>Value of Waiting Time (₹/hour)</td>
<td>410.12</td>
</tr>
<tr>
<td>Value of Delay (₹/hour)</td>
<td>485.91</td>
</tr>
<tr>
<td>Value of Comfort (₹/level)</td>
<td>71.37</td>
</tr>
<tr>
<td>Value of Feeder Service Availability (₹)</td>
<td>49.30</td>
</tr>
<tr>
<td>Value of Park and Ride Availability (₹)</td>
<td>95.33</td>
</tr>
<tr>
<td>Value of Walkway and Walkalator Availability (₹)</td>
<td>48.55</td>
</tr>
<tr>
<td>Value of Wi-Fi Availability (₹)</td>
<td>5.58</td>
</tr>
</tbody>
</table>

*1 = ₹75.
Source: Authors.
13.5.4 Land Use

According to the latest Metro Rail Policy (Ministry of Housing and Urban Affairs 2017) of the Government of India, commercial development at metro stations is a key instrument in maximizing revenues. Also, it is mandatory that all the metro project proposals follow the transit-oriented development policy. With this background, the influence of the land-use factors on the metro ridership was examined. A circular buffer zone of 800 meters around all the proposed metro stations was considered for this analysis (Figure 13.11).

The existing FSI values in the buffer zone of each of the proposed metro stations were calculated using the digitized built-up area. The built-up area considered within 800-meter circular buffer zones of proposed metro stations is shown in Figure 13.12.
Then, we examined the change in metro ridership if the FSI was increased to 4. The planning variables (population and employment) were redistributed (keeping the totals unchanged) for all TAZs considered for the study area in such a way that the FSI value in each station buffer was increased to 4 (2 residential and 2 commercial). The four-stage travel demand model was then rerun to obtain the change in metro ridership. An increase of 22.36% in the metro ridership was observed. It is thus understood that long-term land-use planning, land-use type and mix, and land-use intensity around the proposed metro stations will have a large influence on the metro ridership.

13.5.5 Summary

Table 13.7 summarizes the percentage increase in metro ridership with respect to the various influencing factors considered in this study.

From Table 13.7, we can say that the provision of last mile connectivity including multimodal integration (combined influence of the first four factors in the table) accounted for an estimated increase in ridership of nearly 30%. The regulation of land-use developments was estimated
Factors Influencing the Ridership of a Proposed Metro Rail System

13.6 Conclusion

A number of factors that influence the ridership of a public mass transit system, which were identified through an extensive review of related works, were considered in this study. Among the various factors considered, land-use and last mile connectivity including multimodal integration were found to have the highest influence on enhancing the metro ridership. The land-use factors, i.e., long term land-use, land-use type and mix, and land-use intensity, were examined by considering an FSI value of 4 (2 commercial and 2 residential) for an 800-meter buffer zone around the proposed metro stations. They were observed to boost metro ridership by 22.36%. Providing last mile connectivity by a two-wheeler park and ride, bus feeder service, or a walkway and walkalator service, and including multimodal integration was estimated to enhance ridership by more than 20%. The improvement in the level of the service factor with respect to comfort of travel and Wi-Fi availability was estimated to increase ridership by 5.92%. This is relatively less since the metro rail systems inherently operate at a better level of service than other modes of public transport.

Table 13.7: Impact of Influencing Factors on Metro Ridership

<table>
<thead>
<tr>
<th>Number</th>
<th>Factor</th>
<th>Percentage Increase in Metro Ridership</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Multimodal integration</td>
<td>11.00%</td>
</tr>
<tr>
<td>2.</td>
<td>Two-wheeler park and ride service availability</td>
<td>5.00%</td>
</tr>
<tr>
<td>3.</td>
<td>Bus feeder service availability</td>
<td>9.00%</td>
</tr>
<tr>
<td>4.</td>
<td>Walkway and walkalator service availability</td>
<td>4.00%</td>
</tr>
<tr>
<td>5.</td>
<td>Level of service</td>
<td>5.92%</td>
</tr>
<tr>
<td>6.</td>
<td>Long term land-use, land-use type and mix, and land-use intensity</td>
<td>22.36%</td>
</tr>
</tbody>
</table>

Source: Authors.
The study clearly shows that the regulation of land-use developments by promoting commercialization and increasing the FSI around the metro stations, and the provision of an effective and efficient last mile connectivity service including multimodal integration, will promote the public mass transit systems (metro rail) to the best possible extent. Consideration of these factors by urban planners while planning and implementing metro rail systems will surely help in attracting the maximum ridership and thereby maximizing the revenues. Further, it will fuel growth toward a sustainable urban transport system focused on moving people rather than moving vehicles between different urban places.
References


Pune Metropolitan Region Development Authority. 2018. Projects (Metro).


14

Land Value Capture for Transit-Oriented Development in the North-South Commuter Railway Extension Project in the Philippines

Akihiro Sato

14.1 Introduction

Transit-oriented development (TOD) for rail in the Philippines has not progressed to a level close to that of cities such as Hong Kong, China; and countries like Singapore and Japan, where the concept of TOD has successfully been adopted for station area development. Enhanced accessibility and land use change in areas around the stations should follow railway development. Both national and local governments understand the necessity of TOD to some extent, its effects are not so visible to decision makers and the effort it requires, especially the financing gap for implementing TOD support infrastructures, are challenging. Moreover, past TOD initiatives for rail led by the governments have not fully materialized or have turned out to be complete misfires.

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1 Research for this chapter was done in 2018 as a part of a project named the Detailed Design Study (Including Supplementary Feasibility Study) of the Malolos – Clark Railway Project and the North South Railway Project – South Line (Commuter). That project was funded by grant assistance provided to the Department of Transportation (DOTr) of the Republic of the Philippines by the Japan International Cooperation Agency (JICA). As the leader of that study team, I am deeply indebted to the efforts of contributors such as officers of the DOTr, of JICA, and of other members of the team.
To tackle the challenges of TOD in the Philippines, we estimated the future total land value increase brought about by the operation of a railway in a feasibility study funded by the Japan International Cooperation Agency (JICA) for the North–South Commuter Railway Extension (NSCR-EX) Project. With our estimation of the total future land value increase caused by the project, we aimed to show the effects of railway development as part of the effects of TOD for rail in an intuitive way. We expected that, knowing the effects of TOD, stakeholders would be motivated to invest more in TOD in order to maximize the benefits from the rail. Our estimation also illustrated the viability of financing TOD support infrastructures through revenue from increased land value resulting from the railway implementation.

The estimated amount was ₱1,156 billion (approximately $24 billion), which is 1.84 times the railway investment cost. This chapter explains how this amount was estimated. We begin by explaining the NSCR-EX Project briefly. Second, we discuss the overall methodology used for the study. Next, we describe the data sampling. Then, we explain the estimation of the hedonic price function. Last, we explain how the future increased land value was computed using estimated land prices induced by the hedonic price functions.

For the purposes of this chapter, TOD will be used to refer to railway development as well as developments or improvements in the areas around stations.

14.2 Project Summary of the North–South Commuter Railway Extension

In 2017, the Government of the Philippines received grant assistance from Japan to conduct a feasibility study of the NSCR-EX Project, which aimed to provide a commuter and intercity railway service connecting Metro Manila to its adjacent northern and southern suburban areas. The Clark–Calamba Railway was deemed an important mass transit backbone for the metropolis as well as for the growth corridor of the Greater Capital Region, which comprises the three broader administrative regions of Region III, Metro Manila, and Region IV-A. The National Economic and Development Authority Board approved the project on 15 November 2018. The outline of the NSCR-EX Project is shown below.

---

1 ₱1 = $0.021.
(i) Executing Agency: Department of Transportation (DOTr) and Philippine National Railways (PNR)

(ii) Subcomponents:
• NSCR Clark Extension (hereinafter referred to as “N2”)
• NSCR Calamba Extension (hereinafter referred to as “SC”)

(iii) Project Description (N2):
• 53 kilometers (km) connecting Malolos and Clark
• Contract for civil works signed in August 2020
• Will reduce travel time from Buendia (Metro Manila) to Clark from 2 hours (by car) to 55 minutes
• Will feature country’s first airport railway express
• Will include 6 stations

(iv) Project Description (SC):
• Ongoing procurement of civil works packages
• 56 km to run from Solis, Manila to Calamba, Laguna
• Will reduce travel time from Manila to Calamba from 3 hours to 1 hour
• Will include 19 stations

14.3 Methodology

We used the hedonic method to estimate the total future increased land value. The basic steps are as follows:

(i) Hedonic functions are estimated using cross-sectional data of land prices and local amenities, including generalized costs, assuming that all local amenities are exogenous for agents. Residential land prices and commercial land prices are estimated separately.

(ii) The generalized cost to the central station decreases after the NSCR-EX Project is implemented.

(iii) Substituting the decrease in the generalized cost into the hedonic functions, land price changes are estimated for each station. Then, the total land value increase in the affected area of the NSCR-EX Project is computed.

Figure 14.1 shows an analytical diagram of the study. First, we captured the relationship between land prices and the generalized commuting cost from each location to the central station, estimating hedonic functions with cross-sectional data. Next, we analyzed how land prices increased with improvements in the generalized commuting cost due to the NSCR-EX Project. Our target was to estimate the increase in the total land values of the affected areas, not for each location. The data at each location is represented by a dot in Figure 14.1.
14.4 Data Sampling

The hedonic approach requires the market price data of the commodity that we are interested in. In this case, we needed data on market land prices in the subject area. We used the land price data surveyed in the NSCR-EX Project by a local appraisal company, since there was no appropriate property market database that covered the whole subject area. Both the national and local government have assessed value of lands for taxation purposes, but we did not use that data because it is not regularly updated in some areas, and there may be political bias that could result in big gaps between the value assessed by a tax assessor and the actual market values.

14.4.1 Sampling Points

We employed stratified random sampling in this survey. The subject area was divided into 7 regions. The sampling regions were as follows:

A = Railway stations inside Metro Manila: Light rail transit-1 and -2 and mass rapid transit-3 stations
B = Railway stations outside Metro Manila: PNR stations
C = Planned railway stations: NSCR-EX stations
D = No railway station area inside Metro Manila
E = No railway station area from Malolos to Epifanio de los Santos Avenue (EDSA)
F = No railway station area from Tutuban to Clark International Airport
G = No railway station area from north to south along major commuter roads

The total number of sample locations or areas of interest (AOIs) for the whole survey area was 145. In each AOI, a specific number of residential and commercial areas was randomly selected. Regions A, B, and C required 5 residential and 5 commercial sample areas while regions D, E, F, and G required 3 samples of combined residential and commercial areas. This brought the total number of target sample points to 806. Table 14.1 shows the sample distribution per region.

<table>
<thead>
<tr>
<th>Represented Sampling Region</th>
<th>No. of Sample Locations or AOIs</th>
<th>Description of Samples</th>
<th>Total No. of Samples per Location or AOI</th>
<th>Total No. of Random Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>18</td>
<td>5 residential and 5 commercial</td>
<td>10</td>
<td>180</td>
</tr>
<tr>
<td>B</td>
<td>26</td>
<td>5 residential and 5 commercial</td>
<td>10</td>
<td>260</td>
</tr>
<tr>
<td>C</td>
<td>9</td>
<td>5 residential and 5 commercial</td>
<td>10</td>
<td>90</td>
</tr>
<tr>
<td>D</td>
<td>32</td>
<td>3 residential and commercial</td>
<td>3</td>
<td>96</td>
</tr>
<tr>
<td>E</td>
<td>20</td>
<td>3 residential and commercial</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>F</td>
<td>20</td>
<td>3 residential and commercial</td>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>G</td>
<td>20</td>
<td>3 residential and commercial</td>
<td>3</td>
<td>60</td>
</tr>
</tbody>
</table>

Total Random Samples = 806

AOI = area of interest.
Source: Japan International Cooperation Agency Design Team for North–South Commuter Railway Extension Project.
14.4.2 Gathered Data Items (Variables)

The variables of the hedonic approach depend on the land that we are interested in. There was no common set of explanatory variables to explain the lands in the subject area. Therefore, the variables (or local amenities) that may contribute to determining the land price were listed and gathered for each sampling point. Those local amenities were obtained not only from existing data sources but also from observations made by visiting the land in person. All the data were used for estimating the hedonic functions. Table 14.2 describes the database items.

### Table 14.2: Description of Database Items (or Amenities)

<table>
<thead>
<tr>
<th>No.</th>
<th>Item (Variable)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sample points ID</td>
<td>Unique sample point ID assigned</td>
</tr>
<tr>
<td>2</td>
<td>Latitude</td>
<td>Latitude of point (in decimal degrees)</td>
</tr>
<tr>
<td>3</td>
<td>Longitude</td>
<td>Longitude of point (in decimal degrees)</td>
</tr>
<tr>
<td>4</td>
<td>AOI</td>
<td>Area of interest based on the sampling guidelines</td>
</tr>
<tr>
<td>5</td>
<td>AOI_2</td>
<td>Specific AOI buffer area</td>
</tr>
<tr>
<td>6</td>
<td>Elevation</td>
<td>Elevation of point (in m above mean sea level)</td>
</tr>
<tr>
<td>7</td>
<td>Province</td>
<td>Province</td>
</tr>
<tr>
<td>8</td>
<td>City/Municipality</td>
<td>City/Municipality</td>
</tr>
<tr>
<td>9</td>
<td>Barangay</td>
<td>Barangay</td>
</tr>
<tr>
<td>10</td>
<td>Street</td>
<td>Street</td>
</tr>
<tr>
<td>11</td>
<td>Address</td>
<td>Address</td>
</tr>
<tr>
<td>12</td>
<td>Region</td>
<td>IMM or OMM</td>
</tr>
<tr>
<td>13</td>
<td>Category</td>
<td>NRP or ORP</td>
</tr>
<tr>
<td>14</td>
<td>Nearest railway station</td>
<td>Nearest railway station</td>
</tr>
<tr>
<td>15</td>
<td>Land use</td>
<td>Existing land use of the point</td>
</tr>
<tr>
<td>16</td>
<td>Land price</td>
<td>Land price per m²</td>
</tr>
<tr>
<td>17</td>
<td>YEAR</td>
<td>Year of land price</td>
</tr>
<tr>
<td>18</td>
<td>Land price S</td>
<td>Land price at time S</td>
</tr>
<tr>
<td>19</td>
<td>Time S</td>
<td>Year in which railway station is completed</td>
</tr>
<tr>
<td>20</td>
<td>FAR...S</td>
<td>FAR at time S</td>
</tr>
<tr>
<td>21</td>
<td>FAR...PRESENT</td>
<td>FAR at present</td>
</tr>
<tr>
<td>22</td>
<td>DIST...1</td>
<td>Distance of sample point to the nearest station (straight-line distance in km)</td>
</tr>
</tbody>
</table>

*continued on next page*
### Table 14.2  
*continued*

<table>
<thead>
<tr>
<th>No.</th>
<th>Item (Variable)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>DIST_2</td>
<td>Distance of nearest station to the central station (straight-line distance in km). If the sample point is outside a 2-km radius of existing stations or if the sample point whose nearest railway station is a proposed NSCR-EX or NSCR station, then the distance measured is from the sample point to the central (Ayala) station.</td>
</tr>
<tr>
<td>24</td>
<td>TIME_1</td>
<td>Average time (peak and off-peak) required to travel by train from the nearest station to central station (in minutes).</td>
</tr>
<tr>
<td>25</td>
<td>TIME_2</td>
<td>Average time (peak and off-peak) required to travel using general transportation from the nearest station to central station (in minutes).</td>
</tr>
<tr>
<td>26</td>
<td>WATER_SUPPLY</td>
<td>High: continuous supply of water from faucet with pressure that can push an extended hand. Medium: continuous supply of water with weak pressure. Low: intermittent supply of water with weak pressure.</td>
</tr>
<tr>
<td>27</td>
<td>TELEPHONE</td>
<td>High: strong signal with full bar indicator producing continuous clear and crisp voice volume accessible anytime. Medium: below full signal bar indicator with interference producing interrupted voice volume. Low: choppy signal and unreliable service.</td>
</tr>
<tr>
<td>28</td>
<td>SEWAGE</td>
<td>High is connection to a system of sewer pipes (sewers) with a sewage treatment plant. Medium is connection to septic tanks. Low is connection to damaged septic tanks or simply absence of septic tank.</td>
</tr>
<tr>
<td>29</td>
<td>POWER</td>
<td>High: no power interruption or brownouts in a week. Medium: few (up to 3) interruptions or brownouts in a week. Low: many brownouts in a week, no electricity provider, or localized (e.g., home solar panels).</td>
</tr>
<tr>
<td>30</td>
<td>GARBAGE</td>
<td>High: regular (4 or more times a week) garbage collection and no visible trash in the streets. Medium: 2 to 3 garbage collections in a week, resulting in some piles of trash in the streets. Low: once or irregular garbage collection resulting in piles and scattered garbage in the area.</td>
</tr>
<tr>
<td>31</td>
<td>CABLE_TV</td>
<td>High: the presence of multiple cable providers and many channel options. Medium: one cable provider or monopoly of service. Low: the absence of cable provider or use of personal equipment (e.g., satellite dish).</td>
</tr>
<tr>
<td>32</td>
<td>INTERNET</td>
<td>High: presence of fiber optic service with around 20+ megabits per second (Mbps). Medium: around 5 Mbps. Low: 2 Mbps or less. Field surveyor can ask whether there is fiber service for home or café to determine speed.</td>
</tr>
</tbody>
</table>
Table 14.2  
continued

<table>
<thead>
<tr>
<th>No.</th>
<th>Item (Variable)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>PUB_MARKET</td>
<td>Distance from the midpoint of the property’s road frontage to the nearest public market (straight-line distance in km).</td>
</tr>
<tr>
<td>34</td>
<td>MALL</td>
<td>Distance from the midpoint of the property’s road frontage to the nearest shopping mall (straight-line distance in km).</td>
</tr>
<tr>
<td>35</td>
<td>HOSPITAL</td>
<td>Distance from the midpoint of the property’s road frontage to the nearest hospital (straight-line distance in km).</td>
</tr>
<tr>
<td>36</td>
<td>SCHOOLS</td>
<td>Distance from the midpoint of the property’s road frontage to the nearest school (straight-line distance in km).</td>
</tr>
<tr>
<td>37</td>
<td>POLICE</td>
<td>Distance from the midpoint of the property’s road frontage to the nearest police station (straight-line distance in km).</td>
</tr>
<tr>
<td>38</td>
<td>GOVT_CTR</td>
<td>Distance from the midpoint of the property’s road frontage to the nearest government center (straight-line distance in km).</td>
</tr>
<tr>
<td>39</td>
<td>NBRHD</td>
<td>Informal if there are informal houses within the vicinity of the property. Otherwise, it is a formal neighborhood.</td>
</tr>
<tr>
<td>40</td>
<td>ISF_DIST</td>
<td>Adjacent: informal settler family is immediately beside the property. Near: informal settler family is within walking distance (up to 300 m away). Far: informal settler family is more than 300 m away.</td>
</tr>
<tr>
<td>41</td>
<td>ISF_No</td>
<td>Few: less than 10 families. Many: 10 or more families.</td>
</tr>
<tr>
<td>42</td>
<td>CRIME_RATE</td>
<td>Low: 1 or almost no crimes per month. Medium: crime is reported more than once a month. High: crime is reported at least once a week or 4 times a month. Generated from interviews of barangay officials.</td>
</tr>
<tr>
<td>43</td>
<td>ACDNT_RATE</td>
<td>Low: 1 or almost no accidents per month. Medium: accidents are reported more than once a month. High: accidents are reported at least once a week or 4 times a month. Generated from interviews of barangay officials.</td>
</tr>
<tr>
<td>44</td>
<td>ROADWIDTH</td>
<td>Measured or estimated in m.</td>
</tr>
<tr>
<td>45</td>
<td>ROCON</td>
<td>Road condition based on the quality of the surface and shoulder. Excellent: cement with well-defined shoulders and looks new. Good: cement or asphalt without defined shoulders and looks old. Damaged: unpaved surface or paved with multiple potholes.</td>
</tr>
</tbody>
</table>

continued on next page
Table 14.2 continued

<table>
<thead>
<tr>
<th>No.</th>
<th>Item (Variable)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>RD_ESMNT</td>
<td>Road easement based on quality and width. Excellent: cement surface, at least 2-m width, and looks new. Good: paved sidewalk with 2-m or less width and looks old but useful. Damaged: nonexistent sidewalk with multiple potholes or not useful to pedestrians.</td>
</tr>
<tr>
<td>47</td>
<td>CORNER_EFF</td>
<td>Yes: located at corner or road intersection. No: not located at corner or road intersection but between corners.</td>
</tr>
<tr>
<td>48</td>
<td>RISK</td>
<td>High, medium, and low depending on the multi-hazard maps in which flood, landslide, and earthquake data are considered,</td>
</tr>
</tbody>
</table>

AOI = area of interest, FAR = floor-area ratio, IMM = inside Metro Manila, km = kilometer, m = meter, NRP = near railway project, NSCR = North–South Commuter Railway, NSCR-EX = North–South Commuter Railway Extension Project, OMM = outside Metro Manila, ORP = outside railway project.

Source: Japan International Cooperation Agency Design Team for North–South Commuter Railway Extension Project.

14.4.3 Estimation of Hedonic Function

Hedonic functions were estimated using cross-sectional data of land prices and local amenities, including generalized costs, assuming that all local amenities are exogenous for agents. Residential land prices and commercial land prices were estimated separately.

Setting Generalized Commuting Cost

Generalized commuting costs ($Gcost$) were calculated as follows. Two modes were assumed: train and road transport such as buses and cars. We assumed that households use trains when their nearest railway station is a station of Light Rail Transit Line 1, Light Rail Transit Line 2, or Metro Rail Transit Line 3. Regarding the current PNR stations, $Gcost$ was compared between the two modes and the smaller mode was chosen. The central station was defined to be Ayala station.

\[
Gcost_{\text{train}} = VoT \times (\text{TIME} + \text{WaitT}) + \text{Fare}_{\text{train}},
\]

\[
Gcost_{\text{road}} = VoT \times \text{TIME} + \text{Fare}_{\text{road}}
\]

in which

\[
\text{WaitT} = \text{TransferT} \cdot EDSA + \text{IntervalT} / 3
\]

and

\[
\text{Fare}_{gm} = \text{DIST} \cdot 2 \times \frac{1}{CR_{fuel}} \times P_{fuel} \times \alpha,
\]
where

\( TIME_1 \) = average time required to travel by train from the nearest station to the central station (in minutes),

\( WaitT \) = how long a train user waits during the whole trip (in minutes),

\( TIME_2 \) = average time required to travel by road transportation mode from the nearest station to the central station (in minutes),

\( DIST_{-2} \) = distance from the nearest station to the central station (straight-line distance in kilometers),

\( VoT \) = ₱1.2/minute per capita,

\( TransferT@EDSA \) = 15 minutes needed when a current user of PNR transfers at EDSA,

\( IntervalT \) = train interval time (users are assumed to wait for one-third of the interval time at their nearest station),

\( CR_{fuel} \) = fuel consumption rate (20 km/liter),

\( P_{fuel} \) = fuel price (₱53.73/liter including 12% value-added tax), and

\( \alpha \) = coefficient determined using R-squared, 1.0 or 2/3, and \( G_{cost} \) defined by \( \alpha = 1.0 \) and \( \alpha = 2/3 \) is referred to as \( G_{cost}_{-02} \) and \( G_{cost}_{-03} \), respectively.

### Adopted Functional Forms

The functional form of hedonic functions cannot be predetermined. We adopted three typical functional forms: linear, full log, and semi-Box-Cox.

**Linear:**

\[
P_i = \alpha_0 + \sum_{k=1}^{K} \alpha_k z_{ik} + \varepsilon_i \quad (i = 1, 2, \ldots, n)
\]

**Full log:**

\[
\ln(P_i) = \alpha_0 + \sum_{k=1}^{K} \alpha_k \ln(z_{ik}) + \varepsilon_i \quad (i = 1, 2, \ldots, n)
\]

**Semi-Box-Cox:**

\[
\frac{P_i^\lambda - 1}{\lambda} = \alpha_0 + \sum_{k=1}^{K} \alpha_k z_{ik} + \varepsilon_i \quad (i = 1, 2, \ldots, n),
\]

where \( P_i \) = land price (₱/m²), \( \alpha_k \) = regression coefficient, \( z_{ik} \) = kth dependent variables (or amenities), \( \varepsilon_i \) = error, \( \lambda \) = parameter (0 ≤ \( \lambda \) ≤ 1), and \( i \) = location.

We assumed that error term \( \varepsilon_i \) follows \( N(0, \sigma^2) \), that is, normal distribution with mean zero and variance \( \sigma^2 \). The coefficient \( \lambda \) in the
semi-Box-Cox takes some value between zero and one, which is called the Box-Cox (1964) transformation. Coefficient $\lambda$ was estimated using a method similar to Kanemoto, Nakamura, and Yazawa (1989) and Yazawa et al. (1992).

**Expected Signs of Explanatory Variables**
The expected signs of each explanatory variable in the hedonic functions are shown in Table 14.3. The estimated signs should follow these expected signs.

<table>
<thead>
<tr>
<th>No.</th>
<th>Variable</th>
<th>Definition</th>
<th>Expected Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Region D</td>
<td>Dummy of region. IMM = 1, OMM = 0</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>Category D</td>
<td>Dummy of points location. Near railway station (IMM, 1,000 m, OMM, 2,000 m) = 1, others = 0</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>Land Use D</td>
<td>Dummy of land use category. Commercial = 1, residential = 0</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>Gcost</td>
<td>Generalized commuting cost (₱)</td>
<td>−</td>
</tr>
<tr>
<td>5</td>
<td>FAR_PRESENT</td>
<td>Floor-area ratio, at present time</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>DIST_1</td>
<td>Distance of sample point to the nearest station (km)</td>
<td>−</td>
</tr>
<tr>
<td>7</td>
<td>WATER_SUPPLY_V</td>
<td>Dummy of water supply level. High = 1, others (medium and low) = 0</td>
<td>+</td>
</tr>
<tr>
<td>8</td>
<td>TELEPHONE_V</td>
<td>Dummy of telephone signal level. High = 1, others (medium and low) = 0</td>
<td>+</td>
</tr>
<tr>
<td>9</td>
<td>SEWAGE_V</td>
<td>Dummy of sewage level. High = 1, others (medium and low) = 0</td>
<td>+</td>
</tr>
<tr>
<td>10</td>
<td>POWER_V</td>
<td>Dummy of power supply. High = 1, others (medium and low) = 0</td>
<td>+</td>
</tr>
<tr>
<td>11</td>
<td>GARBAGE_V</td>
<td>Dummy of garbage collection level. High = 1, others (medium and low) = 0</td>
<td>+</td>
</tr>
<tr>
<td>12</td>
<td>CABLE_TV_V</td>
<td>Dummy of cable TV service level. High = 1, others (medium and low) = 0</td>
<td>+</td>
</tr>
<tr>
<td>13-1</td>
<td>INTERNET_Low</td>
<td>Dummy of internet service level. Low = 1, others (medium and high) = 0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(not used)</td>
<td></td>
</tr>
<tr>
<td>13-2</td>
<td>INTERNET_Medium</td>
<td>Dummy of internet service level. Medium = 1, others (low and high) = 0</td>
<td>+</td>
</tr>
</tbody>
</table>

*Table 14.3: Expected Signs of Explanatory Variables*
Table 14.3  continued

<table>
<thead>
<tr>
<th>No.</th>
<th>Variable</th>
<th>Definition</th>
<th>Expected Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-3</td>
<td>INTERNET_High</td>
<td>Dummy of internet service level. High = 1, others (medium and low) = 0</td>
<td>+</td>
</tr>
<tr>
<td>14</td>
<td>PUB_MARKET</td>
<td>Distance to the nearest public market (km)</td>
<td>−</td>
</tr>
<tr>
<td>15</td>
<td>MALL</td>
<td>Distance to the nearest mall (km)</td>
<td>−</td>
</tr>
<tr>
<td>16</td>
<td>HOSPITAL</td>
<td>Distance to the nearest hospital (km)</td>
<td>−</td>
</tr>
<tr>
<td>17</td>
<td>SCHOOLS</td>
<td>Distance to the nearest school (km)</td>
<td>−</td>
</tr>
<tr>
<td>18</td>
<td>POLICE</td>
<td>Distance to the nearest police station (km)</td>
<td>−</td>
</tr>
<tr>
<td>19</td>
<td>GOVT_CTR</td>
<td>Distance to the nearest government center (km)</td>
<td>−</td>
</tr>
<tr>
<td>20</td>
<td>NBRHD_V</td>
<td>Dummy of property vicinity. There are no informal houses = 1, others = 0</td>
<td>+</td>
</tr>
<tr>
<td>21-1</td>
<td>ISF_DIST_Adjacent</td>
<td>Dummy of distance to informal settler families. Adjacent = 1, others (near and far) = 0</td>
<td>0 (not used)</td>
</tr>
<tr>
<td>21-2</td>
<td>ISF_DIST_Near</td>
<td>Dummy of distance to informal settler families. Near = 1, others (adjacent and near) = 0</td>
<td>−</td>
</tr>
<tr>
<td>21-3</td>
<td>ISF_DIST_Far</td>
<td>Dummy of distance to informal settler families. Far = 1, others (adjacent and near) = 0</td>
<td>−</td>
</tr>
<tr>
<td>22</td>
<td>ISF_No_V</td>
<td>Dummy expressing the number of informal settler families around the property. Few = 1, many = 0</td>
<td>−</td>
</tr>
<tr>
<td>23</td>
<td>CRIME_RATE_V</td>
<td>Dummy of crime rate. Low = 1, others (medium and high) = 0</td>
<td>+</td>
</tr>
<tr>
<td>24</td>
<td>ACDNT_RATE_V</td>
<td>Dummy of accidents per month. Low = 1, others (medium and high) = 0</td>
<td>+</td>
</tr>
<tr>
<td>25</td>
<td>ROADWIDTH</td>
<td>Road width (m)</td>
<td>+</td>
</tr>
<tr>
<td>26-1</td>
<td>ROCON_Excellent</td>
<td>Dummy of road condition of surface. Excellent = 0, others (good and damaged) = 0</td>
<td>0 (not used)</td>
</tr>
<tr>
<td>26-2</td>
<td>ROCON_Good</td>
<td>Dummy of road condition of surface. Good = 1, others (excellent and damaged) = 0</td>
<td>−</td>
</tr>
<tr>
<td>26-3</td>
<td>ROCON_Damaged</td>
<td>Dummy of road condition of surface. Damaged = 1, others (excellent and good) = 0</td>
<td>−</td>
</tr>
</tbody>
</table>

continued on next page
### Table 14.3 continued

<table>
<thead>
<tr>
<th>No.</th>
<th>Variable</th>
<th>Definition</th>
<th>Expected Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>27-1</td>
<td>RD_ESMNT_Excellent</td>
<td>Dummy of width and quality of road condition. Excellent = 0, others (good and damaged) = 0</td>
<td>0 (not used)</td>
</tr>
<tr>
<td>27-2</td>
<td>RD_ESMNT_Good</td>
<td>Dummy of width and quality of road condition. Good = 1, others (excellent and damaged) = 0</td>
<td>-</td>
</tr>
<tr>
<td>27-3</td>
<td>RD_ESMNT_Damaged</td>
<td>Dummy of width and quality of road condition. Damaged = 1, others (excellent and good) = 0</td>
<td>-</td>
</tr>
<tr>
<td>28</td>
<td>CORNER_EFF_V</td>
<td>Dummy of location (corner or road intersection). Yes = 1, others = 0</td>
<td>+</td>
</tr>
<tr>
<td>29-1</td>
<td>RISK_Low</td>
<td>Dummy of risk rate. Low = 0, others (medium and high) = 0</td>
<td>0 (not used)</td>
</tr>
<tr>
<td>29-2</td>
<td>RISK_Medium</td>
<td>Dummy of risk rate. Medium = 1, others (high and low) = 0</td>
<td>-</td>
</tr>
<tr>
<td>29-3</td>
<td>RISK_High</td>
<td>Dummy of risk rate. High = 1, others (low and medium) = 0</td>
<td>-</td>
</tr>
</tbody>
</table>

IMM = inside Metro Manila, km = kilometer, m = meter, OMM = outside Metro Manila.

Note: “0 (not used)” means that this variable is used as a reference point to other related variables, which are denoted below the variable.

Source: Japan International Cooperation Agency Design Team for North–South Commuter Railway Extension Project.

### Regression Results

Regressions were carried out for commercial land and residential land separately. The total sample number is 806 locations: 295 locations in commercial land areas and 511 locations in residential land areas. In the estimation, we first considered all the variables as explanatory variables. But when the p-value of the coefficient for an explanatory variable was large or the obtained sign of the coefficient was opposite the expected sign, we dropped the explanatory variables. We set the threshold as 0.05 for the p-values. We assumed that all local amenities are exogenous for agents.

Table 14.4 shows the parameter estimates for commercial land price hedonic functions. In the Box-Cox model, we transform Gcost as well as land prices using Box-Cox transformation. To maximize the likelihood of the hedonic function, we determine $\mu$ for $Gcost$ as 0.60. This new variable is named as Gcost_02 (or 03)_CB. $\lambda$ is determined as 0.0.
Table 14.4: Parameters and Statistics for Commercial Areas

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Linear Model</th>
<th></th>
<th>Ln Model</th>
<th></th>
<th>Box-Cox Model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Parameter</td>
<td>p-value</td>
<td>Parameter</td>
<td>p-value</td>
<td>Parameter</td>
<td>p-value</td>
</tr>
<tr>
<td>Intercept</td>
<td>8,655.757</td>
<td>0.689</td>
<td>12.122</td>
<td>0.000</td>
<td>11.011</td>
<td>0.000</td>
</tr>
<tr>
<td>RegionD</td>
<td>41,065.168</td>
<td>0.000</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Gcost 02 CB</td>
<td>-91.663</td>
<td>0.008</td>
<td>-0.464</td>
<td>0.000</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Gcost 03 CB</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>-0.023</td>
<td>0.000</td>
</tr>
<tr>
<td>FAR_PRESENT</td>
<td>7,414.493</td>
<td>0.000</td>
<td>0.603</td>
<td>0.000</td>
<td>0.102</td>
<td>0.000</td>
</tr>
<tr>
<td>DIST_1</td>
<td>-1,844.917</td>
<td>0.050</td>
<td>-0.143</td>
<td>0.000</td>
<td>-0.048</td>
<td>0.000</td>
</tr>
<tr>
<td>CABLE_TV_V</td>
<td>...</td>
<td>...</td>
<td>0.308</td>
<td>0.004</td>
<td>0.367</td>
<td>0.001</td>
</tr>
<tr>
<td>POLICE</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>-0.156</td>
<td>0.003</td>
</tr>
<tr>
<td>ROCON_Good</td>
<td>...</td>
<td>...</td>
<td>-0.237</td>
<td>0.011</td>
<td>-0.446</td>
<td>0.002</td>
</tr>
<tr>
<td>ROCON_Damaged</td>
<td>...</td>
<td>...</td>
<td>-0.507</td>
<td>0.022</td>
<td>-0.706</td>
<td>0.002</td>
</tr>
<tr>
<td>NBRHD_V</td>
<td>35,921.287</td>
<td>0.008</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>ISF_DIST_Near</td>
<td>-17,715.983</td>
<td>0.012</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>ROADWIDTH</td>
<td>1,235.446</td>
<td>0.003</td>
<td>-0.374</td>
<td>0.001</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>RD_ESM_Good</td>
<td>-42,840.890</td>
<td>0.000</td>
<td>-0.563</td>
<td>0.000</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>RD_ESM_Damaged</td>
<td>-41,755.610</td>
<td>0.000</td>
<td>0.156</td>
<td>0.038</td>
<td>-0.204</td>
<td>0.023</td>
</tr>
<tr>
<td>CORNER_EFF_V</td>
<td>19,347.909</td>
<td>0.003</td>
<td>12.122</td>
<td>0.000</td>
<td>0.182</td>
<td>0.017</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.583</td>
<td>0.646</td>
<td>0.642</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of samples</td>
<td>306</td>
<td></td>
<td>306</td>
<td></td>
<td></td>
<td>306</td>
</tr>
</tbody>
</table>

Source: Japan International Cooperation Agency Design Team for North–South Commuter Railway Extension Project.

Table 14.5 shows the parameter estimates for residential land price hedonic functions. To maximize the likelihood of the hedonic function, we determine $\mu$ for $Gcost$ as 0.70. In the Box-Cox model is determined as 0.0. Similarly, to maximize the likelihood of the hedonic, $\lambda$ function, we determine $\mu$ for $Gcost$ as 0.60.
### Table 14.5: Parameters and Statistics for Residential Areas

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Linear Model</th>
<th></th>
<th>Full Log Model</th>
<th></th>
<th>Box-Cox Model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Parameter</td>
<td>p-value</td>
<td>Parameter</td>
<td>p-value</td>
<td>Parameter</td>
<td>p-value</td>
</tr>
<tr>
<td>Intercept</td>
<td>30,592.187</td>
<td>0.000</td>
<td>11.298</td>
<td>0.000</td>
<td>9.697</td>
<td>0.000</td>
</tr>
<tr>
<td>RegionD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gcost_02 CB</td>
<td>-109.416</td>
<td>0.000</td>
<td>-0.398</td>
<td>0.000</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>Gcost_03 CB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.018</td>
<td>0.000</td>
</tr>
<tr>
<td>FAR_PRESENT</td>
<td>4,291.468</td>
<td>0.000</td>
<td>0.131</td>
<td>0.047</td>
<td>0.064</td>
<td>0.000</td>
</tr>
<tr>
<td>DIST_1</td>
<td>-1,099.031</td>
<td>0.007</td>
<td>-0.250</td>
<td>0.000</td>
<td>-0.039</td>
<td>0.000</td>
</tr>
<tr>
<td>SEWAGE_V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MALL</td>
<td></td>
<td></td>
<td>-0.098</td>
<td>0.005</td>
<td>-0.073</td>
<td>0.006</td>
</tr>
<tr>
<td>NBRHD_V</td>
<td>11,875.225</td>
<td>0.003</td>
<td>0.154</td>
<td>0.050</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>ISF_DIST_Near</td>
<td>-19,051.250</td>
<td>0.000</td>
<td>-0.279</td>
<td>0.000</td>
<td>-0.283</td>
<td>0.000</td>
</tr>
<tr>
<td>ROCON_Damaged</td>
<td></td>
<td></td>
<td>-0.219</td>
<td>0.014</td>
<td>-0.235</td>
<td>0.012</td>
</tr>
<tr>
<td>ROADWIDTH</td>
<td>2,216.888</td>
<td>0.000</td>
<td>...</td>
<td></td>
<td>0.031</td>
<td>0.008</td>
</tr>
<tr>
<td>RD_ESM_Good</td>
<td></td>
<td></td>
<td>-0.212</td>
<td>0.042</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>RD_ESM_Damaged</td>
<td>-15,241.743</td>
<td>0.000</td>
<td>-0.662</td>
<td>0.000</td>
<td>-0.459</td>
<td>0.000</td>
</tr>
<tr>
<td>RISK_Medium</td>
<td>-11,133.656</td>
<td>0.001</td>
<td>...</td>
<td></td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.402</td>
<td></td>
<td>0.748</td>
<td></td>
<td>0.720</td>
<td></td>
</tr>
<tr>
<td>Number of samples</td>
<td>511</td>
<td></td>
<td>511</td>
<td></td>
<td>511</td>
<td></td>
</tr>
</tbody>
</table>

Source: Japan International Cooperation Agency Design Team for North-South Commuter Railway Extension Project.

### 14.5 Computation of Total Increased Land Value

Regression results were used for estimating land prices after the NSCR-EX Project. The areas affected by the project and future commercial and residential land use were determined. Increased land values for both commercial and residential lands in the affected areas were computed compared to current land prices. Then, the total increased land value was computed using the accumulated increased land values in the affected areas.
14.5.1 Estimation of Land Prices with the Hedonic Functions

Assumptions
The following assumptions were made:

- We estimated land prices at locations within 0.5 km or 2 km of each station for commercial land and residential land, respectively. The shorter distance for commercial land was set because commercial areas lie close to stations, whereas residential areas expand up to the boundary.
- Many stations had data samples within 0.5 km or 2 km of each station. For such stations, we estimated all the samples within 0.5 km or 2 km of the station.
- Some stations (e.g., Clark International Airport station) had no data points within 0.5 km or 2 km of the station. In these cases, current land prices at 0.25 km or 1 km from the station were estimated using the hedonic function. The explanatory variables except for $G_{\text{cost}}$ were set based on the average values (or dummies) around the station.

Average Decreases in $G_{\text{cost}}$ with the North–South Commuter Railway Extension
After the NSCR-EX Project is completed, households living in the project areas will be able to choose trains as their commuting mode, so the $G_{\text{cost}}$ for residents around each station will change to:

$$G\text{cost}_{\text{train}} = V_o T \times (T I M E_3 + W a i t T + D I S T_1 \times 60 / 4) + F a r e_{\text{train}}$$
$$W a i t T = T r a n s f e r T @ E D S A + I n t e r v a l T / 3,$$

where $T I M E_3$: refers to the average time required to travel by train from the nearest station to the central station (in minutes) after the project.

If the new $G\text{cost}_{\text{train}}$ is greater than the present $G\text{cost}_{\text{road}}$, households will use the road transport mode. For the PNR stations outside Metro Manila, we assumed that if the distance from a sample point to the nearest station is less than 5 km, the residents will choose the train even if $G\text{cost}_{\text{road}}$ is less than $G\text{cost}_{\text{train}}$.

We determined which mode is used at respective locations based on the proposed calculation method. However, this result does not necessarily represent the real situations when focusing on each station. Indeed, mode choice around most stations depends on people and is not necessarily either rail or road transport, but the mode share is between
1 and 0. For our purpose, the exact value of \( G_{\text{cost}} \) at each station was not necessary. It was enough that the overall slope of the \( G_{\text{cost}} \) with respect to the distance from the central station was estimated correctly.

**Land Price Estimation**

Land prices around a station were estimated with the hedonic functions in the following way:

\[
\hat{P} = \hat{P} + (P - \bar{P})
\]

- \( \hat{P} \) = Expected land price of a proposed station after the NSCR-EX Project,
- \( \hat{P} \) = Estimated land price of a proposed station by hedonic functions with new \( G_{\text{cost}} \),
- \( P \) = Present land price of a proposed station, and
- \( \bar{P} \) = Estimated land price of a proposed station with hedonic functions with the current variables.

Note: Present land prices were not collected at all stations. If we do not have data points within 2 km of a station, we suppose \( P = \bar{P} \).

**14.5.2 Areas Affected by the North–South Commuter Railway Extension Project**

We set the area where the land price is expected to increase due to the NSCR-EX Project as follows:

- Basically 2-km radius of each station,
- Suburban area covers a maximum of 3-km radius,
- Halfway distance between the centers of 2 nearby proposed stations, and
- Sea and lake areas are excluded from affected areas.

Current and future land use in the affected area were set for each station. Primary land use information was based on the following:

- Data from the Land Management Bureau,
- Cadastral maps,
- Comprehensive land use plans from local government units, and
- Tax maps.

Percentages of residential and commercial use in a particular AOI were calculated based on geospatial mapping software and defined per
100-meter (m) radius for locations inside Metro Manila and 200-m radius for locations outside Metro Manila. Land use researchers triangulated these percentages through actual field survey impressions and the latest Google Earth imagery outputs of the AOIs. More recent observed conditions were given more weight for appropriate adjustments. Future commercial and residential areas were assumed to be 1.2 times higher than the current ones. Figure 14.2 shows an indicative image of the change from current to future land use in Calumpit Station area, where the commercial area and residential area are increased in the future land use map. Table 14.6 shows the computed area of land use in each station.

Table 14.6: Commercial and Residential Areas in the Affected Areas (m²)

<table>
<thead>
<tr>
<th>Rail</th>
<th>Station Name</th>
<th>Current Commercial Area</th>
<th>Current Residential Area</th>
<th>Future Commercial Area</th>
<th>Future Residential Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>N2</td>
<td>Clark International Airport</td>
<td>1,749,239</td>
<td>5,411,079</td>
<td>2,098,022</td>
<td>6,490,003</td>
</tr>
<tr>
<td>N2</td>
<td>Clark</td>
<td>1,749,239</td>
<td>5,411,079</td>
<td>2,098,022</td>
<td>6,490,003</td>
</tr>
<tr>
<td>N2</td>
<td>Angeles</td>
<td>6,295,765</td>
<td>11,075,214</td>
<td>7,551,088</td>
<td>13,283,519</td>
</tr>
</tbody>
</table>
Table 14.6  continued

<table>
<thead>
<tr>
<th>Rail</th>
<th>Station Name</th>
<th>Current</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Commercial Area</td>
<td>Residential Area</td>
</tr>
<tr>
<td>N2</td>
<td>San Fernando</td>
<td>3,647,389</td>
<td>17,185,140</td>
</tr>
<tr>
<td>N2</td>
<td>Apalit</td>
<td>161,384</td>
<td>3,084,471</td>
</tr>
<tr>
<td>N2</td>
<td>Calumpit</td>
<td>531,884</td>
<td>2,671,920</td>
</tr>
<tr>
<td>N2</td>
<td>Malolos</td>
<td>950,018</td>
<td>3,669,380</td>
</tr>
<tr>
<td>SC</td>
<td>Solis</td>
<td>1,396,466</td>
<td>580,058</td>
</tr>
<tr>
<td>SC</td>
<td>Blumentritt</td>
<td>1,007,181</td>
<td>162,590</td>
</tr>
<tr>
<td>SC</td>
<td>España</td>
<td>710,300</td>
<td>35,155</td>
</tr>
<tr>
<td>SC</td>
<td>Santa Mesa</td>
<td>553,471</td>
<td>2,016,917</td>
</tr>
<tr>
<td>SC</td>
<td>Paco</td>
<td>959,439</td>
<td>2,357,377</td>
</tr>
<tr>
<td>SC</td>
<td>Buendia</td>
<td>662,212</td>
<td>779,678</td>
</tr>
<tr>
<td>SC</td>
<td>EDSA</td>
<td>478,638</td>
<td>921,607</td>
</tr>
<tr>
<td>SC</td>
<td>Nichols</td>
<td>559,902</td>
<td>687,000</td>
</tr>
<tr>
<td>SC</td>
<td>FTI</td>
<td>25,988</td>
<td>472,153</td>
</tr>
<tr>
<td>SC</td>
<td>Bicutan</td>
<td>153,868</td>
<td>443,335</td>
</tr>
<tr>
<td>SC</td>
<td>Sucat</td>
<td>1,435,542</td>
<td>572,228</td>
</tr>
<tr>
<td>SC</td>
<td>Alabang</td>
<td>1,283,875</td>
<td>507,489</td>
</tr>
<tr>
<td>SC</td>
<td>Muntinlupa</td>
<td>1,879,131</td>
<td>1,820,892</td>
</tr>
<tr>
<td>SC</td>
<td>San Pedro</td>
<td>793,562</td>
<td>849,214</td>
</tr>
<tr>
<td>SC</td>
<td>Pacita</td>
<td>772,950</td>
<td>814,174</td>
</tr>
<tr>
<td>SC</td>
<td>Biñan</td>
<td>595,664</td>
<td>1,365,064</td>
</tr>
<tr>
<td>SC</td>
<td>Santa Rosa</td>
<td>799,865</td>
<td>2,655,288</td>
</tr>
<tr>
<td>SC</td>
<td>Cabuyao</td>
<td>788,421</td>
<td>1,591,859</td>
</tr>
<tr>
<td>SC</td>
<td>TBD or Gulod</td>
<td>468,169</td>
<td>2,355,030</td>
</tr>
<tr>
<td>SC</td>
<td>TBD or Banlic</td>
<td>468,169</td>
<td>2,355,030</td>
</tr>
<tr>
<td>SC</td>
<td>Calamba</td>
<td>1,244,102</td>
<td>5,287,434</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>32,121,832</td>
<td>77,137,858</td>
</tr>
</tbody>
</table>

EDSA = Epifanio de los Santos Avenue, N2 = North–South Commuter Railway Clark Extension, SC = North–South Commuter Railway Calamba Extension, TBD = to be determined.

Source: Japan International Cooperation Agency Design Team for North–South Commuter Railway Extension Project.
14.6 Total Future Increased Land Value by North–South Commuter Railway Extension

We computed the total future land values estimated using the hedonic functions in the areas affected by the implementation of the railway. The increased land value is computed using the following method:

Increased Land Value per Station (₱) = Future Land Value – Current Land Value

Current Land Value (₱) = Current Commercial Area (m²) \times \text{Current Unit Commercial Land Price (₱/m}^2\) + Current Residential Area (m²) \times \text{Current Unit Residential Land Price (₱/m}^2\)

Future Land Value (₱) = Future Commercial Area (m²) \times \text{Future Unit Commercial Land Price (₱/m}^2\) + Future Residential Area (m²) \times \text{Future Unit Residential Land Price (₱/m}^2\)

Figure 14.3: Comparison of Current and Future Land Value (₱ million)

Source: Japan International Cooperation Agency Design Team for North–South Commuter Railway Extension Project.
Figures 14.3 and 14.4 show the results of computation. The future land value in the total affected areas was ₱3,518,573 million (equivalent to approximately $74 billion), while the current land value of the same areas was ₱2,361,853 million (equivalent to approximately $50 billion). Thus, the increased land value was ₱1,156,720 million (equivalent to approximately $24 billion).

14.6 Conclusion and Recommendations

In this study, we estimated the increase in land prices associated with the NSCR-EX Project, using the hedonic approach. In the case of several stations, the increase depended on the form of hedonic function, but in most cases, the increase was almost the same among all the functional specifications. Accordingly, there was a wide range in the resulting estimates of increase in land prices. Since our purpose was to capture the increase in the total land price along the improved railway, some variation in the result for each station can be considered negligible. The result is sufficient for use in policy discussions.

The study revealed that the total increased land value as a result of the NSCR-EX is about at ₱1,156 billion (approximately $24 billion), which is 1.84 times the railway investment cost. Moreover, the national government’s understanding of the effects of the railway development, or the effects of transit-oriented development (TOD) for rail, was
strengthened because key decision makers could easily appreciate its potential. They became motivated to leverage potential increased land value toward further developments. In using increased land values to finance TOD support infrastructures and land conversion projects, accessibility in the station area will be improved and change in land use will be accelerated, thus enhancing the effects of TOD for rail making them more feasible.

This type of study is especially useful for helping decision makers employ land value capture and TOD policies. It enables them to understand the mechanisms behind TOD and its benefits. It helps them visualize how improved accessibility and change of land use will increase land values in the area around a station. The effects of railway development will can be understood as increase in land value, so it will be easier for decision makers to evaluate its effects and leverage this information to implement TOD support infrastructures and/or to change land use in the area toward the realization of TOD. Finally, we recommended conducting similar studies during early stages of railway planning especially for mass-transit systems.
References


15.1 Research Background

Over the past two decades, there has been a growing interest in improving community livability and a rising commitment by various hierarchies of urban governances to provide the structure, resources, and data for planning and building livable communities driven by sustainable transportation (Carr et al. 2011; Miller, Witlox, and Tribby 2013). Research on the interdependence of transportation planning and community livability is gaining significant ground when understood spatially and over time (Lee and Sener 2016). The mosaic of a vast urban agglomeration across an initial transportation feeder like a maritime channel is an important working economic baseline (Arifwidodo and Perera 2011; Xu et al. 2019). The evolution of the indwelling community agglomerating over time is the other part. Therefore, such research is advanced when the two are coupled and an appropriate case is explored to best understand the intertwined roles (Steg and Gifford 2005; Horan, Serrano, and McMurran 2016).

Livability is a comprehensive standard of human development and a basic yardstick for assessing the degree of community well-being and overall quality of life (QoL) (Wyatt 2009; Paul 2020). In most cases, the term livability has been used as a policy approach by various levels of urban governances (Li and Yao 2013). Livability is a holistic paradigm
of human development (Wyatt 2009) and community well-being based on an augmentation of the twin physical-environmental and cultural dimensions of urban and regional spaces. Livability means the ability to dwell in certain physical spaces with appropriate preparedness in the cultural and environmental dimensions as its prerequisite (Balsas 2004).

Based on our previous work, the rate of urbanization in India is estimated to increase by 60% by 2050 (Paul 2020; Paul and Sen 2018; Paul and Sen 2020). The main concern for policymakers and urban practitioners is the impact of the rising pressure of urbanization on urban amenities and facilities (Mukherjee 2011; Azami and Razavian 2013; Riley 2019). Especially since the coronavirus disease (COVID-19) pandemic began, community livability has become one of the prime agendas for urban development and management (Paul and Sen 2020). From this perspective, the livable community approach has reemerged and has been redesigned in the domain of urban planning and regional development to best evaluate a deep and inclusive relationship between communities’ QoL and their surroundings (Paul 2020).

“Livable community” is an all-encompassing term (National Research Council 2002). Researchers and policymakers have typically established the extents and aspects of livable community based on their own perspective and research contexts. The American Association of Retired Persons (AARP) defines a livable community as having a good to best degree of safety and a secure surrounding environment, affordable mobility options, and urban services for the communities (Lehning and Harmon 2013). The Transportation Research Board (1997) describes a well-thought-out livable community as having secure transportation options and a safe urban environment. Hur and Morrow-Jones (2008) prescribe factors that influence citizens’ perception of a place they find livable based on neighborhoods’ qualities and transportation affordability. Based on empirical observations, we delineate a livable community as being well facilitated and providing an accessible way of living with manageable and affordable transportation options under strong and smart urban governance.

This chapter develops a policy framework for identifying the major components of the livable community based on various transportation strategies. With the rising importance of livability in the intertwined milieu of urbanism, sub-regional governances, and transportation options, we investigate two key research questions:

(i) What are the major components of a livable community based on transportation strategies from the perspective of developing countries?

(ii) What are the dynamics of transportation strategies and their impacts on community livability across a metropolitan urban agglomeration?
Figure 15.1 presents a schematic diagram of our research idea and our strategy for addressing the abovementioned research questions. We conducted a case study of the Kolkata Urban Agglomeration (KUA) in India. This metropolitan area has evolved across both the banks of the Hooghly River, catalyzing the beginning of British colonization in India and earmarking the future of the celebrated “City of Joy”; it is the well-known livable cultural capital of India (Wann-Ming 2019). We assess its spatial dimensions by considering the evolution of the conurbation in four phases and by looking at the dynamics of transportation strategies and their impacts on community livability within the urban agglomeration (Miller, Witlox, and Tribby 2013; Schneider, Guo, and Schroeder 2013).

15.2 Research Design

15.2.1 Case Study: The Kolkata Urban Agglomeration

The KUA is the third largest urban agglomeration in India. It is primarily the metropolitan outfit of Kolkata. The KUA has a population of 14,112,536 (Directorate of Census Operations West Bengal 2011) and
extends over an area of 1,886.67 square kilometers. It has three major spatial components. The first one is the core city of Kolkata, which is the central business district for the entire urban agglomeration (Paul and Sen 2018). The second component is an amalgamation of 39 urban local bodies along both the banks of the Hooghly River in a linear form (Paul 2020). The third one is the concentric form of rural areas within the metropolitan landscape.

15.2.2 Spatial and Temporal Evolution of the Kolkata Urban Agglomeration Based on Transportation Nodes

The initial settlement phase (prior to 1600) of the KUA started in the Islamic period (1526–1857). The settlement was initially formed at the northern periphery of the present KUA boundary. Rapid colonization was started by the formation of various European settlements, mainly the Portuguese (1517), French (1673), Danes (1679), and finally the British (1690) (Shaw and Satish 2007; Shaw 2012). With the establishment of British colonization around the eastern part of this regional landscape, the settlement’s significance shifted rapidly (Banerjee 2005). During this period, Hooghly River became one of the well-known and key maritime networks in this area (Shaw and Satish 2007; Shaw 2012).

A great transformation of the socioeconomic gravity of what was to become the KUA took place in 1757. It brought two significant features: (i) the non-British European settlements around the western bank of the Hooghly River became temporary and lost their glory after the establishment of the British settlement at the eastern part and (ii) the strategic approaches of the British settlements amalgamated and delineated the initial form of the current metropolitan landscape of Kolkata. The British settlements were heavily reliant on port activities. To improve the overall economic activities at the eastern bank, the British delineated Kolkata (at that time Calcutta) with the consolidation of three important and self-sufficient villages: Sutanati, Gobindapur, and Kalikata. The activity was further reinforced by the colonial industrialization form where Kolkata continued to play a harmonizing role to enhance the industrialization processes and accommodate the growing population. Ultimately, the port city of Kolkata became a standard of higher accessibility between new sectors of accomplishments, rapid maritime infrastructure, and growing trade activities for the whole of eastern India.

During 1800, a chain of settlements was consolidated along each of the two riverbanks. The two stretches in due course were developed as two national highways: the Grand Trunk Road (western part) and the Barrackpore Trunk Road (eastern part). The two stretches connected
other associated nodes to increase the significance of the existing port and the economic improvements. This also initiated port-based economic activities that led to settlements across the entire metropolitan landscape. As a consequence of these settlements, the railway system began to evolve in 1857. During this era, several major railway colonies evolved across various non-livable lands in and around the core (Shaw 2012).

During 1890–1930, British colonization was established in Kolkata; it lasted until 1947. As a consequence, better economic opportunities and higher standards of living in the core had evolved (Banerjee 2005). The rapid improvement of sociophysical infrastructure, new housing opportunities, planned green and public spaces, and better quality of urban amenities and facilities increased overall livability within Kolkata (Sengupta 2013; Sadashivam and Tabassu 2016). But other towns did not prosper in the same way. During this period, socioeconomic and sociocultural inequality existed across the entire metropolitan landscape. This inequality is still observed today.

The communities in the core city had benefitted from all the amenities and facilities. After the initiation of the two railway stations (Howrah and Sealdah), the living standard in the core had improved. Howrah provided significant national linkages to other parts of the country (Kundu 2003; Yadav and Bhagat 2015; Karmakar 2015). Sealdah served the suburban linkages across the entire regions of Bengal. Also, numerous public roads, which later became national highways (NHs) like NH-2 and NH-6, improved rapidly growing urban amenities and shaped out the settlement pattern across the metropolitan landscapes (Pal 2006).

Lastly, with the introduction of airways (1924) and the construction of the international airport at Dumdum, the way of life of high and middle-income groups emerged in the core area and began to amalgamate colonial urbanism and living standard in an all-inclusive way (Bhagat 2004). But this development also contributed to the present socioeconomic and cultural imbalances across Kolkata’s metropolitan landscape (Pal 2016).

### 15.2.3 Development of Variables

A set of questions regarding existing transportation options and behavior was asked of KUA residents to assess the overall degree of livability. The first section of the survey focuses on socioeconomic attainments of the respondents and the second deals with questions regarding transportation options and mobility patterns. The responses have been recorded based on a five-point Likert scale.
15.2.4 Determination of the Sample Size

To determine the sample size, we used the Cochran sample determination approach. According to this approach, the required sample size for KUA was 385 individuals (Cochran 1977). To collect the required samples, we conducted a residents’ survey in various parts of the KUA from October to December 2018. A total of 432 samples were collected. After an initial evaluation, 414 valid samples were finalized for use in the research.

15.2.5 Ordinal Logistic Regression Model

Numerous logistic regression techniques are utilized to assess ordinal responses (Adriaanse 2007; Panero, Murante, and Perucca 2010; Takehira et al. 2011; Eygu and Gulluce 2017). Among them, the proportional odds model is the most commonly used technique in urban studies (Eboli and Mazzulla 2009; Eygu and Gulluce 2017). The Wald test validates the level of significance in the model. This test examines whether the null hypothesis (H0) equals zero. Pseudo R-square is used to measure the goodness of fit (Gujarati 2003). We follow the Nagelkerke pseudo R-square approach to assess the goodness of fit within the proposed model (Eygu and Gulluce 2017).

15.3 Results and Discussion

15.3.1 Socioeconomic Profiles of the Respondents within the Kolkata Urban Agglomeration

The majority of the respondents were male (57.4%) and the largest age group was 26–35 (39.1%), followed by 18–25 (18.5%). Respondents with a degree of postgraduate or higher (37.9%) were overrepresented within the KUA (Figure 15.2). A large proportion were in informal skilled occupations (35.6%), followed by self-employment (19.5%).

In terms of civil status, 43.7% were single. Most of them were expatriates, residing there for education and employment purposes. In the northern parts of the KUA, the existence of large families was observed with more than 5 members staying together within the same household. Overall, 65.8% of respondents lived in their own houses and 28.2% stayed in rental properties within the KUA (Figure 15.3). In terms of housing option, a large share (>42%) preferred to stay in plotted houses. The ratio is a little high in the central and southern parts of the KUA. Most of the respondents opted to stay in 1- and 2-bedroom, hall,
and kitchen apartments in these areas depending on their budget and affordability. The level of satisfaction in affordable and accessible public transportation is quite high. In the central and southern parts of the KUA, paratransit options are well developed at various neighborhood levels. Overall, the basic transportation options (mainly buses; sub-urban, circular, and metro railways; ferries; and tram services) are enormously efficient and affordable.
15.3.2 Transportation Strategies and Their Impacts on Livability

Initiation of Factors to Assess Various Intensities of Impact

We initiate a set of factors to assess the overall community livability within the KUA based on transportation strategies. The factors mainly explain the number of essential dimensions that make up community livability. The set of factors is generally used to reorder the 33 variables into a particular set of clusters based on the shared variance.

Confirmatory factor analysis was used for initiating the factors. The Kaiser-Meyer-Olkin test measure of sampling adequacy and Bartlett’s test of sphericity (Baglin 2014) are computed to validate the level of significance. For the present research, Kaiser-Meyer-Olkin (0.754) and Bartlett’s test (significance level 0.000) indicate that the data is suitable for the analysis.
Table 15.1 presents the factors extracted from the variables with their eigenvalues. It replicates the number of extracted factors whose sum should be equal to the number of variables. We extract four factors with eigenvalues of more than 1. The first factor accounts for 32.1% of the variance, and with the four factors, the present research explains 47.9% of the total variance. The higher the absolute value of the factor loading, the more the factors contribute to overall community livability (Table 15.1).

Table 15.1 also presents the initiated four factors in the present context. The first factor is categorized as “standard of neighborhood.” It represents the quality of social comforts for creating a livable environment. The second factor is classified as “extent of transportation options.” It denotes the quantity and quality of accessibility options available to an individual or group, taking their specific needs and abilities into consideration. The third factor is classified as “degree of accessibility.” This refers to the ability to reach a place with respect to another place. The last one is classified as “degree of safety,” which represents the condition of being safe in terms of public transportation.

Table 15.1: Initiation of Variables

<table>
<thead>
<tr>
<th>Factors</th>
<th>Variables</th>
<th>Factor Loadings</th>
<th>Eigenvalue</th>
<th>Variance Explained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard of neighborhood</td>
<td>Extent of a livable locality</td>
<td>0.611</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extent of housing development</td>
<td>0.709</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quality of urban services</td>
<td>0.789</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Level of regular maintenance</td>
<td>0.776</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.269</td>
<td>32.089</td>
<td></td>
</tr>
<tr>
<td>Extent of transportation options</td>
<td>Degree of affordable public transportation options</td>
<td>0.812</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Degree of safe public transit</td>
<td>0.792</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extent of accessible public transportation options</td>
<td>0.700</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extent of availability of public transportation options</td>
<td>0.553</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extent of availability of shared transportation options</td>
<td>0.652</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extent of problems with transportation options</td>
<td>0.682</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extent of well-maintained streets</td>
<td>0.651</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standards of public parking spaces</td>
<td>0.671</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.272</td>
<td>7.099</td>
<td></td>
</tr>
</tbody>
</table>

continued on next page
### Table 15.1 continued

<table>
<thead>
<tr>
<th>Factors</th>
<th>Variables</th>
<th>Factor Loadings</th>
<th>Eigenvalue</th>
<th>Variance Explained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of accessibility</td>
<td>Access to air travel</td>
<td>0.765</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Access to rail transportation</td>
<td>0.737</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Access to taxis and other similar services</td>
<td>0.681</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Degree of accessibility to educational facilities for disabled people</td>
<td>0.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Degree of accessibility to colleges</td>
<td>0.595</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Degree of accessibility to educational facilities for lower-income groups</td>
<td>0.756</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Degree of accessibility to schools</td>
<td>0.609</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Degree of maintained accessible open spaces</td>
<td>0.720</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Degree of maintained accessible public restrooms</td>
<td>0.778</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extent of sidewalks</td>
<td>0.828</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Level of well-maintained parks and green spaces</td>
<td>0.668</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Traffic information</td>
<td>0.490</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.638</td>
<td>5.118</td>
</tr>
<tr>
<td>Degree of safety</td>
<td>Degree of road safety</td>
<td>0.548</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extent of safety of bicyclists</td>
<td>0.593</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extent of safety for railroad crossings</td>
<td>0.724</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Level of feeling safe to roam around the vicinities</td>
<td>0.761</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Degree of safety for children</td>
<td>0.789</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extent of police services</td>
<td>0.521</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extent of violent and petty crimes</td>
<td>0.765</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extent of alcohol-related disorders</td>
<td>0.729</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.153</td>
<td>3.603</td>
</tr>
</tbody>
</table>

Source: Authors.

**Identification of the Degree of Impacts of the Initiated Factors on Community Livability**

We use an ordinal logistic regression (OLR) model to understand the degree of impacts the initiated factors have on community livability.
Table 15.2 presents the computed values of impacts from the OLR model. Both the dependent and independent variables used in the model are ordinal. The model with maximum likelihood (likelihood ratio: 707.289 and degrees of freedom = 14) assesses the degree of impacts of the selected factors on community livability in a comprehensive way.

A critical hypothesis of this model is the assumption of parallel curves. The hypothesis proposes factors under the assumption that determined regression coefficients are equal in all the categories of the ordered categorical variable. The hypothesis is verified based on a high chi-square value (1,356.039) and the assumption of parallelism, which are statistically significant for the present OLR model.

<table>
<thead>
<tr>
<th>Factor</th>
<th>B</th>
<th>Wald</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perception on 1–5 scale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 = Not at all important</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 = Slightly important</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 = Moderately important</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 = Slightly important</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 = Extremely important</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Model fitting norms: Log-Likelihood (707.289), df (14)
Goodness of fit: Pearson’s chi-squared test (χ²) = 1,356.039
Pseudo R²: Nagelkerke R² (0.539)
Source: Authors.

The pseudo R-square values are calculated to comprehend the proportion of variance for the response variable explained by the independent variables. We computed Nagelkerke’s R-square, which explained 53.9% of the variance of the model.

The Wald test determines the degrees of impact of the initiated factors of community livability within the KUA. All four factors are significant and positive, which implies that the increasing affluence of these four factors is associated with increased odds for achieving good livability within the KUA. Most importantly, the standard of the neighborhood has the highest impact on community livability, followed by extent of transportation options, degree of safety, and degree of accessibility.
15.4 Conclusion

This study has produced two findingsthat can contribute to effective assessment of the impacts of transportation strategies on community livability within an urban agglomeration. The first finding concerns the identification of prime factors through which the impacts can be evaluated using these steps: First, a range of variables related to transportation strategies was identified from the review of the literature. Next, four factors were initiated from 33 variables through which the assessment of community livability within the KUA could be best evaluated. For this step, confirmatory factor analysis was used.

For our second and conclusive finding, we used an OLR model to best understand the significance and the degree of impacts of initiated factors of community livability in the KUA. It was evident that the residents’ desire for positive and favorable factors related to transportation options and behavior were best represented to define the KUA as more livable and habitable. The standard of the neighborhood was the most dominant factor for assessing community livability, followed by degree of safety and extent of transportation options. Accordingly, we recommend further investigation of possibilities to improve livability and to advance the overall QoL in order to enhance the quality of urbanism on the whole.
References


16
Socioeconomic, Environmental, and Accessibility Assessment of High-Speed Rail Station Location Using a Geographic Information System Network Analyst
Sandeepan Roy, Avijit Maji, and Prasanta Sahu

16.1 Introduction
Identifying station locations is one of the vital aspects of a high-speed rail (HSR) project. Stations provide access to rail service, serve as multi-modal transportation hubs (connecting regional and local transit systems), and are the prime locations for transit-oriented development. Thus, selection of station location can maximize the overall utility or benefit for the target population and adjacent environment while optimizing ridership and travel time. These objectives are achieved when station locations are well integrated with other travel modes, have uninterrupted access to existing transportation facilities and services, avoid environmentally sensitive zones and extensively developed land with high right-of-way costs, and meet strategic necessities such as proximity to the downtown area and socioeconomic development hubs or are located outside the urban core (Roy and Maji 2019). The existing process for identifying candidate station locations is manual and usually involves maps of the study area with superimposed information on topography, geographical features, transportation facilities, population distribution, downtown location, etc. Although some vital station location requirements might be considered in the analysis, there is no
way to test the optimality of the generated solution. Also, there is no certainty that all possible locations are evaluated in the process.

Most of the studies on HSR planning have assumed possible station locations as a priori information and focused on identifying routes and locating stops for services along the HSR corridor (Chang, Yeh, and Shen 2000; Bruno, Gendreau, and Laporte 2002; Schöbel 2005; Laporte et al. 2011; Repolho, Antunes, and Church 2013; Repolho, Church, and Antunes 2016). The physical location of the station was not the primary objective of these studies. Thus, the problems were oversimplified by excluding information about local attributes of the study area such as (i) accessibility from existing public transportation services, local transit, and road networks, (ii) right-of-way cost details, (iii) availability of sufficient land for facility location, and (iv) environmental and geographically sensitive locations (Bruno, Gendreau, and Laporte 2002; Schöbel 2005; Repolho, Antunes, and Church 2013). Such oversimplifications during the planning stage could result in suboptimal solutions in the subsequent steps of alignment development. Although certain studies have included study area information for urban transit, the accessibility measures used in these studies were derived from buffer analysis, which often overestimated the accessibility scores and, thus, would not be entirely realistic. Also, the literature on HSR station location modeling is quite limited (Repolho, Antunes, and Church 2013; Repolho, Church, and Antunes 2016; Roy and Maji 2019). Therefore, a methodology that integrates study area information, desirable indicators, and existing network-based analysis to identify feasible station locations for HSR planning would be greatly beneficial to planners.

The application of geographical information systems (GISs) for spatially analyzing potential station locations could provide a solution to the problems mentioned earlier. GIS, with its advanced mapping, geoprocessing, and visualization capabilities, ensures a better possibility of identifying optimal station location over manual analysis. Spatial data such as land-use and land-cover maps, property data, maps showing demographic information, and other important facility locations could be integrated into the model as well. A utility-based station location model that considers and quantifies various station location requirements would be greatly beneficial to HSR planners in determining possible alternative locations. We developed a GIS-based HSR station location utility model in the past (Roy and Maji 2019) and further extend the model in this study. Utility functions that quantify the extent to which a potential location satisfies each of the desired indicators were developed. These functions were integrated into the GIS-based analytical framework, where network-based analysis is
performed instead of buffer analysis to reduce overestimations. Multiple real-world case studies are presented to demonstrate the efficacy of the developed model under varied conditions.

16.2 High-Speed Rail Station Location Utility Quantification

The utility of a potential HSR station location can be quantified based on improved area-wide, local accessibility and intermodal integration with existing transportation infrastructure (like airports, train stations, and bus stops), transit network and services (like commuter rail, road network, and feeder bus service), avoidance of higher right-of-way cost and environmentally sensitive land parcels (such as water bodies, wetlands, and forests), and proximity to socioeconomic development hubs, i.e., the effect on commercial and industrial land use within the actual service area of the potential HSR station location (Roy and Maji 2019). We formulated some of these indicators in our previous study (Roy and Maji 2019). City-wide road and transit networks were not considered previously and are being considered here. Network distance is thus considered. It is the distance measured between locations through the given road and/or transit network. The desirable indicators, their mathematical formulations, and their utility functions are stated as follows.

Let $C_s$ be the study area and $S_f$ be the set of infeasible locations or areas. The set of feasible station locations $S_f$ can be formulated as given in equation 1.

$$S_f = \left( C_s \cap S_f' \right)$$  \hspace{1cm} (1)

A binary function may be formulated, as shown in equation 2 (Roy and Maji 2019).

$$y_i = \begin{cases} 1 & \text{if } G_i \in S_f \\ 0 & \text{if } G_i \in S_f' \end{cases}$$  \hspace{1cm} (2)

where $G_i$ represents the candidate station location $i$.

Stations may be located closer to the city center or downtown area of large regional cities that have commercial and industrial sectors, to enhance ridership potential (Menéndez et al. 2002), or outside the urban core to foster future land use development in surrounding areas (Shi 2016; Zheng et al. 2019). A binary function can be formulated, as shown in equation 3.
\[ U_{i1} = \begin{cases} 1 & \text{if } D_{ni} \leq D_{Th}, \\ 0 & \text{if } D_{ni} > D_{Th}, \end{cases} \]  \tag{3}

where
\[ D_{ni} = \] the network distance of candidate station location \( i \) from the downtown area,
\[ D_{Th} = \] the threshold network distance from the downtown area.

Similarly, when candidate station locations are modeled as outside the urban core, they can be represented as in equation 4.

\[ U_{i1} = \begin{cases} 1 & \text{if } D_i > D_{Th}, \\ 0 & \text{if } D_i \leq D_{Th}, \end{cases} \]  \tag{4}

Extensively developed neighborhoods with high right-of-way costs should be avoided when selecting potential station locations. Thus, a utility quantification based on a normalized cost (in the range \([1,0]\)) can be formulated as equation 5 (Roy and Maji 2019).

\[ U_{i2} = (1 - \frac{C_{iROW} - C_{iMin\_ROW}}{C_{iMax\_ROW} - C_{iMin\_ROW}}), \]  \tag{5}

where
\[ C_{iROW} = \] the cost of land or right-of-way cost for candidate station location,
\[ C_{iMin\_ROW} = \] the minimum cost of land or right-of-way cost,
\[ C_{iMax\_ROW} = \] the maximum cost of land or right-of-way cost.

Stations should be within accessible distance from the existing transportation infrastructure to improve local and regional accessibility and promote intermodal integration. Hence, a utility quantification that assigns the maximum value, i.e., 1, with a continuously decreasing value with increasing network distance, can be formulated, as shown in equation 6.

\[ U_{i3} = \begin{cases} 1 & \text{if } D_{ni} \leq D_t \\ \frac{1}{e \left( \frac{D_{ni}^m}{D_t} - 1 \right)} & \text{if } D_{ni}^m > D_t, \end{cases} \]  \tag{6}

where
\[ D_{ni}^m = \] the network distance of candidate station location \( i \) from the existing transportation facility \( m \),
\[ D_t = \] the threshold average travel distance for mode \( t \).
16.3 Problem Formulation

The problem can be formulated as the maximization of the total utility score of candidate station locations in the study area. The utility score would reflect the extent of the desirable indicators being satisfied. Thus, the location with the maximum utility score would be the most optimal station location under the considered parameters. The combined utility score can be estimated by the weighted summation of the individual utility scores evaluated from the respective utility functions (Roy and Maji 2019). The weights assigned reflect the relative importance of each indicator. The station location identification can thus be formulated with the objective function, as shown in equation 7, subject to the constraints in equations 8–10.

\[
\begin{align*}
\text{Max} & \sum_{i=1}^{nc} \sum_{d=1}^{nd} \alpha_i \cdot \gamma_i \cdot w_d \cdot U_{id}, \\
\text{subject to} & \sum_{j=1}^{nj} w_d = 1, \quad 0 < w_d < 1, \tag{8} \\
& 0 \leq U_{id} \leq 1, \tag{9} \\
& \sum_{i=1}^{nc} \alpha_i = 1, \tag{10}
\end{align*}
\]

where
\[
\begin{align*}
\alpha_i & = \begin{cases} 
1 & \text{if candidate station location } i \text{ is selected} \\
0 & \text{otherwise}
\end{cases}, \\
U_{id} & = \text{Utility score based on desirable indicator } d \text{ for candidate station location } i, \\
w_d & = \text{weights assigned to indicator } d, \\
nc & = \text{total number of candidate locations in the study area}, \\
nd & = \text{total number of desirable indicators being considered}.
\end{align*}
\]

16.4 Methodology

Our methodology is adopted from previous research by Roy and Maji (2019). The feasible region of the study area is obtained by screening out infeasible locations, identified a priori. Grids equal to the station area size are developed in the feasible region with each grid representing
a candidate feasible station location. The utility score of each feasible station location concerning each desirable indicator is estimated using the respective utility functions. The weighted summation of these utility scores is the total utility of each feasible station location. The total utility score lies within the range of $[0, 1]$. Thus, grid locations with a total utility score close to 1 are the most suitable locations for an HSR station, whereas the grid locations with a total utility score close to 0 are the least suitable locations. The novelty of this methodology compared to the previous study is that network distance is considered over buffer distance for utility quantification. In this way, the study utilizes the road and transit network information of the study area, which was not considered in our previous research. Figure 16.1 shows the difference between buffer- and network-based accessibility.

From Figure 16.1, it can be observed that the buffer distance usually overestimates accessibility in comparison to the network-based distance. Hence, accessibility and proximity measures are more accurate when distance along the network is considered in the analysis over the buffer distances. Similarly, the derived utility quantification would also be more accurate and realistic.
16.5 Case Studies

Four cities in the Mumbai–Ahmedabad HSR corridor (which will be India’s first HSR line) were chosen as case studies to test the efficacy of the proposed model. The cities are Ahmedabad, Vadodara, Surat from the state of Gujarat, and Mumbai from the state of Maharashtra. A brief background on each of these cities is discussed in the subsequent sections. It is followed by a discussion on various types of data with their sources and usage. The data were processed and GIS operations were applied for further analysis.

**Mumbai.** Mumbai, formerly known as Bombay, is the capital city of the state of Maharashtra. As of 2018, Mumbai ranked second in terms of cost of living and population in India behind Delhi (UN 2018). Also, Mumbai city is the center of the Mumbai Metropolitan Region, which is the sixth most populous metropolitan region in the world (Cox 2019). The public transportation system in the city comprises the Mumbai Suburban Railway network (three corridors), Metro Rail Transit and Monorail (one corridor each), and Brihanmumbai Electric Supply and Transport (BEST) buses (over 390 routes). Among these, the BEST buses and suburban railway accounted for nearly 88% of the passenger traffic in 2008 (MMRDA 2009).

**Ahmedabad.** Ahmedabad is the former capital and the largest city of the state of Gujarat, India. As of 2011, it was the fifth most populous city in India (Chandramouli and General 2011). It is part of the urban agglomeration that is the seventh most populous in India (Cox 2019). Ahmedabad contributes 17% of Gujarat’s gross domestic product (GIDB 2005). The transportation system in the city is mainly roadway-based, with five ring roads and 17 radial roads (Islam et al. 2018; Vaidya et al. 2011). Janmarg, also known as Ahmedabad bus rapid transit system (BRTS), combined with the city bus service, accounts for a significant portion of the public transportation system in the city. The BRTS consists of 12 trunk routes that are well integrated (Islam et al. 2018; Vaidya et al. 2011).

**Surat.** Surat is the second-largest city in the state of Gujarat, India. It is a major economic and commercial center in south Gujarat and is the first smart information technology city in the country (CEPT 2018). The transport system in the city is mainly road-based with the Sitilink or Surat BRTS as the major public transit system with 11 corridors and 148 bus stops (CEPT 2018).

**Vadodara.** Vadodara, formerly known as Baroda, is the third largest city in the state of Gujarat, India (Chandramouli and General 2011). The city is characterized by high-density built-up areas and mixed land-use patterns. The transportation system in the city is mainly road-based and consists of city buses, with a BRTS system to be developed in the future (CEPT 2019).
16.5.1 Data Types

The various types of data used for spatial analysis in this study consist of spatial data in the form of vector shapefiles and raster GeoTIFF image files. Certain vector shapefiles and raster files were manually digitized and/or generated in ArcGIS 10.4 from secondary data sources, while others were downloaded from websites. Table 16.1 describes the parameters used in this study. Table 16.2 summarizes the data along with their type, usage, and source.

### Table 16.1: Parameters and Corresponding Values

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold Distance for Buffer Layer</td>
<td>$d$</td>
<td>13 km</td>
<td>RITES (2013)</td>
</tr>
<tr>
<td>Grid Size for Station Locations</td>
<td>$A_{r_g}$</td>
<td>70 acres</td>
<td>Brinckerhoff (2004)</td>
</tr>
<tr>
<td>Threshold Average Walking Distance</td>
<td>$D_w$</td>
<td>400 m</td>
<td>Guerra et al. (2012)</td>
</tr>
<tr>
<td>Threshold Distance from Downtown Area</td>
<td>$D_{th}$</td>
<td>3 km</td>
<td>Assumed</td>
</tr>
</tbody>
</table>

km = kilometer, m = meter.  
Source: Authors.

### Table 16.2: Available Data for Spatial Analysis

<table>
<thead>
<tr>
<th>GIS Data File</th>
<th>Type</th>
<th>Usage</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Network</td>
<td>Vector Polyline</td>
<td>To create bus stop service areas, downtown proximity following network distance and to determine road connectivity</td>
<td>Open Street Maps (n.d.)</td>
</tr>
<tr>
<td>Rail Network</td>
<td>Vector Polyline</td>
<td>To create station service areas, downtown proximity following network distance and to determine rail connectivity</td>
<td>Islam et al. (2018), Swami (2017), CEPT (2018, 2019)</td>
</tr>
<tr>
<td>Bus Network</td>
<td>Raster GeoTIFF</td>
<td>To create bus stop service areas, following network distance and to determine bus network connectivity</td>
<td>Islam et al. (2018), Swami (2017), CEPT (2018, 2019)</td>
</tr>
<tr>
<td>Land Use</td>
<td>Raster GeoTIFF</td>
<td>To extract spatial data of infeasible areas from the study area</td>
<td>Bhuvan (n.d.)</td>
</tr>
</tbody>
</table>
16.5.2 Weight Assignment

The effect of change in weights on the utility quantification was covered in the previous study by the authors (Roy and Maji 2019). In this study, equal weights are assigned to each desirable indicator for utility quantification, i.e., all the desirable indicators are considered equally important.

16.6 Results and Discussion

This section shows the results obtained when the proposed model was applied to the four cities. Figure 16.2 shows the study area within the buffer region surrounding the existing railroad. The infeasible regions were identified from the land use data and screened out to obtain the feasible regions. The feasible region was then fragmented into grid locations using the grid size mentioned earlier. Figure 16.2 shows the feasible grid locations obtained.

The feasible grid locations are the candidate station locations. It can be observed that for Ahmedabad, Mumbai, and Vadodara, the feasible locations are modeled to be close to the downtown area, whereas for Surat, the feasible locations are modeled to be outside the urban core. Figures 16.3, 16.4, and 16.5 show the variation of the utility score for the feasible grid locations with regard to accessibility to existing transportation facilities, downtown area proximity, and avoiding high right-of-way costs.

### Table 16.2 continued

<table>
<thead>
<tr>
<th>GIS Data File</th>
<th>Type</th>
<th>Usage</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway Stations</td>
<td>Vector</td>
<td>To determine rail network service areas, using data regarding rail station locations</td>
<td>Open Street Maps (n.d.)</td>
</tr>
<tr>
<td>Property Data</td>
<td></td>
<td>To calculate the possible price of land as per Chakravorty (2013)</td>
<td>99acres.com (n.d.), Magicbricks.com (n.d.)</td>
</tr>
<tr>
<td>Administrative Boundaries</td>
<td>Vector</td>
<td>To generate a grid layer with user-specified grid size for station locations</td>
<td>Open Street Maps (n.d.)</td>
</tr>
</tbody>
</table>

Source: Compiled by authors.
respectively, for each of the cities in this case study. We used the Network Analyst extension of ArcGIS 10.4 to evaluate the network distance-based service area of the transportation facilities, i.e., bus stops and train stations, along the road, bus, and train network data set. The service area polygons obtained were used to assign the accessibility utility score to the feasible grid locations based on the network distance and utility function shown in equation 6. Since Mumbai has both suburban rail and bus networks, the accessibility-based utility for Mumbai is the summation of the utility score based on network distance along both road and rail networks. For
other cities, the accessibility-based utility score is derived based on the network distance along the road network only.

The utility score for proximity to the downtown area was evaluated by developing the network distance-based service area from the downtown area. It provides locations within the proximity to or far away from the downtown area measured along the network. Again, in the case of Mumbai, the utility score is measured along both the suburban rail and road networks, whereas for the other cities, the utility score
is measured along the road network only. Mumbai, Ahmedabad, and Vadodara have higher utility values for feasible grid locations close to the downtown area, whereas Surat has a higher utility value for feasible grid locations outside the urban core. Since the downtown area is more densely developed, the cost-based utility score shows lower values for feasible grid locations closer to the downtown area and higher values outside the downtown area for all the cities (Figure 16.4).

**Figure 16.4: Utility Score—Downtown Proximity**

*Panel A. Vadodara*  
*Panel B. Mumbai*  
*Panel C. Ahmedabad*  
*Panel D. Surat*

HSR = high-speed rail.  
Source: Authors.
Figure 16.6 shows the total utility score of all feasible grid locations across all the cities. It forms the candidate pool for HSR station locations. Table 16.3 shows the value of each of the desirable indicators considered along with individual utility scores for the planned HSR station locations in Mumbai, Vadodara, Ahmedabad, and Surat. Equal weights were given to each desirable indicator. The planned HSR station location for Ahmedabad reported the highest utility score, whereas the lowest utility score was observed for Mumbai. The station location in Mumbai
reported the lowest value because even though the station location was closer to the downtown by road network distance, the absence of a nearby rail station means that the location does not have direct access to the downtown by suburban rail. The planned HSR station locations at Vadodara and Surat have similar utility scores. The station location at Vadodara was situated on land with a high-cost right-of-way, whereas the station location at Surat was located outside the urban core of the city and farther away from the nearest transportation facility and, thus, would require longer walking distance for access.

**Figure 16.6: Total Utility Score of All Feasible Grid Locations**

HSR = high-speed rail.
Source: Authors.
16.7 Conclusion

HSR station locations are vital, as they provide access to riders, serve as multi-modal transportation hubs (with connections to regional and local transit), and are prime locations for transit-oriented development. A GIS-based analytical model has been presented in this study that quantifies station location-specific, desirable indicators, which maximize the utility or benefit of the station. The study lists indicators related (but not limited) to the effect of improved area-wide, local accessibility and intermodal integration with existing transportation infrastructure, transit networks, avoidance of higher right-of-way cost and environmentally sensitive land parcels, and proximity to socioeconomic development hubs, i.e., the effect on commercial and industrial land uses within the actual service area of the potential HSR station location. The overall utility of an HSR station was quantified using suitable utility functions that analyze the extent to which a potential location satisfies each of these indicators. The novelty of this methodology compared to the previous study is that network distance is used rather than the buffer distance for utility quantification.

The utility quantification is more realistic and thorough as the accessibility of a potential location from the existing transportation infrastructure considers the actual service area of said transportation infrastructure that is dependent on the existing road and transit networks, unlike with simple buffer analysis. Planners can use such quantification for further analysis and station location selection as it
is more accurate. The proposed methodology was used to quantify the utility of the planned station locations at four major cities connected across the Mumbai–Ahmedabad HSR corridor in India and visually compare the obtained results with other potential locations across these cities. The developed methodology has improved upon our previously published work by making the analysis more realistic and, thus, more robust for field application. The future scope of work in this methodology could be the inclusion of additional amenities, details such as types of stations, parking requirements, access by a different mode of travel other than walking, and modeling subsequent steps of HSR development.
References


MMRDA (Mumbai Metropolitan Region Development Authority). 2009. Reports.


17

Transport Investment and Quality of Life: Evidence from Asian Countries

Md Aslam Mia

17.1 Introduction

It is widely accepted that quality transport infrastructure is a prerequisite for sustainable development and growth (Laird and Venables 2017; Jiang et al. 2017; Melia 2018), enhanced tourism and housing values (Chen and Haynes 2015), urbanization (Maparu and Mazumder 2017), strong international trade (Lorz 2020), improved resident well-being (Spinney, Scott, and Newbold 2009), and better quality of life (Steg and Gifford 2005; Kim and Ulfarsson 2013).

Due to the tremendous benefits of transport investment on a country and its inhabitants, most developing countries, while relying on interest-based external funding, have embarked on similar projects, despite their lack of favorableness in terms of cost-benefit analysis (CBA) (Eliasson et al. 2015). Although CBA had remained the center of focus for transport investment decisions for the past 50 years, there are other scopes beyond the CBA that policy makers should consider before implementing megaprojects. For example, financing a micro-project in some cases could be more effective than large-scale projects, although micro-projects are often difficult to quantify ex ante (Vickerman 2017). Another study also highlights the need to account for the dynamic structure and multi-dimensional effect of transport investment on several aspects of the society.

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1 The author would like to thank the participants of the ADBI transport conference held virtually in March and October 2020 for very useful and constructive comments and suggestions.

2 “Transport investment” is frequently used as a proxy for “transport and communication investment” in this study.
and economy (Caliskan 2006). As such, many developed and developing countries scrutinize the dynamic benefits of some of the government-funded projects rather than focus on the cost implications before implementing them. To better understand the importance of transport investment, the study also aims to investigate the comprehensive role of transport investment in various aspects of quality of life in Asia.

Despite the marked increase in transport investment in recent years, studies have suggested that most Asian countries have failed to fully utilize their trade potential and achieve economic progress due to the lack of quality transport system and road network connectivity with other countries (Su, Ke, and Lim 2011). In the context of developing countries, limited financial resources and the lack of financing options to fund infrastructure were not properly addressed in the early 1990s. This negligence was attributed to low economic growth, as most developing and emerging countries including India were preoccupied with liberalization and regulatory reforms at the time (Arvind 2004). However, many Asian countries have recently made significant progress in economic growth, which enabled governments to allocate more resources for infrastructure development. Additionally, regulatory reform and promotion of market-oriented approaches created a level playing field that attracts many private investors to the transport sector.

In recent years, several regional and international organizations and institutions have scaled up their investment loans to partnering countries, particularly for infrastructure projects. For example, the Belt and Road Initiative (BRI) of the People’s Republic of China (PRC) has injected around $68 billion into the infrastructural development of South Asian countries since 2013 (Rana and Ji 2020b). Similarly, the Asian Development Bank (ADB), a regional bank whose aim is to promote social and economic development in Asia and the Pacific, has also invested approximately $36.4 billion since its establishment in 1966 (ADB 2020). Although ADB is dedicated to improving several sectors in the region, around one-third of its total lending is devoted to infrastructure development, particularly in the transport sector (ADB 2020). Additionally, the World Bank has a portfolio of $36.95 billion that covers 83 countries and 179 projects to promote sustainable transport across the world (World Bank 2019). However, the current investment in transport by the multilateral development banks and bilateral financing is far below the yearly demand of $500 billion–$900 billion, according to the transport sector strategy report of the Asian Infrastructure Investment Bank (2018a, 2018b).

Understanding the consequences of the bulk of investment in transport and communication remains a growing concern for policy makers and academics due to limited studies from a macro perspective.
Thus, this study empirically investigates the effects of transport investment and other factors on the quality of life and its various components.

The chapter is organized as follows. Section 17.2 is a literature review, Section 17.3 explains the methodology, Section 17.4 provides a discussion of the results, and Section 17.5 concludes the chapter.

17.2 Literature Review

17.2.1 Conceptual Framework

Ample theoretical and empirical research has investigated the effect of transport investment on various aspects of economies and individuals. Generally, investment in transport infrastructure can be accomplished in two different forms: via qualitative improvement (e.g., reconstruction, expansion) or quantitative improvement (e.g., new roads). Developing countries generally prefer to undertake the quantitative mode of transport improvement by building new infrastructure (roads, ports, railways, etc.) to connect different cities within the country. Additionally, transnational roads and railways are also being built in developing countries, including in South Asia, on a regional basis. Qualitative improvement, on the other hand, is often conducted to reduce deterioration of the existing transport infrastructure. For example, an extra lane added to existing roads will increase the capacity of the road system. The benefit enjoyed by the users of the transport system may vary between these two forms of transport investment depending on the existing conditions of the transportation network. In other words, a new road will be significantly more useful if it is constructed in areas with no existing road network. Similarly, the expansion or qualitative improvement of a road may be more advantageous to residents of a city area if it reduces traffic congestion.

Despite the differences in the utility or satisfaction levels between the two modes of transport investment, both will have a profound impact on the quality of life, as daily commuting from one place to another is largely unavoidable in today’s circumstances. Investment in transportation connects cities, thereby minimizing travel time and disutility. In addition, passengers get to enjoy travel comfort and, hence, a better quality of life. However, investment in transport may also bring negative consequences; greater connectivity due to rapid growth in the infrastructure network will transform rural areas into urban, thereby increasing the cost of living and property prices (Zhong and Li 2016). Additionally, rapid investment, particularly in transportation, could cause environmental degradation as natural resources will be used for new construction or expansion of existing projects, consequently
affecting the quality of life (Shen, Sakata, and Hashimoto 2009; Tricker 2007).

To understand how transport investment affects various aspects of a country’s or individual’s development, Olsson (2009) has divided the effect into two dimensions, namely direct and indirect. The direct effect of transport investment is linked with the transport benefits, such as travel time reduction, enhanced utility, reliability, and cost reduction, all of which are less questionable due to their proven effect in the existing literature (Banister and Berechman 2001; Olsson 2009). Apart from the direct benefits of transport, the indirect or additional advantages to the road users or surrounding neighborhood remain unclear and inconclusive. Consequently, we hypothesize that increasing transport investment will have either a positive or negative effect on the subdimensions of quality of life (Figure 17.1), proposed based on the available data and literature (details are discussed in the methodology section). In line with the argument of Olsson (2009), apart from the

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**Figure 17.1: Framework of Transport and Communication Investment and Quality of Life**

- Transport and communication investment → Quality and quantity improvement
- Quality and quantity improvement → Purchasing power → Safety → Health care → Cost of living → Quality of life
- Quality and quantity improvement → Property price to income → Traffic commute → Pollution

Note: Factors or dimensions identified in this framework are not exhaustive, as other aspects of quality of life might be affected by transport investment.

Source: Author.
impact on traffic, we believe that other subdimensions are better classified under the indirect effect of transport investment since they are usually beyond the direct coverage of the transport sector as depicted in Figure 17.1.

17.2.2 Overview of Transport Investment in Asian Countries

For the past 2 decades, many Asian countries have witnessed rapid growth in transport investment, which has been financially aided by the central government, public–private partnerships (PPPs), private investment, and local government (Qin 2016). According to an estimate by the Asian Development Bank (ADB), out of the $26 trillion investment in Asia’s infrastructure development between 2016 and 2030, the transport sector needs a whopping $8.4 trillion (Abiad, Farrin, and Hale 2019).

Among countries in Asia, the PRC has experienced the most expansion in the transport sector in a bid to enhance its connectivity with the neighboring countries to spur trade and development. A major driver of this huge infrastructure investment is the rapid growth of the PRC’s economy over the last three decades (Qin 2016; Démurger 2014). Moreover, infrastructure development was also necessary for the PRC to reduce the economic disparity between its various provinces by enhancing movement of goods and services within the country. Thus, investment in infrastructure has been one of the priorities in the PRC’s five-year plan since the 1990s. To date, a substantial amount is still injected into the PRC’s transport sector, which exceeds those of almost all other Asian economies (Li, Wu, and Bin 2017). The recent surge in the PRC’s transport investment conforms with the country’s ambitious BRI project to connect roughly 70 countries along the ancient Silk Route (Zhai 2018).

After the PRC in infrastructure development is India, an emerging country with significant investment in transport infrastructure projects. To attain the intended level of economic growth in the country, the government has recently acknowledged the importance of infrastructure development, as the capacity and efficiency of the existing transport facilities were found to be inadequate (Thillairajan and Menon 2014). As a result, the Government of India has prioritized this sector in formulating its policies. There are sizeable economic disparities among various states of India, and without ensuring greater connectivity among all states, achieving progressive and uniform development will be relatively difficult. This also partly explains the interest of the Indian government to continuously invest in the transport infrastructure. Interestingly, the
majority of the large infrastructure investment including transportation between 1950 and 2012 was from the public sector (Mitra 2006; Bahal, Raisi, and Tulin 2018). However, the situation has changed in recent years with increasing participation of the private sector in India's infrastructure development (Thillairajan and Menon 2014). This trend is welcome, but as the PRC’s BRI increases that country’s competitive edge, the situation demands a still greater connectivity both within the country and with neighboring countries to retain India’s geopolitical influence in the region.

In recent years, a remarkable investment in transport was also observed in Pakistan, a long-time rival of India in many respects. While India failed to officially acknowledge the BRI of the PRC, Pakistan applauded the initiative and consequently received significant loans from the PRC to expand its domestic transport sectors and establish economic corridors with the PRC. Estimates also suggest that Pakistan received the highest portion of BRI funds among other South Asian countries (Rana and Ji 2020b). The stronger ties between the two countries in recent years was perhaps motivated by Pakistan’s aims to capitalize on the BRI to enhance its domestic rail, road, and port facilities as well as cross-border connectivity with the PRC (Rana and Ji 2020a). Consequently, Pakistan has enjoyed significant progress in transport investment most years, particularly after 2005.

Bangladesh has also been emphasizing its transport investment in recent years. This is reflected in some of the country’s mega infrastructure projects like Padma Multipurpose Bridge (Mahmood and Keast 2016) and the expansion of national highways to enhance connectivity among districts and with its neighboring countries to promote transnational trade. Initially, Bangladesh lacked transport investment via PPPs (Gordon 2012); however, the trend is now reversed, whereby PPP types of infrastructure financing are gaining momentum in Bangladesh (Hassan 2012; Sahrer and Haider 2020). To reiterate the importance of transport infrastructure in enhancing connectivity, growth, and development, the country had suffered a low rate of economic growth over the years (during the early 2000s) due to the lack of transport investment, particularly from the private sector (Islam, Dinwoodie, and Roe 2006).

Among the East Asian countries, Thailand took the lead toward transport infrastructure development, investing a huge amount into the sector in the early years of the 1990s (Pomlaktong et al. 2013). This is also demonstrated in the initiation of ADB’s Greater Mekong Subregion Economic Cooperation Program to connect other countries such as Cambodia, the PRC, the Lao People’s Democratic Republic, Myanmar, and Viet Nam by international road transport (ADB 2015). Other East
Asian countries have also followed suit with considerable investment in the sector in the early 2000s (e.g., Lao People’s Democratic Republic, Malaysia, and Viet Nam) (Andersson and Banomyong 2010; Mitsui 2004; Naidu 2008).

17.3 Methodology

17.3.1 Modeling Transport Investment and Quality of Life

The lack of data coupled with the complexity in representing the quality of life from a macro perspective has made modeling of transport investment and quality of life relatively difficult. Given the nature of the available data and the objectives of the study, the following econometric model is considered:

\[
\text{Quality of life}_{it} = \alpha_0 + \beta_1 \ln \text{Transport}_{it} + \beta_2 \ln \text{GDPPC}_{it} \\
+ \beta_3 \text{Inflation}_{it} + \beta_4 \text{Education}_{it} + \epsilon_{it}, \tag{1}
\]

where \( i \) represents a country, \( t \) is the respective time period or year, and \( \epsilon_{it} \) is the error term. We are particularly interested in estimating the coefficients of \( \beta_1 \) in order to examine the impact of transport and communication investment (natural logarithm, \( \ln \text{Transport} \)) on quality of life and its various subdimensions. The quality of life was represented by a series of dependent variables: cost-of-living index, safety index, health care index, price-to-income ratio, pollution index, and traffic index. While considering all these factors, the aggregate—quality-of-life index—was also regarded as a dependent variable in order to understand the impact of transport investment. The relationship between transport investment and quality of life (and its subdimensions) remains unclear (whether positive or negative); therefore, it will be examined in this study.

This study also employed a macroeconomic factor as an independent/control variable—the gross domestic product per capita (GDPPC), which is an effective proxy for measuring the economic well-being of the people (Becker, Philipson, and Soares 2005; Diener and Diener 1995; Bérenger and Verdier-Chouchane 2007). In general, a higher GDPPC results in an increased expenditure to meet material and leisure demands, consequently improving the living condition. Overall, a higher living standard and better quality of life are associated with higher national wealth; therefore, a positive association between GDPPC and quality of life is anticipated in this study.

Education levels can also reflect an individual’s quality of life. For example, Ross and Van Willigen (1997) highlighted that education has
two main effects on an individual's well-being and, subsequently, their quality of life. Firstly, by being educated, an individual stands a better chance of getting a well-paid job and getting access to various economic and noneconomic resources, consequently increasing their control of life and standard of living. Secondly, supportive relationships such as marriage and social bonds with various networks in the society can be established by acquiring formal education, which may subsequently enhance the well-being of an individual. Therefore, we believe that a positive association exists between education and quality of life. While there are broad ways to classify education (Michalos 2017), the country's compulsory minimum formal education will be established as the independent variable in this study.

Inflation remains a major factor affecting the general population (James 2001), as it is often said that wages do not increase with the rate of inflation and wage growth is lower than inflation growth in the majority of cases. In the context of a growing inflation rate, prices of necessary goods and services increase, resulting in an offset in income. It follows, therefore, that higher inflation will have a negative consequence on the quality of life. For ease of interpretation and normalization, the value of transport investment and GDPPC has been transformed into a natural logarithm. The definition of dependent and independent variables included in this study is presented in Appendix Table A17.1.

17.3.2 Data and Sources of Data

The study relied on three secondary sources for its data: Numbeo, ADB, and the World Bank. The quality-of-life data and its various components were collected from Numbeo, transport investment data from ADB, and other variables from the World Bank. Numbeo is considered the world's largest database where users directly submit data of various cities and countries. Numbeo filters submitted surveys to eliminate potential spam and ensure the validity and reliability of data. Due to its reliability and authenticity, Numbeo's data has been extensively used as the main source in many international media outlets (e.g., BBC, Forbes, Economist, Time, Financial Times). Hence, we are confident of the reliability, validity, and authenticity of the source and data. The main variable of interest is the investment in the transport sector, which was collected from ADB.

Initially, we attempted to capture data for as many countries as possible, but we encountered limitations. For instance, not all the Asian

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countries’ quality-of-life indexes (and their components) were reported by Numbeo; the quality-of-life index is the main dependent variable of interest in this study. Hence, only Asian countries having a quality-of-life index for a minimum period of a year were selected. This resulted in an unbalanced panel of data. In selecting the time period, we used some techniques to capture as many years as possible. However, Numbeo only recently commenced reporting their data from 2012 up to 2020, with ADB providing data for infrastructure only up to 2017 (after which no data exists as of the time of this research). Therefore, a timeline of 2012 to 2017 was selected for this study. After combining all three sources, only data for nine economies in Asia within a time period of 2012 to 2017 were selected and the observations were adequate to run a regression.\footnote{The economies are Bangladesh; Cambodia; People’s Republic of China; Hong Kong, China; Malaysia; Philippines; Singapore; the Republic of Korea; and Thailand.}

### 17.4 Findings and Discussion

To minimize the effect of outliers, all variables (except education) were winsorized at 5% levels; the descriptive statistics are reported in Table 17.1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs.</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality-of-Life Index</td>
<td>42</td>
<td>67.42</td>
<td>39.01</td>
<td>-4.40</td>
<td>135.62</td>
</tr>
<tr>
<td>Purchasing Power Index</td>
<td>42</td>
<td>62.32</td>
<td>25.26</td>
<td>28.37</td>
<td>102.38</td>
</tr>
<tr>
<td>Safety Index</td>
<td>42</td>
<td>63.21</td>
<td>17.61</td>
<td>31.45</td>
<td>83.65</td>
</tr>
<tr>
<td>Health Care Index</td>
<td>42</td>
<td>70.33</td>
<td>9.11</td>
<td>54.17</td>
<td>85.44</td>
</tr>
<tr>
<td>Cost-of-Living Index</td>
<td>42</td>
<td>61.02</td>
<td>19.95</td>
<td>37.47</td>
<td>100.01</td>
</tr>
<tr>
<td>Property Price to Income Ratio</td>
<td>42</td>
<td>18.87</td>
<td>6.94</td>
<td>8.04</td>
<td>30.09</td>
</tr>
<tr>
<td>Traffic Commute Index</td>
<td>42</td>
<td>41.21</td>
<td>7.10</td>
<td>30.50</td>
<td>54.89</td>
</tr>
<tr>
<td>Pollution Index</td>
<td>42</td>
<td>71.47</td>
<td>16.11</td>
<td>40.40</td>
<td>100.00</td>
</tr>
<tr>
<td>Lntransport</td>
<td>41</td>
<td>2.07</td>
<td>1.37</td>
<td>0.35</td>
<td>5.01</td>
</tr>
<tr>
<td>LnGDPPC</td>
<td>42</td>
<td>9.31</td>
<td>1.08</td>
<td>7.73</td>
<td>10.89</td>
</tr>
<tr>
<td>Inflation</td>
<td>42</td>
<td>1.99</td>
<td>1.31</td>
<td>-0.52</td>
<td>4.44</td>
</tr>
<tr>
<td>Education</td>
<td>41</td>
<td>8.32</td>
<td>1.79</td>
<td>5.00</td>
<td>11.00</td>
</tr>
</tbody>
</table>

GDPPC = gross domestic product per capita.

Source: Author’s estimate based on secondary data.
Generally, regression analysis built upon primary or secondary data is prone to a multicollinearity issue, where one independent variable is highly correlated with another. In the presence of this issue, the estimation of coefficients may be biased and weak. Consequently, we had to screen the data set for the inexistence of the multicollinearity problem. Upon estimating the variance inflation factors (VIFs) and pairwise correlation (Table 17.2), which are commonly used in the existing literature to test multicollinearity, the results were discovered to be much lower than the maximum threshold (Kennedy 2008; O’Brien 2007). Hence, the estimated regression models are not affected by the problem of multicollinearity.

Table 17.2: Pairwise Correlation and Variance Inflation Factors among Independent Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>VIF</th>
<th>LnTransport</th>
<th>LnGDPPC</th>
<th>Inflation</th>
<th>Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>LnTransport</td>
<td>1.10</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LnGDPPC</td>
<td>1.30</td>
<td>0.10</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation</td>
<td>1.09</td>
<td>-0.07</td>
<td>-0.18</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>1.36</td>
<td>0.28</td>
<td>-0.44</td>
<td>-0.07</td>
<td>1.00</td>
</tr>
<tr>
<td>Mean VIF</td>
<td>1.21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GDPPC = gross domestic product per capita, VIF = variance inflation factor.
Source: Author’s estimate based on secondary data.

Subsequent to the availability of the panel data, the pooled ordinary least square (POLS) and random effect model (REM) were employed. The results are reported in Tables 17.3 and 17.4. However, the fixed effect model (FEM) could not be implemented, as the education variable is time invariant. After the POLS and REM were run, the Lagrange multiplier (LM) test was performed to decide which model was better. Our results suggested that the REM was better than the POLS except between Models 15 and 16. Since the LM test was insignificant between Models 15 and 16, Model 16 was consequently considered to be better fit than Model 15. Thus, we take the coefficient of Model 16 as a reference for explaining the impact of transport investment in the pollution index. Taking the model specification into consideration, the F statistics under POLS and Wald Chi² under REM were discovered to remain significant at the 1% to 10% levels for all models. Moreover, the estimated models were also discovered to possess a reasonably good R² (ranging from 19% to 82%) regardless of the POLS or REM.
Initially, it was discovered that transport investment had a significant positive effect on the pollution index (under POLS) and a significant negative effect on the traffic index (lower is better) (Table 17.4). One of the main objectives of investment in transport is to provide the commuter with a quality, hassle-free, and efficient travel experience. Our findings emphasized the negative impact that transport investment will have on the travel commute index, which implies that people will enjoy a better quality of movement from one place to another, and travel will require comparatively less time and probably less cost. As expected, greater investment in transport infrastructure comes with a price, which is environmental pollution and degradation. Construction of roads will result in the exploitation of natural resources and an increase in overall carbon emissions, greenhouse gases, acid rain, and a threat to the overall geographical diversity (Button 1993; Banister and Button 2015). Our finding also echoes the argument of Andong and Sajor (2017), who observed that rapid urbanization and expansion of transport industry leads to greater carbon emission.

Table 17.3: Factors Affecting Quality of Life and Its Components, Models 1–8

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
<th>Model 6</th>
<th>Model 7</th>
<th>Model 8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>REM</td>
<td>POLS</td>
<td>REM</td>
<td>POLS</td>
<td>REM</td>
<td>POLS</td>
<td>REM</td>
<td>POLS</td>
</tr>
<tr>
<td>Quality-of-Life  Index</td>
<td>5.14</td>
<td>(5.75)</td>
<td>-0.10</td>
<td>(4.22)</td>
<td>2.74</td>
<td>(2.01)</td>
<td>2.52</td>
<td>(1.82)</td>
</tr>
<tr>
<td>Purchasing       Power Index</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lntransport</td>
<td>33.36***</td>
<td>(7.75)</td>
<td>29.03***</td>
<td>(3.60)</td>
<td>20.07***</td>
<td>(4.06)</td>
<td>18.47***</td>
<td>(2.40)</td>
</tr>
<tr>
<td>LnGDPPC</td>
<td>-4.54***</td>
<td>(1.68)</td>
<td>-6.08***</td>
<td>(2.21)</td>
<td>-1.08</td>
<td>(1.16)</td>
<td>0.13</td>
<td>(1.42)</td>
</tr>
<tr>
<td>Inflation</td>
<td>3.47</td>
<td>(2.78)</td>
<td>3.76*</td>
<td>(2.18)</td>
<td>-1.12</td>
<td>(1.78)</td>
<td>-1.37</td>
<td>(1.38)</td>
</tr>
<tr>
<td>Education</td>
<td>-271.98***</td>
<td>(78.43)</td>
<td>220.34***</td>
<td>(42.11)</td>
<td>-118.29***</td>
<td>(37.78)</td>
<td>-103.61***</td>
<td>(28.99)</td>
</tr>
<tr>
<td>Cons</td>
<td>18.90***</td>
<td>(42.11)</td>
<td>24.21***</td>
<td>(37.78)</td>
<td>18.35***</td>
<td>(28.99)</td>
<td>16.97***</td>
<td>(29.98)</td>
</tr>
<tr>
<td>F-stat</td>
<td>48.60***</td>
<td></td>
<td>429.11***</td>
<td></td>
<td>38.45***</td>
<td></td>
<td>37.63***</td>
<td></td>
</tr>
<tr>
<td>Chi²</td>
<td>6.51***</td>
<td></td>
<td>15.14***</td>
<td></td>
<td>26.59***</td>
<td></td>
<td>31.57***</td>
<td></td>
</tr>
<tr>
<td>LM Test</td>
<td>0.59</td>
<td></td>
<td>0.62</td>
<td></td>
<td>0.67</td>
<td></td>
<td>0.74</td>
<td></td>
</tr>
<tr>
<td>R²(Overall)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GDPPC = gross domestic product per capita, LM = Lagrange multiplier, POLS = pooled ordinary least square, REM = random effect model.

Note: Robust standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

Source: Author’s estimate.
With an improvement in movability and connectivity, an increase in the presence of people and traffic enforcement officers is bound to occur, resulting in a low probability of occurrence of crimes and a subsequent positive effect on the safety index. The results also indicated that transport investment will have a negative effect on the health care index, which may signal that countries focusing heavily on transport investment may have to trade off with health care commitments as the resources are limited. However, these results remained statistically insignificant despite having an intended sign of the coefficient.

We also discovered that a higher income as proxied by GDPPC will have a significant positive impact on explaining the quality of life (Table 17.3). Generally, when an individual earns more, they will be able to spend more on their needs and lead a better life. An increase in the GDPPC also indicates an improvement in the overall well-being of an

Table 17.4: Factors Affecting Quality of Life and Its Components, Models 9–16

<table>
<thead>
<tr>
<th></th>
<th>Model 9</th>
<th>Model 10</th>
<th>Model 11</th>
<th>Model 12</th>
<th>Model 13</th>
<th>Model 14</th>
<th>Model 15</th>
<th>Model 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost-of-Living</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>REM</td>
<td>POLS</td>
<td>REM</td>
<td>POLS</td>
<td>REM</td>
<td>POLS</td>
<td>REM</td>
<td>POLS</td>
</tr>
<tr>
<td>Lntransport</td>
<td>-2.71</td>
<td>-0.14</td>
<td>0.38</td>
<td>1.52**</td>
<td>-2.30**</td>
<td>-2.35***</td>
<td>-2.30**</td>
<td>3.77***</td>
</tr>
<tr>
<td></td>
<td>(2.57)</td>
<td>(0.95)</td>
<td>(1.26)</td>
<td>(0.63)</td>
<td>(1.12)</td>
<td>(0.86)</td>
<td>(1.12)</td>
<td>(1.16)</td>
</tr>
<tr>
<td>LnGDPPC</td>
<td>12.71***</td>
<td>18.73***</td>
<td>2.67</td>
<td>2.91**</td>
<td>0.53</td>
<td>-0.12</td>
<td>0.53</td>
<td>-9.43***</td>
</tr>
<tr>
<td></td>
<td>(4.04)</td>
<td>(1.72)</td>
<td>(2.38)</td>
<td>(1.13)</td>
<td>(2.75)</td>
<td>(1.11)</td>
<td>(2.75)</td>
<td>(1.56)</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.91</td>
<td>0.32</td>
<td>0.89***</td>
<td>0.01</td>
<td>0.55</td>
<td>1.36*</td>
<td>0.55</td>
<td>3.17***</td>
</tr>
<tr>
<td></td>
<td>(1.18)</td>
<td>(1.17)</td>
<td>(0.34)</td>
<td>(0.63)</td>
<td>(0.78)</td>
<td>(0.70)</td>
<td>(0.78)</td>
<td>(1.01)</td>
</tr>
<tr>
<td>Education</td>
<td>0.95</td>
<td>1.76</td>
<td>1.32</td>
<td>1.58**</td>
<td>-0.42</td>
<td>0.42</td>
<td>-0.42</td>
<td>-0.33</td>
</tr>
<tr>
<td></td>
<td>(1.60)</td>
<td>(1.13)</td>
<td>(0.93)</td>
<td>(0.60)</td>
<td>(1.58)</td>
<td>(0.69)</td>
<td>(1.58)</td>
<td>(1.11)</td>
</tr>
<tr>
<td>Cons</td>
<td>-61.59***</td>
<td>-128.84***</td>
<td>-15.79</td>
<td>-24.76*</td>
<td>44.45</td>
<td>41.16***</td>
<td>44.45</td>
<td>148.16***</td>
</tr>
<tr>
<td></td>
<td>(30.42)</td>
<td>(22.80)</td>
<td>(25.53)</td>
<td>(14.07)</td>
<td>(32.29)</td>
<td>(13.90)</td>
<td>(32.29)</td>
<td>(19.27)</td>
</tr>
<tr>
<td>F-stat</td>
<td>37.54***</td>
<td>3.92***</td>
<td>2.87**</td>
<td>2.08***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chi^2</td>
<td>24.23***</td>
<td>17.43***</td>
<td>17.38***</td>
<td>17.38***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LM Test</td>
<td>12.18***</td>
<td>50.80***</td>
<td>21.76***</td>
<td>0.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R^2</td>
<td>0.75</td>
<td>0.82</td>
<td>0.24</td>
<td>0.31</td>
<td>0.19</td>
<td>0.28</td>
<td>0.59</td>
<td>0.60</td>
</tr>
</tbody>
</table>

GDPPC = gross domestic product per capita, LM = Lagrange multiplier, POLS = pooled ordinary least square, REM = random effect model.

Note: Robust standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.
Source: Author’s estimate.
individual and, consequently, an increase in the overall purchasing power, safety, cost of living, and property prices. Interestingly, our results also revealed that an increasing GDPPC will have a resulting negative impact on the pollution index, as exhibited in economically developed nations, whose growing concern is to preserve the environment to ensure a healthy transition to the future generations (Model 16). Ample studies have investigated the impact of economic growth—often measured by GDPPC—on environmental quality based on the environmental Kuznets curve (EKC) hypothesis (Dinda 2004). Empirical studies generally agree that a rise in the income level up to a certain threshold causes people or countries to be more conscious of the environment (Sarkodie 2018). Although the EKC hypothesis was not directly tested in this study, our observation of a negative relationship between GDPPC and the pollution index partially supports the general argument of the EKC hypothesis.

Although a minimum compulsory education has a positive effect on the overall quality of life, this factor remained statistically insignificant at all conventional levels. That being established, the minimum education was discovered to have a positive and statistically significant effect on the safety and health care indexes. Interestingly, we also discovered that higher inflation would have a negative consequence on the quality of life as the overall living expenses increase. It will also lead to a decrease in the property price-to-income ratio since an increase in income is disproportionate to an increase in inflation. In contrast, higher inflation will result in a higher pollution index, a result that is statistically significant.

17.5 Conclusion

The study has examined the factors affecting the quality of life and its components for nine Asian countries by considering panel data techniques with a longitudinal data set from 2012–2017. Although transport investment had an insignificant effect on the overall quality of life, we discovered that greater investment in transport resulted in a better commuting experience for residents. Unfortunately, greater investment is tantamount to a higher pollution index, a tension that presents an important question to policy makers when taking on mega-infrastructure projects. There should be an adequate policy response to minimize the effects of investments in transport on environmental pollution.

Among others, our study also finds that people with higher income will enjoy a better quality of life and will be more concerned about preserving the environment. Higher inflation erodes the income of people and consequently lowers their quality of life. Since minimal
compulsory education is found to have a significant effect on the various components of the quality of life (safety and health care indexes), countries may consider reviewing the length of compulsory education.

The study attempted to model the quality of life and its various determinants based on secondary sources of data; hence, as in other studies, some limitations exist. For example, a static model due to a small sample size has been considered; however, it would be more beneficial to consider a dynamic panel model to better capture the determinants of quality of life (e.g., taking time lag of transport investment and dependent variable(s) and considering generalized methods of moment) with a large sample size, if this is possible in the future. Moreover, the study considered only a macro perspective of quality of life and its components; the results may vary when modeling the individual-level quality of life. In testing this, cross-sectional data from an individual level may provide a micro perspective of quality of life and various aspects of living standards.
References


## Appendix 17.1

### Table A17.1: Variables and Definition

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Unit</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality-of-life index</td>
<td>Is an estimation of overall quality of life by using an empirical formula that takes into account purchasing power index, pollution index, house price to income ratio, cost-of-living index, safety index, health care index, traffic index, and climate index.</td>
<td>Number</td>
<td>Higher is better</td>
</tr>
<tr>
<td>Purchasing power index</td>
<td>Shows relative purchasing power in buying goods and services in a given city for the average net salary in that city, local.</td>
<td>Number</td>
<td>Higher is better</td>
</tr>
<tr>
<td>Cost-of-living index</td>
<td>Is a relative indicator of consumer goods prices, including groceries, restaurants, transportation, and utilities.</td>
<td>Number</td>
<td>Exclude accommodation expense, lower is better</td>
</tr>
<tr>
<td>Safety index</td>
<td>Safety index is the opposite of the crime index. Crime Index is an estimation of overall level of crime in a given city or a country.</td>
<td>Scale</td>
<td>Higher is better</td>
</tr>
<tr>
<td>Health care index</td>
<td>Is an estimation of the overall quality of the health care system, health care professionals, equipment, staff, doctors, cost, etc.</td>
<td>Scale</td>
<td>Higher is better</td>
</tr>
<tr>
<td>Property price to income ratio</td>
<td>Is the basic measure for apartment purchase affordability.</td>
<td>Ratio</td>
<td>Lower is better</td>
</tr>
<tr>
<td>Pollution index</td>
<td>Is an estimation of the overall pollution in the city.</td>
<td>Scale</td>
<td>Lower is better</td>
</tr>
<tr>
<td>Traffic index</td>
<td>Is a composite index of time consumed in traffic due to job commute, estimation of time consumption dissatisfaction, CO₂ consumption estimation in traffic, and overall inefficiencies in the traffic system.</td>
<td>Number</td>
<td>Lower is better</td>
</tr>
<tr>
<td>LnTransport</td>
<td>Natural logarithm of central government expenditure on transport and communication.</td>
<td>$ billion</td>
<td>Local currency was converted to $ based on current exchange rate by the author.</td>
</tr>
</tbody>
</table>

*continued on next page*
Table A17.1 continued

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Unit</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>LnGDPPC</td>
<td>Natural logarithm of GDP per capita</td>
<td>$</td>
<td>Higher is better</td>
</tr>
<tr>
<td>Inflation</td>
<td>Inflation as measured by the consumer price index</td>
<td>%</td>
<td>Lower is better</td>
</tr>
<tr>
<td>(annual %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>Duration of compulsory education measured by the number of years that children are legally obliged to attend school.</td>
<td>Number of years</td>
<td>Higher is better</td>
</tr>
</tbody>
</table>

$\text{CO}_2 = \text{carbon dioxide, GDP = gross domestic product, GDPPC = gross domestic product per capita.}$

Source: Author’s compilation from NUMBEO, the Asian Development Bank, and the World Bank. Details of the estimation procedure of quality of life and its various sub-dimensions can be found here: https://www.numbeo.com/quality-of-life/indices_explained.jsp
18

Urban Transportation Systems in Selected Small Developing Island States: A Comparative Analysis

Urwa Khan and Juan Gonzalez

18.1 Background

In an efficient economy, the transport network plays a crucial role for the movement of people and goods. Rapid economic growth, development, and social change in the Pacific island countries has led to increased mobility and urbanization. These developments are putting pressure on transport systems, which need to be upgraded to provide equal access and better service. Additionally, with the rapid increase in the population, countries have experienced growing demand for well-functioning and sustainable urban transport systems. Over the last few decades, the Asian Development Bank (ADB) has been assisting its developing member countries in different sectors, with the transport sector as one of ADB’s main sectors. This chapter gives deep insight into the current status of urban transportation systems and ADB’s efforts in supporting the development of sustainable transportation systems in the Pacific developing member countries (DMCs).

This study brings to light the challenges and opportunities in the urban transportation sector in the Pacific DMCs, where ADB is financing projects in every sector to achieve more inclusive, resilient, and sustainable socioeconomic growth.

This study covers the following topics on urban transport challenges and opportunities in particular small island developing states (SIDS):

- socioeconomic characteristics of SIDS and main cities;
- transport overview of countries and cities including car ownership, car use, and existing public transport modes;
• institutional organization of the broad transport sector and urban transport, including public–private partnerships and provision of transport services in terms of quality and safety;
• challenges regarding the development of sustainable urban transport systems; and
• investment needs and opportunities for the implementation of sustainable urban transport systems.

18.1.1 Asian Development Bank’s General Approach to Urban Transportation

ADB has evaluated different approaches to ensure the sustainability of operations in urban transport systems. The following elements are likely to feature in urban transport operations:
• public transport systems;
• nonmotorized transport;
• integrated urban transport planning.

ADB’s Sustainable Transport Initiative (STI) points out essential areas for new and enhanced lending to augment support for sustainable infrastructure (ADB 2010). The initiative supports climate-resilient transport, safety, cross-country trade infrastructure, and investments in urban transport.

18.1.2 Pacific Growth, Challenges, and Scenarios

The Pacific islands’ growth performance has been poor. The area has experienced low or negative per capita income growth. Four of the five Micronesian countries had negative growth in the period 1990–2004 and only Fiji produced an average growth of more than 1% per year (WB 2018b).

The Pacific will be unable to meet its pressing challenges without sustained acceleration in growth. Resilient urban transport infrastructure is a key to achieving the necessary gross domestic product (GDP) growth, as the tourism industry—the main source of income for these islands—requires efficient and resilient urban transport systems.

In the Pacific island countries, transportation infrastructure growth lags far behind when compared to the Caribbean. Geography, poor institutional governance, and lack of investment in the sustainable transport systems also contribute to the appalling situation of the urban transport systems in SIDS in the Pacific.
18.1.3 Asian Development Bank Strategy 2030 and Sustainable Transport in the Pacific

The Pacific DMCs are exposed to a wide range of worsening climate-related hazards, such as tropical cyclones, floods, droughts, storm surges, and sea level rise. The region also faces geophysical hazards such as volcanic eruptions and earthquakes. To drive the economic growth and to ensure the quality of life in the Pacific, it becomes crucial to provide communities with sound transport infrastructure. In order to achieve a more equitable, resilient, and sustainable development track in Asia and the Pacific, ADB Strategy 2030 sets operational goals. The following focus areas highlight the important operational considerations:

- tackling poverty and reducing inequality;
- dealing with the impact of climate change by ensuring resilience in the development projects and focusing on environmental sustainability;
- promoting food security and rural development;
- fostering regional cooperation and integration;
- accelerating progress in gender equality;
- making cities more livable; and
- strengthening governance and institutional capacity.

18.2 Methodology

There is relatively little comparative research on urban transportation systems, especially among small island developing states. This chapter uses a desktop study on the urban transportation systems of six SIDS economies. The small islands under consideration are Fiji, Papua New Guinea, Jamaica, Cuba, Maldives, and Mauritius. The list comprises small island economies in the Caribbean (Cuba and Jamaica), the Pacific (Fiji and Papua New Guinea), and the Indian Ocean (Maldives and Mauritius). The choice of SIDS is limited by data availability. Nevertheless, to the authors' best knowledge, this is the first piece of research to analyze the urban transportation systems of SIDS in such a systematic way using a variety of socioeconomic and transportation indicators. We also incorporated the Sustainable Urban Transport Index (SUTI) to examine the urban transportation systems of Suva and Port Moresby. SUTI has been developed by the United Nations Economic and Social Commission on Asia Pacific and is a tool to analyze the performance of urban transportation systems in cities.
18.2.1 Selection of Countries to Review the Urban Transportation System

Small island developing states (SIDS) represent a diverse group of low-lying coastal countries. The United Nations currently classifies 52 countries and territories as SIDS. These islands are positioned across the Indian, Pacific, and Atlantic Oceans with the highest concentration of SIDS in the Caribbean and the Southwest Pacific. Due to the small size, remoteness from larger markets, and vulnerability to natural disasters, these islands experience greater risks of economic shocks and are more marginalized from the global economy than are many other developing countries.

From the Indian and Pacific Oceans. Mauritius and Maldives are good examples from the Indian Ocean. Other SIDS can learn from the economic miracle of Mauritius that helped in maintaining the stable economy. Mauritius's urban land transport system is appealing for two important reasons. Firstly, the transport sector is the third-largest contributing sector to the Mauritian economy and is perceived as a crucial driver for the economic growth of Mauritius. Secondly, the urban transport in Mauritius has many of the transport problems faced in other developing countries such as traffic congestion, traveler discontent about public transportation modes, rapid growth of private motorization, and lack of nonmotorized transport infrastructure.

In the Pacific, Fiji is one of the most developed of the Pacific island economies, though it remains a developing country that still requires substantial investments in its transport sector to promote tourism. Papua New Guinea has dealt with numerous challenges over the past few years, including the earthquake in 2018 that had a devastating impact on so many lives and the economy.

From the Caribbean. From the Caribbean, we chose Cuba and Jamaica to compare the urban transportation systems of their capital cities. Cuba's revolution resulted in an early and abrupt shift from personal transport to public transport. The government ended the ban on private vehicle sales in 2013, but even used cars remain costly for most individuals. If expenditure stays concentrated on public transport and nonmotorized infrastructure, major changes in access could be made at relatively little expense. In this case, Cuba has a rare opportunity to develop an effective, sustainable urban transportation system.

Jamaica's GDP per capita is a little lower than that of Fiji (WB 2017) and its economy is as vulnerable as those of Fiji and Papua New Guinea. The urban transportation system is already affected by weather extremes. Recently, Jamaica is bringing a change in the urban transportation sector as part of Vision 2030 Jamaica: National Action
Plan. Similarly, the Fijian government has also launched its Greater Suva Transportation Strategy 2030 to bring change in the urban transportation sector and to make it more sustainable and resilient. In the wake of this, studying the current transportation systems of the capital cities of the SIDS will allow us to learn what these SIDS can learn from each other in managing urban transportation systems. Based on the above discussion, the next part of this chapter will explore the urban transportation systems of the capital cities of the following six SIDS:

- Pacific Ocean
  - Fiji (Suva)
  - Papua New Guinea (Port Moresby)
- Caribbean
  - Cuba (Havana)
  - Jamaica (Kingston)
- Indian Ocean
  - Maldives (Malé)
  - Mauritius (Port Louis)

### 18.2.2 Socioeconomic Analysis of the Selected Countries

This section inspects the following listed socioeconomic indicators for the selected SIDS:

- Logistics performance index (World Bank 2018d)
  - Infrastructure
- Notre Dame Global Adaptation Initiative country index (University of Notre Dame 2017)
  - Vulnerability (ecosystem services, food, health, human habitat, infrastructure, water, adaptive capacity, exposure, and sensitivity)
  - Adaptability (economic, governance, and social readiness)
- Human development index (UNDP 2017)
- GDP per capita in international $ (IMF 2018b)
- Land area and population

### 18.2.3 Logistics Performance Index

The logistics performance index (LPI) is an interactive benchmarking tool developed to assist countries to highlight the challenges and opportunities they face on trade logistics and ways to improve their performance.

The LPI is the country’s weighted average on the six key dimensions mentioned in Figure 18.1. This chapter focuses on the LPI dimension.
that measures the transport-related infrastructure. Figure 18.2 shows the 2018 LPI rankings of the small island developing states and the top 5 leading countries in the LPI rankings. It can be seen that, among the selected SIDS, Mauritius is performing better on LPI rankings compared

**Figure 18.1: Logistics Performance Index Key Dimensions**

![Diagram showing key dimensions of logistics performance index]


**Figure 18.2: Logistics Performance Index Ranking Comparison**

![Bar chart showing LPI rankings for selected countries and top performing countries]

to other SIDS, whereas Germany is the top performer among the 155 economies ranked in the LPI. Figure 18.3 shows the comparison of the selected SIDS and the top-performing economies on the LPI score and its dimensions on the infrastructure. Among the selected SIDS, Mauritius and Maldives are performing better than other SIDS, while Germany is ranked at the top in terms of the infrastructure dimension of LPI.

![Figure 18.3: Logistics Performance Index Score and Dimension for Infrastructure Comparison](image)

LPI = logistics performance index.


### 18.2.4 Notre Dame Global Adaptation Initiative Country Index

The Notre Dame Global Adaptation Initiative (ND-GAIN) country index is a free open-source index that shows a country’s current vulnerability to and readiness for climate disruptions. Figure 18.4 shows that Mauritius is the top performer in the ND-GAIN index among the selected SIDS, whereas Norway ranked at the top overall. Figure 18.5 shows that Maldives is more vulnerable than the other economies—Fiji, Papua New Guinea, Cuba, Jamaica, and Mauritius.

The ND-GAIN country index shows that small islands face increasing challenges to address the impact of climate change. In recent years, record-breaking hurricanes and typhoons in the Caribbean and Pacific have caused huge damage to the infrastructure. In the Pacific, most of the small islands have shown increasing vulnerability on the
Figure 18.4: Comparison of the Notre Dame Global Adaptation Initiative Country Index

Selected Countries

Index score

Papua New Guinea, Cuba, Jamaica, Maldives, Mauritius

Top 5 Performing Countries

Index score

Norway, New Zealand, Finland, Sweden, Australia, Switzerland

Source: University of Notre Dame (2017).

Figure 18.5: Vulnerability and Readiness Score Comparison for Selected Countries

Vulnerability

Readiness

Fiji, Papua New Guinea, Cuba, Jamaica, Maldives, Mauritius

Source: University of Notre Dame (2017).
ND-GAIN index over the last 5 years, including Fiji and Papua New Guinea.

For Papua New Guinea, the high vulnerability score and low readiness score show that the country urgently needs investment and innovation to improve readiness. Cuba’s ND-GAIN index suggests that its current vulnerabilities are manageable but improvements in readiness will help it better adapt to future challenges.

Jamaica has enhanced its adaptive capacity over the past few years with improvement in sanitation facilities and access to clean drinking water. As a result, the country has become less dependent on imported energy and now performs considerably better than other Caribbean island states. Figure 18.6 shows the ND-GAIN index for top performing countries for vulnerability and readiness.

Table 18.1 shows a set of indicators that help describe the context of transport and climate change policy in the six countries, using secondary data from different sources. Out of a large set of possible indicators, we used those that provided the most important information on the socioeconomic and transport system and are comparable between different countries.
Table 18.1: Selected Country Indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Unit</th>
<th>Source</th>
<th>Fiji</th>
<th>Papua New Guinea</th>
<th>Cuba</th>
<th>Jamaica</th>
<th>Maldives</th>
<th>Mauritius</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>Thousands</td>
<td>WB (2018a)</td>
<td>883</td>
<td>8,606</td>
<td>1,133</td>
<td>2,935</td>
<td>436</td>
<td>1,265</td>
</tr>
<tr>
<td>GDP/Capita</td>
<td>International $</td>
<td>IMF (2018a)</td>
<td>5,752</td>
<td>2,530</td>
<td>8,433</td>
<td>5,392</td>
<td>10,536</td>
<td>10,547</td>
</tr>
<tr>
<td>HDI Index</td>
<td>Number</td>
<td>UNDP (2018)</td>
<td>0.741</td>
<td>0.544</td>
<td>0.777</td>
<td>0.732</td>
<td>0.717</td>
<td>0.790</td>
</tr>
<tr>
<td>Area</td>
<td>Km²</td>
<td>WB (2018c)</td>
<td>18,272</td>
<td>462,840</td>
<td>109,884</td>
<td>10,991</td>
<td>297.8</td>
<td>2,040</td>
</tr>
<tr>
<td>Urbanization</td>
<td>%</td>
<td>WB (2018e)</td>
<td>56</td>
<td>13</td>
<td>77</td>
<td>56</td>
<td>39.8</td>
<td>40.8</td>
</tr>
<tr>
<td>tCO₂/Capita</td>
<td>Tons</td>
<td>WB (2016)</td>
<td>2.3</td>
<td>0.9</td>
<td>2.5</td>
<td>2.8</td>
<td>3.0</td>
<td>3.4</td>
</tr>
<tr>
<td>Motorization Index</td>
<td>Number vehicles/1,000 capita</td>
<td>NM (2014)</td>
<td>179</td>
<td>13</td>
<td>38</td>
<td>188</td>
<td>N/A</td>
<td>192</td>
</tr>
<tr>
<td>GDP Growth Rate</td>
<td>%</td>
<td>WB (2018b)</td>
<td>3</td>
<td>0.2</td>
<td>2.2</td>
<td>1.9</td>
<td>8.8</td>
<td>3.8</td>
</tr>
</tbody>
</table>

GDP = gross domestic product, HDI = Human Development Index, IMF = International Monetary Fund, NM = NationMaster, km = kilometer, tCO₂ = CO₂ emissions per capita in tons, UNDP = United Nations Development Program, WB = World Bank.

Source: Compiled by authors.

18.3 Urban Transport Review of the Selected Cities

This section will explain the transportation systems of the capital cities of the chosen SIDS. We emphasized the importance of addressing challenges and proposing sustainable solutions for the urban transportation systems.

18.3.1 Suva (Capital City of Fiji)

With the resulting effects of unemployment, insufficient socioeconomic services, and informal settlements, Suva is experiencing the pressure of rapid urbanization. The *Atlas of Urban Expansion* (Lincoln Institute of Land Policy 2016) estimates Suva’s population at 181,160 people.

Due to rapid urbanization, the key issues faced by Suva are relatively consistent across all modes of transport. Following are the key issues with the Suva transportation network:
• traffic congestion;
• deteriorating bus infrastructure;
• lack of quality infrastructure to support a sustainable transportation system;
• lack of nonmotorized transportation infrastructure;
• lack of enforcement and regulations; and
• need for safety and transport education for the general public.

**Mode share in Suva.** It is important to note that Suva has a higher share of motorized transport (63%), unlike the national statistics that showed a higher share for nonmotorized transport (53%). Buses, minibuses, and taxis form an important part of the urban transport system, with buses being the most frequently used.

**Number of vehicles registered.** Fiji’s strong economic growth over the past 9 years has seen a corresponding growing trend of motor vehicle and car ownership (Figure 18.7). As a result, traffic congestion has become a severe problem for daily commuters and is affecting the already vulnerable economy.

**Figure 18.7: Motor Vehicles Registered in Fiji**

<table>
<thead>
<tr>
<th>Type of Vehicle</th>
<th>2012</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private vehicles</td>
<td>85,642</td>
<td>54,919</td>
</tr>
<tr>
<td>Commercial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxis</td>
<td>16,646</td>
<td>18,684</td>
</tr>
<tr>
<td>Rental cars</td>
<td>6,071</td>
<td>6,394</td>
</tr>
<tr>
<td>Government vehicles</td>
<td>2,096</td>
<td>4,040</td>
</tr>
<tr>
<td>All other vehicles (including omnibus and diplomats)</td>
<td>1,988</td>
<td>2,010</td>
</tr>
</tbody>
</table>


**Road transport authorities in Fiji.** The Fiji Roads Authority is the main agency responsible for managing the public transportation system. The Ministry of Finance, Ministry of Local Government, and the Ministry of Works are some of the main stakeholder institutions involved the development of the transport system in Fiji.

**Public transportation.** In Suva, public transportation is provided mainly by buses and taxis. Fiji’s bus service covers 95% of the population.
Private companies also entered into the transport system by introducing buses in the network. Generally, passengers considered bus services affordable, but they also highlighted the lack of comfort, safety, and cleanliness.

**Challenges for public transportation.** To avoid unfair competition by private operators, the public transport system was shielded by the governmental policy. Recently, due to the excessive introduction of legal and illegal minibuses in the network by private operators, the industry is putting the pressure on the government. An aging fleet and deteriorating road conditions are some of the causes in the increased operational costs.

**Public perception of the bus industry.** As per the survey conducted in 2009, most people consider buses to be affordable, safe, and good (Table 18.2). Safety (34%), accessibility (32%), and quality of service (26%) were some of the important indicators mentioned by the users in the survey conducted by Orion consultants in 2009. The Fiji Land Transport Authority contracted with Orion Consultants to undertake a review of the Fiji bus industry. The Orion consulting team spent 4 weeks in Fiji from December 2008 to January 2009. During the field visit, the team contacted Land Transport Authority officials, the Transport Planning Unit, the Fiji Bus Operators Association, the Consumer Council of Fiji, and other relevant agencies. The survey also shows the respondents’ views on the level of bus fares and willingness to pay extra to save 20 minutes (Table 18.3). Table 18.3 shows that 45% of the respondents responded “OK” on the question asking their views on the level of bus fares, whereas 60% of the respondents were not willing to pay extra to save 20 minutes.

**Table 18.2: Passenger Perceptions of the Best Features of Bus Services**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Number of Respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safe</td>
<td>77</td>
<td>34</td>
</tr>
<tr>
<td>Affordable</td>
<td>72</td>
<td>32</td>
</tr>
<tr>
<td>Good service level</td>
<td>58</td>
<td>26</td>
</tr>
<tr>
<td>Comfortable</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>226</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: Fiji Land Transport Authority (2016).
Table 18.3: Respondents’ Views on the Level of Bus Fares and Willingness to Pay to Save 20 Minutes

<table>
<thead>
<tr>
<th>Response</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>OK</td>
<td>110</td>
<td>45</td>
</tr>
<tr>
<td>A bit too high</td>
<td>89</td>
<td>37</td>
</tr>
<tr>
<td>Much too high</td>
<td>40</td>
<td>16</td>
</tr>
<tr>
<td>Can afford a bit more</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Can’t afford it now</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>I don’t care</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>243</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cents extra</th>
<th>Number of Respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>141</td>
<td>60</td>
</tr>
<tr>
<td>10</td>
<td>31</td>
<td>13</td>
</tr>
<tr>
<td>20</td>
<td>37</td>
<td>15</td>
</tr>
<tr>
<td>30</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>40</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>236</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Fiji Land Transport Authority (2016).

Future scenarios for sustainable transportation in Suva.
To develop a sustainable urban transport system, the Fiji Roads Authority drafted the Greater Suva Transportation Strategy for the years 2015 to 2030, with the vision to have an inclusive, prosperous, and environmentally friendly capital city. The World Bank is also cooperating with the national government to have a resilient and sustainable transportation system through the Transport Infrastructure Investment Project for Fiji (WB 2015). Car sharing schemes, inclusion of electric taxis, bicycle infrastructure, and pedestrian crossings are some of the important considerations mentioned in the plan.

Mid-block pedestrian crossings were installed in 2018 in several locations across Suva as part of the Greater Suva Transportation Strategy 2015–30. Previously, pedestrians were supposed to cross the road using a zebra crossing. There is a need to have a bicycle and pedestrian path system with essential features such as signage, bicycle parking places near bus stations and parks, and related infrastructure that includes public restrooms. The Greater Suva Transportation Strategy 2015–30 suggests banning illegal parking of cars to promote nonmotorized transport.

18.3.2 Port Moresby (Capital City of Papua New Guinea)

With a population of about 350,000, Port Moresby is the largest city in the South Pacific. The steady growth in the population of Port Moresby places its urban public transport system on the verge of collapse.
Public transport authorities. The National Road Safety Council, Road Traffic Authority, and Land Transport Division are some of the major governmental agencies responsible for developing and managing the urban transport system.

Types of public transportation systems. The popular modes of urban transportation modes used in Papua New Guinea are buses, especially 25-seat coasters and 15-seat minibuses. For short distances, people prefer 25-seat buses, and they prefer 15-seat buses for long distances. The suitability of the bus is determined by the heat and humidity or the atmosphere in Port Moresby. From a safety viewpoint, many city residents prefer 25-seat buses. Buses have been found to be the dominant mode in urban public transportation (Table 18.4).

Public perception of public transport in Port Moresby. The interviews and observations made in the study by Assa (2015) show that public transport in the capital of the nation is not effective and affordable.

According to the study on efficient and affordable public transport, only 9% of the participants think that the cleanliness of the buses is excellent (Table 18.5). However, other participants believe that operators should focus on cleanliness.

Nonmotorized transport. Nonmotorized transport infrastructure in Port Moresby is almost nonexistent. There are very few pedestrian crossings, and those that exist lack clear markings. Additionally, to ensure the safety of pedestrians, road signage is sparse and is mostly vague, while motorists cannot clearly see the existing road signage and markings. Traffic lights have been improved and are assisting in managing the flow during peak hours. A better choice than installing expensive overpasses that are not secure or user-friendly is to accommodate pedestrian crossing signals at existing traffic lights.

### Table 18.4: Types of Public Motor Vehicles in Port Moresby

<table>
<thead>
<tr>
<th>Type</th>
<th>Capacity (Seats)</th>
<th>Coverage of Service Provided in the City (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coaster bus</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>Minibus</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Trucks</td>
<td>36</td>
<td>20</td>
</tr>
<tr>
<td>Taxi</td>
<td>4</td>
<td>30</td>
</tr>
</tbody>
</table>

Source: Assa (2015).
Table 18.5: Survey Results on Bus Transport Service

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Assessment</th>
<th>Number of Participants</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friendliness</td>
<td>Excellent</td>
<td>20</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>Very good</td>
<td>75</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>174</td>
<td>58.0</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>16</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>Very poor</td>
<td>15</td>
<td>5.0</td>
</tr>
<tr>
<td>Cleanliness</td>
<td>Excellent</td>
<td>27</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td>Very good</td>
<td>131</td>
<td>43.7</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>119</td>
<td>39.7</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>17</td>
<td>5.7</td>
</tr>
<tr>
<td></td>
<td>Very poor</td>
<td>6</td>
<td>2.0</td>
</tr>
<tr>
<td>Comfortable seats</td>
<td>Excellent</td>
<td>88</td>
<td>29.3</td>
</tr>
<tr>
<td></td>
<td>Very good</td>
<td>102</td>
<td>34.0</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>70</td>
<td>23.3</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>39</td>
<td>13.0</td>
</tr>
<tr>
<td></td>
<td>Very poor</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>Traffic rule adherence</td>
<td>Excellent</td>
<td>16</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>Very good</td>
<td>41</td>
<td>13.7</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>101</td>
<td>33.7</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>142</td>
<td>47.3</td>
</tr>
<tr>
<td></td>
<td>Very poor</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Safety</td>
<td>Excellent</td>
<td>63</td>
<td>21.0</td>
</tr>
<tr>
<td></td>
<td>Very good</td>
<td>108</td>
<td>36.0</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>118</td>
<td>39.3</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>7</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>Very poor</td>
<td>14</td>
<td>4.7</td>
</tr>
<tr>
<td>Respect for women</td>
<td>Excellent</td>
<td>8</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>Very good</td>
<td>15</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>67</td>
<td>22.3</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>135</td>
<td>45.0</td>
</tr>
<tr>
<td></td>
<td>Very poor</td>
<td>75</td>
<td>25.0</td>
</tr>
</tbody>
</table>

Source: Assa (2015).
18.3.3 Havana (Capital City of Cuba)

Havana is located on the northern coast of Cuba and is one of the island’s 15 administrative provinces. Cuba’s transport situation has been well studied (Warren and Enoch 2003). It resembles those of Latin America and Europe in the 1960s with very low vehicle ownership. Intra- and inter-urban transit service is limited. Many boroughs in Havana are compact, with most services available within walking distance. Urban street networks are well developed with small street grids and multi-lane arterials feeding into the center city (Warren et al. 2015).

**Transportation challenges in Havana.** Transportation is another challenge in Havana. While it is known for its iconic mid-century American cars, Havana has low rates of private vehicle ownership, an estimated 37 cars per thousand people (Warren et al. 2015), and high reliance on transit. However, the austerity of the Special Period included cuts to public transportation service, which continue to be felt. Analysts have suggested that the addition of a bus rapid transit trunk line to the city’s network, accessible to local routes and feeder services in low-density areas, could increase connectivity and service levels.

**Opportunities in Havana.** Havana is well positioned to learn from other countries that have experienced similar phases of transformation. Major investments in the transportation sector without proper planning resulted in disappointing results owing to poor patronage, improper pricing, or lack of control and expenditure over time. Investments in transportation system technologies such as modeling, smart transportation planning, and user-centered design approaches open the door for the operators to ensure sustainability and efficiency in the transport operations. Interventions like public car and bike share schemes can facilitate a shift away from traditional motorized transport to efficient urban transportation systems.

**Public transport in Havana (metro bus and suburban railway).** Havana Metro Bus is a part of the public transport network and is the major public transport mode in Havana. The fleet of the Metro Bus is linked to several suburban rail stations. Havana Suburban Railway is a passenger rail network serving Havana and its suburbs. Owned by the national company Ferrocarriles de Cuba, is the only suburban rail system of the Caribbean island.

**Nonmotorized transport.** Havana can take pride in maintaining majestic sidewalks and must concern itself about suffering from too many narrow, squalid, damaged sidewalks. It is also a city where pedestrians naturally take over a good part of the streets, de facto pedestrianizing them. Several reputable companies in Havana hire out bikes that are fine for getting around town. In a country with economic constraints and limited resources, the bicycle culture of Havana has both flourished for
its alternative mode of transportation and struggled as new bikes and repair parts become more and more scarce.

18.3.4 Kingston (Capital City of Jamaica)

Kingston’s transportation system is already affected by weather extremes. Damage to transport infrastructure due to natural disasters and extreme weather conditions is commonplace. With the upcoming revision of Jamaica’s National Transport Policy, the government aims to build climate-proof future and current investments in light of a changing climate. In view of an evolving and more complex environment, the government aims to invest in climate-resilient transport infrastructure.

Public transport in Kingston. In the Kingston area, the Jamaica Urban Transit Company operates bus routes, providing public access for over 250,000 people daily across a network that stretches for 2,747 kilometers. It is a government-run bus company that operates in and around the corporate area of greater Kingston. Coasters are smaller privately owned public buses that often blare loud music and drive recklessly.

Challenges and opportunities for public transportation. Monitoring and enforcement of the regulations that have long been established is a serious concern for the regulators. Government agencies responsible for managing the public transportation system are lacking funds and facing a lot of pressure from the informal transport operators. Lack of institutional capacity is also contributing to the inefficiency of the urban transportation system in Kingston.

Nonmotorized transport as per Vision 2030. Kingston is planning to have a transport infrastructure that will support nonmotorized transport in the capital city by implementing the following policy measures:

- Establish infrastructure to encourage use of bicycles.
- Install signage, sidewalks, and other related facilities along the road infrastructure for the pedestrians.
- Maintain and enforce minimum standards and guidelines for sidewalks.
- Repair all sidewalks and remove utility poles in sidewalks.
- Enforce regulations on the transport network to facilitate nonmotorized transport.
- Promote knowledge of the road laws and safety issues among bicyclists and pedestrians.
- Carry out road safety public education programs.
- Promote the pedestrian transport mode in appropriate areas.
18.3.5 Malé (Capital City of Maldives)

The Republic of Maldives is a small South Asian developing country. In fact, it is the sixth-smallest sovereign state in the world in terms of land area. Maldives is an archipelago that consists of approximately 1,200 islands scattered along a chain of 20 administrative coral atolls, which makes Maldives among the most vulnerable and least defensible countries to the projected impacts of the global problem of climate change, including sea level rise.

**Urban transportation in Malé.** Malé has moved rapidly from nonmotorized to motorized transport. The number of vehicles is remarkably high considering the size of Malé. The rapid increase in private vehicle ownership is a major concern. Although most of the roads are paved, there is still a need to ensure the safety of pedestrians and bicyclists. The introduction of a sustainable public transport system has been proposed to tackle the current problems. Transport policies and national strategies on transport development are the responsibility of the Ministry of Transport and Communication in the small island country.

**Public transportation.** Taxis are the main mode of public road transport in Malé. Buses are the main mode of public road passenger transport in Hulhumale (the newly created residential island in the greater Malé urban area). No other type of public transit system is used, and this causes heavy local congestion during the peak hours.

**Transport challenges and opportunities.** Over 50% of households that own a car do not have their own parking for vehicles. Many office buildings and commercial establishments are putting up buildings without even a fraction of the required parking. Every new vehicle that is imported will need approximately two new parking spaces apart from space for circulation. There is no parking fee and no effective control of parking at the present time. The biggest reason for the present congestion is the haphazard traffic management and lack of parking management.

Even though there is considerable pedestrian activity, facilities for pedestrians are grossly lacking. This has resulted in loss of quality of social interactions especially for children and the elderly in Malé. This also encourages unnecessary motorized travel and parking needs.

18.3.6 Port Louis (Capital City of Mauritius)

Located in the Indian Ocean, the island of Mauritius is a tiny but densely populated developing nation with a total area of 2,050 square kilometers and a population of 1.3 million. With population increase due
to migration to urban areas, the demand for urban transportation has dramatically increased, as in other developing countries.

**Public transport challenges and opportunities.** Public transport in Mauritius is mainly provided by the bus and taxi network throughout the entire island. Public transport passengers during peak hours have faced significant difficulties, including the deteriorating bus infrastructure, lack of cleanliness, and poor scheduling. As for the age distribution of the current bus fleet, 35.3% of the buses are less than 5 years old, 25.8% are between 5 and 9 years old, and 38.9% are between 10 and 18 years old. With no subsidy provided by the government, the bus operators are under increasing financial pressure.

Bus operators have introduced a small number of direct services, which are appealing to passengers. With the current challenges of the bus industry and the rise in general prosperity, taxis serve as an important transport mode to meet specific needs of time and place. The taxi industry has grown in an uncontrolled way, and licenses granted to taxi operators do not best serve the public. Recently, the government adopted the Mauritius Bus Modernization Program, which enables all the bus operators to renew their fleet with no extra cost to be put on passengers.

**Nonmotorized transport.** In Port Louis, the high-density housing requires easy access to the bus stations and nonmotorized transport infrastructure for pedestrians and bicyclists. However, policy makers gave more importance to private vehicle owners than to nonmotorized transport users, which resulted in traffic congestion and environmental concerns. As a priority, the government aims to enhance nonmotorized transport infrastructure in the area.

Vehicle sharing, smart road pricing, enhancement of institutional capacity, and knowledge sharing programs for the transport operators are some of the steps taken by the government to ensure sustainability in the urban transport operations.

### 18.4 Sustainable Urban Transport Index for Suva and Port Moresby

We used the Sustainable Urban Transport Index (SUTI) developed by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP 2017) to compare the performance of the urban transport systems in Suva and Port Moresby. The index is based on 10 important indicators reflecting the social, economic, and environmental dimensions of a sustainable urban transportation system. Data collection and values for the indicators are given in Appendix Table A18.1. Table 18.6 gives the normalized values of the index for Suva and Port Moresby.
Table 18.6: Sustainable Urban Transport Index
Indicators Normalized Values

<table>
<thead>
<tr>
<th>No.</th>
<th>Indicator</th>
<th>Unit of Measure</th>
<th>Range</th>
<th>Normalization: Suva</th>
<th>Normalization: Port Moresby</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Value</td>
</tr>
<tr>
<td>1</td>
<td>Extent to which transport plans cover facilities for active modes and public transport</td>
<td>0–16 scale</td>
<td>0</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>Modal share of active and public transport in commuting</td>
<td>Trips</td>
<td>10</td>
<td>90</td>
<td>65</td>
</tr>
<tr>
<td>3</td>
<td>Convenient access to public transport service</td>
<td>Number of people</td>
<td>20</td>
<td>100</td>
<td>65</td>
</tr>
<tr>
<td>4</td>
<td>User satisfaction with public transport service</td>
<td>% satisfied</td>
<td>30</td>
<td>95</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>Traffic fatalities per 100,000 inhabitants</td>
<td>Number of fatalities</td>
<td>35</td>
<td>0</td>
<td>9.6</td>
</tr>
<tr>
<td>6</td>
<td>Affordability travel costs as part of income</td>
<td>% of income</td>
<td>35</td>
<td>3.5</td>
<td>19</td>
</tr>
<tr>
<td>7</td>
<td>Operational costs of the public transport system</td>
<td>Cost recovery ratio</td>
<td>22</td>
<td>175</td>
<td>95</td>
</tr>
<tr>
<td>8</td>
<td>Investment in public transport systems</td>
<td>Share of total investment</td>
<td>0</td>
<td>50</td>
<td>28</td>
</tr>
<tr>
<td>9</td>
<td>Air quality (PM10)</td>
<td>μg/m³</td>
<td>150</td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>10</td>
<td>Greenhouse gas emissions from transport</td>
<td>Tons</td>
<td>2.75</td>
<td>0</td>
<td>0.87</td>
</tr>
</tbody>
</table>

m = meter, PM = particulate matter. μg = microgram.
Source: Data from UNESCAP (2017).

Figure 18.8 shows a spider diagram presenting the indicators of the two cities.

The results clearly show that the two cities score quite differently overall. Suva City showed good performance with the higher aggregate SUTI score of 57.65, whereas Port Moresby, dominated by deteriorating transport infrastructure with low fares, has the lower aggregate SUTI score of 43.96. The aggregate SUTI score only provides a rough approximation of performance. Port Moresby’s low SUTI score may be due to low accessibility, low public perception of quality and reliability of public transport, and a poor safety and transport infrastructure.
record. In comparison to Port Moresby, Suva City has a good urban transport master plan, with a focus on nonmotorized transport. The fare structure of public transport in the Pacific DMCs is relatively affordable. Fare revision is a sensitive issue for cities and national transport authorities. Often, city authorities or central governments provide subsides to the public transport operators and control for the private operators. Generally, the cities experience different circumstances, spatial conditions, and economic development. Therefore, they will not be able to deliver the same level of performance. Differences in reported performance are, in some cases, influenced by data availability and quality.

18.5 Policy Actions and Interventions

This study highlighted some of the major issues currently facing the public transit system in the SIDS. It has been established that the majority of the population living in cities relies primarily on public transportation. Due to the rapid increase in the population in the urban
areas, it has become crucial for each national government to provide an urban transportation system that offers equal accessibility to the urban dwellers. Despite many common vulnerabilities, Pacific SIDS have different infrastructure resilience profiles and priorities.

18.5.1 For Suva

The urban transportation system in Suva is at a critical point. The time has come to make this area a regional model of sustainable mobility for its people. It would be a perfect time for Fiji to unveil a new transport vision to prove that a low-carbon development paradigm can be accomplished by sustainable transport initiatives. The best way for Fiji to handle congestion is to find ways to maintain the popularity of public transport, especially buses. Effective public transport systems would be suitable for cities in developing countries such as Fiji. Bus transport is already very common in Fiji, with recent studies estimating that it accounts for between 50% and 70% of all journeys. A good first step would be to realize that the privately owned bus industry offers an important service that sustains economic development.

Some of the initiatives that could be introduced rapidly include traffic optimization, such as priority measures for buses and high occupancy vehicles to improve the attractiveness and transport capability of public transport. Investments in bus operations in Fiji will encourage people to shift to public transport from the current rising trend in private cars.

18.5.2 For Papua New Guinea

This chapter found a lack of national agencies responsible for implementation and regulation of the transport operations in Papua New Guinea. This study shows that there are more than three separate transport authorities doing the same job. The study highlights the need to create a common agency to enact the relevant transport policies to resolve the problems reported by users of public transport.

Amendment of current regulations, strengthening of institutional governance, provision of transit shelters, and priority given to nonmotorized transport operations would help Papua New Guinea in dealing with the current urban transport challenges. Roads and streets are not pedestrian-friendly, a problem that highlights the need to introduce policies that focus more on the sustainability of the overall urban transportation system. This can provide an environment that promotes and facilitates social and economic development activities.
These measures would require a holistic approach with substantial investment in public transport systems and nonmotorized infrastructure. Continuing engagement with stakeholders in forums and integrating their views and concerns would make a positive contribution to providing pedestrian-friendly roads, towns, and communities.


### Appendix 18.1

**Table A18.1: Explanation of Sustainable Urban Transport Index Indicators**

<table>
<thead>
<tr>
<th>Indicator 1: Aspects</th>
<th>Explanation: Suva</th>
<th>Score</th>
<th>Explanation: Port Moresby</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking Infrastructure</td>
<td>Improvement in nonmotorized transportation measures include narrowing carriageways, installing green belts along the road, and arranging the traffic space.</td>
<td>3</td>
<td>The Port Moresby Vision 2030 plan depicts the city with the preference for nonmotorized transport, where walking infrastructure (including pedestrian crossings, paved sidewalks, and safety lights) will be given preference in the transportation infrastructure development.</td>
<td>2</td>
</tr>
<tr>
<td>Cycling Network</td>
<td>Installation of a bicycle network along the main carriageways. Inclusion of bicycle riding laws in the urban transport planning framework.</td>
<td>2</td>
<td>Funding for cycling infrastructure is not clear in Vision 2030. Currently, cycling infrastructure is nonexistent across the main carriageways.</td>
<td>1</td>
</tr>
<tr>
<td>Intermodal Transfer Facilities</td>
<td>The strategy highlights the integration of transport and land use by connecting the current urban transportation modes backed by funding.</td>
<td>2</td>
<td>Vision 2030 shows interconnected transport modes that integrate people’s daily lives with a hierarchy of compact urban centers that are the focus of suburbs, settlements (to suburbs), and neighborhoods.</td>
<td>1</td>
</tr>
<tr>
<td>Expansion of Public Transport</td>
<td>Plans for more frequent services, with improved waiting facilities, optimization of the fleet, inclusion of passenger information systems, and park-and-ride facilities, are the main priority measures.</td>
<td>2</td>
<td>The future plan is to complete the primary road network, and improve the public transport network including mass transit, small vans (public motor vehicles), and regional bus routes.</td>
<td>2</td>
</tr>
</tbody>
</table>

*continued on next page*
Table A18.1 continued

<table>
<thead>
<tr>
<th>Indicator 2</th>
<th>Mode</th>
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<tr>
<td>Suva</td>
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<tr>
<td></td>
<td>Minibus</td>
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<tr>
<td></td>
<td>Taxi</td>
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<td></td>
<td>Walking</td>
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<td></td>
<td>Car</td>
<td>30</td>
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<tr>
<td></td>
<td>Public and active (bus, minibus, walking)</td>
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<tr>
<td>Port Moresby</td>
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<tr>
<td></td>
<td>Public motor vehicles (small vans)</td>
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<tr>
<td></td>
<td>Taxi</td>
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<td></td>
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<tr>
<td></td>
<td>Public and active (bus, small vans, walking)</td>
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<th>Port Moresby</th>
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<tr>
<td>3</td>
<td>Convenient access to public transport service</td>
<td>65</td>
<td>Data are based on the bus routes, schedule, and in areas within 500 meters of main nodes.</td>
<td>60</td>
<td>Data are based on the bus routes, schedule, and in areas within 500 meters of main nodes.</td>
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<td>5</td>
<td>Traffic fatalities per 100,000 inhabitants</td>
<td>9.6</td>
<td>World Bank report on the development indicators (WB 2016)</td>
<td>14.2</td>
<td>World Bank report on the development indicators (WB 2016)</td>
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<td>6</td>
<td>Affordability: travel costs as part of income</td>
<td>19</td>
<td>Assessment by the Ministry of Infrastructure and Transport in Fiji in 2019</td>
<td>13</td>
<td>Assessment by the Department of Transport in Papua New Guinea in 2019</td>
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<th>Port Moresby</th>
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<td>7</td>
<td>Operational costs of the public transport system</td>
<td>95</td>
<td>Data are derived from consultations with private and public stakeholders held in Suva in 2019.</td>
<td>70</td>
<td>Data are derived from consultation with bus operators in Port Moresby in 2019.</td>
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<td>8</td>
<td>Investment in public transport systems</td>
<td>28</td>
<td>Based on Fiji Roads Authority (2014, 2019)</td>
<td>17</td>
<td>Based on numbers issued by Papua New Guinea transport sector support program and Department of Transport Papua New Guinea</td>
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<td>9</td>
<td>Air quality (PM10)</td>
<td>24</td>
<td>69 μg/m³ in 1989 to 24 μg/m³ in 2013 (Isley et al. 2017)</td>
<td>12</td>
<td>Data from International Association for Medical Assistance to travelers (IAMAT 2019)</td>
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<td>10</td>
<td>Greenhouse gas emissions from transport (CO₂e tons/year)</td>
<td>0.87</td>
<td>In 2016, greenhouse gas emissions were estimated around 864 Gg of CO₂e (Prasad and Raturi 2019).</td>
<td>0.24</td>
<td>Total greenhouse gas emissions are expected to increase from 2.4 to 3.3–4.5 Mtons CO₂e by 2030 (World Data Atlas 2016).</td>
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CO₂e = carbon dioxide equivalent, Gg = gigagram, m = meter, Mtons = metric tons, PM = particulate matter, μg = microgram.

Source: Data from UNESCAP (2017).
PART V
Research and Innovation for High-Speed Rail Development in Developing Nations
While understanding the different development effects of massive transportation infrastructure (like high-speed rail, or HSR) is critical for policy makers and for governments in countries that envisage it as a policy tool for regional development, it is equally important to develop capacity in multiple areas to handle the complex stakeholder management and smooth realization of project goals. The enormous challenges involved in planning, design, construction, operation, and maintenance of a huge socio-technical system like HSR can be diverse and context-specific depending on the region’s existing capabilities in various disciplines as well as the region’s projects, legal system, procurement system, and so on. These differences range from ease of adopting technological advancements and technology management to the unique set of interdisciplinary needs that a project can impose in terms of engineering, research, innovation, human resource development, quality, safety, reliability, and risk management, etc. Hayashi, Seetha Ram, and Bharule (2020) point out that such complexities cannot be handled in isolation due to the two-way and simultaneous influence and interaction among stakeholders with distinct needs with only a little overlap. It is therefore imperative to ensure that the relationships between these stakeholders stay harmonious throughout the project’s life cycle. Capacity development including the framework of research and development to solve local problems is therefore an inevitable component for sustainable projects.

In the context of HSR development, as discussed in previous chapters, the motivation behind the introduction of HSR systems differed for each country. For some, including Japan, the motivation was

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1 With contributions from Jitendra Sondhi (Railway Management and Engineering Consultant, World Bank, India). Partly drawn from the deliberations and discussions held at the session titled “Capacity Building for Engineering, Research, Innovation, and Construction Technology Management in Sustainable Transport Infrastructure Development” held on 13 October 2020 of the ADBI-Chubu University Conference (virtual) on Transport Infrastructure Development, Spillover Effects, and Quality of Life. The authors also acknowledge the contributions from the participants of this session.
promoting economic development along its famous economic corridor (between Tokaido belt cities in Japan’s case), while for others, such as Spain, it was favoring cohesion and territorial equity. Many a time, countries hoped that a new HSR line would provide better connectivity and frequent service between the many regions and bring changes to the prevalent modal share as discussed in Part III of this volume. Considering such heterogenous objectives in conjunction with the diverse capacity development needs that the local context brings, the impacts of HSR services also vary all over the world. Even in the same country, it is possible that different HSR lines do not replicate a similar framework. During its history of nearly 6 decades, HSR as a technology has evolved significantly with respect to aspects including new track technologies, successive generations of trains and advancing construction methods, tunneling technologies, ticketing systems, project finance, and station area development. Part V of this edited volume presents some ongoing research from the developing world, concerning the technological and social aspects of transport infrastructure development. The case of India, which plans to build its first HSR line spanning 508.09 kilometers between the cities of Mumbai and Ahmedabad (referred to as the Mumbai–Ahmedabad High-Speed Rail, or MAHSR), is an underlying motivation for this part of the edited volume. Four chapters, comprising this fifth part, are refined from the presentations of the authors of the called-for papers and invited papers who participated in the ADBI-Chubu University conference (held virtually during 12–16 October 2020). These cases, along with a summary of the pertinent discussions held during the conference, produce lessons for HSR researchers and development leaders and hopefully also contribute to enhancing understanding of the key issues for involved stakeholders in HSR development in India.

Chapter 19 by Khare presents the vision of HSR development in India and appropriately sets up the context by summarizing the project facts of the MAHSR link and its need in India along with the planning goals and framework, the expected impacts, the prevailing challenges in the implementation, and finally possible opportunities and solutions for the indigenous regional development in the states of Maharashtra and Gujarat, which will experience this enhancement through the HSR service. The author also briefly discusses the institutional frameworks that are devised and adopted by the public organization responsible for India’s HSR development. These frameworks ensure active stakeholder engagement and encourage the fostering of local innovation for the project’s success.

Chapter 20 by Loganathan et al. emphasizes the importance of enhancing the productivity of the construction sector in developing countries so that the envisaged goals of infrastructure developments
can be realized. Factors that can contribute to such an enhancement in construction productivity are identified and discussed in the context of India, where a rapid increase in infrastructure creation has been witnessed. Such a scenario also projects the simultaneously increasing construction and maintenance needs of the planned and existing infrastructure, which can be much more labor intensive in developing countries. It is hence imperative to also improve labor productivity in the construction sector considering its major role in overall construction productivity. The authors articulately discuss the infrastructure needs and plans of India, review the pertinent literature on productivity in the construction sector, and suggest ways for improving this productivity in the Indian case. Four key suggestions in this regard are argued to be the quasi-formalization of the workforce, making the construction sector aspirational, initiatives to train and retain construction workers, and the fixing of wages based on marginal revenue product. Based on their literature review, these authors also conclude that there is a critical need to undertake focused research projects in the future that address the issues of productivity of labor in the construction sector in developing countries like India.

Chapter 21 by Roy and Maji highlights the highly constrained and multi-objective decision-making process of arriving at an HSR alignment. The chapter applies an artificial intelligence-based, computer aided, spatial exploration technique to develop such a process. The authors discuss the various objectives that transportation planners try to optimize during the widely practiced human- and experience-centered approaches, dominated by factors such as construction cost, operations cost, environmental impact, and user cost. Out of an infinite number of alternatives that are possible between two points, this complex task can be carried out by heuristics-based optimization algorithms in which decision variables, viz. station locations and points of intersection, are selected from predefined orthogonal sections, offset points, or grids. The authors propose the use of artificial intelligence-based algorithms, particularly the low-discrepancy point sampling-based approach, to spatially explore the study area for potential points of intersection and minimize the objectives of developing HSR alignment under the imposed constraints. They argue that the traditional approaches confine the alignment around specific predefined locations and hence affect the quality of developed alignment. The proposed computer-aided automated process is capable of developing and evaluating an exhaustive list of alternatives before suggesting the best possible HSR alignment. Its application to a real-world case study is also considered in the chapter to demonstrate the proposed method’s ability in automating the HSR alignment development.
Chapter 22 by Vasudevan et al. discusses the potential of transport infrastructure construction to generate employment, using cases of highway construction in India. Despite policy makers’ interest in estimating employment generated from transportation infrastructure projects, as also briefly discussed in Chapter 19 by Khare, there has been a dearth of studies on this topic conducted in India. Most of the literature that is available comes from developed countries’ cases, the estimates of which are largely inapplicable to developing countries due to substantial differences in the labor requirements and the environment of the construction industry. The authors have hence attempted to introduce and illustrate a framework to estimate generated employment in the data-scarce context of India. The overall employment generated from highway construction is divided into three categories of direct, indirect, and induced employment. While direct employment includes all the employment directly related to the construction activities, indirect employment comprises employment that supports the construction activities (such as employment created for the supply of construction materials) and subcontract work that is not directly related to on-site construction. Induced employment, although constrained by the lack of secondary data, aims to estimate the generated employment once the highway is in operation. The former two categories of employment (direct and indirect) are studied through the cases of four highway projects that were under construction, two each in the states of Maharashtra and Uttar Pradesh in India. The latter category (induced employment) is studied through four completed highway segments in the same states since the estimation requires the highways to be in operation. The estimated employment varies among the studied cases based on the scope of the project, its execution structure, its material consumption requirements, and whether the connected regions were rural or urban. Although the estimates in this study are drawn from highway construction projects in India, it is possible to extend the methodology and framework to other transport infrastructure projects, including HSR construction. As HSR construction may involve greater sophistication in terms of material requirements, execution structure, construction methods, equipment, required worker training, etc., the amount of the generated employment may also be larger than that of highways. Further research dedicated to other transportation projects shall be necessary to unveil the facts and can be an agenda for the future.

The other presentations and discussions during the related virtual session in the ADBI-Chubu University conference provided a timely reminder of the advances, gaps, and skills that need to be integrated into the future capacity building agenda for HSR development. The panelists during the virtual session also discussed highlights regarding
the advances in HSR train technology utilizing applications of artificial intelligence, Internet of Things (IoT), and big data analysis (Asano et al. 2020), and the potential of fifth generation mobile communication technology (5G) in building an efficient communications system for HSR (Ai 2020). While Asano et al. (2020) presented the concepts of the next generation of high-speed trains through the ongoing ALFA-X project of East Japan Railway Company, Ai (2020) presented the enhancements related to the communication aspects of the service model, millimeter-wave communication, IoT for Railways (IoT-R), large-scale antenna array, beam management, and mobile edge calculation, etc., through the use of 5G in HSR systems. These advances in HSR systems can ensure safety, stability, and reliability to the utmost degree. The event also involved further discussions to learn from the experiences of the humongous HSR development in the People’s Republic of China (PRC). It was argued that the credible long-term planning strategies of the HSR projects in the PRC focused on the absorption of the international HSR technologies, technology transfer in designs and products, deployment of a large amount of labor, rapid capacity development programs for contractors and manufacturers, and relatively faster project delivery. These factors ensured the success of the HSR development in the PRC as they led to lower overall unit costs (about 30% lower as compared to other countries), high-quality preliminary designs that did not require significant changes during the later stages, standardization of all designs, competitive pricing in the construction work and supply of products, several locally developed innovations, affordable labor, and smooth land acquisition. For the smooth and successful realization of HSR projects in developing countries like India, credible and long-term planning (for instance 15–20 years) comprising a series of projects may prove to be helpful. Moreover, an emphasis on absorbing HSR technologies for design and construction and promoting international collaborations that involve the public and private sectors as well as foreign firms can also boost such projects’ capabilities. Strategies to encourage manufacturers and construction companies to foresee substantial opportunities and participate make up another crucial area to be developed by the countries undertaking HSR projects, as the participation of more parties can encourage healthy competition in the market.

To briefly summarize, it is imperative to understand that large transportation infrastructure projects in general, and HSR projects in particular, are a “system of systems” straddling ideas not only from the fields of computer science, electronics, and civil, mechanical, and production engineering, but also from fields such as the social sciences, at each of the development stages—planning, design, execution, and operation. Advancements in each of these areas hence must
be integrated into the agenda for the effective capacity building of countries planning to build HSR. There should also be an emphasis on embracing the understanding of interfaces and inter-disciplinarity of these fields in the research and teaching agenda of railway infrastructure development. Such a need in educational programs, however, has to be addressed in addition to the long-existing challenges of bridging the apparent disconnect in engineering education between what is taught at universities and the realities of the field, as rigorously discussed by Misra (2020). A trial of a teaching method using case study-based approaches, which are typically popular in business and public policy schools, for civil engineering education was found to be successful in imparting the interdisciplinary understanding of infrastructure development to students, and HSR projects were also introduced as one of the cases taught (Kato 2020). A platform for the exchange of ideas, information, and data across projects and countries may be necessary to regularly update and learn from the experiences of each of the built or to-be-built HSR projects.
References


19

Indigenous Solutions and Opportunities for High-Speed Rail in India

Achal Khare

19.1 Introduction

India’s need to improve connectivity for economic and social development has been paramount, and this has formed the basis for introducing high-speed rail in the country. With the Mumbai–Ahmedabad High-Speed Rail Project taking strides toward fruition, now is an interesting time to look at the economic, social, and environmental impact of high-speed rail.

The rapid economic growth India has undergone in recent years has been accompanied by a sharp rise in the movement of people and goods in the country. This increase requires new, innovative modes of transport that improve connectivity and make commuting easy. Once completed, the Mumbai–Ahmedabad High-Speed Rail (MAHSR) Project will not only propel India to join the group of countries with a successful high-speed rail (HSR) system but will also connect two important states—Maharashtra and Gujarat—that contribute nearly a third of the country’s gross domestic product (GDP).

19.2 Importance of the Transport Sector and Railways in the Indian Economy

The transport sector plays an important role in bettering and increasing regional connectivity and facilitating the movement of individuals and trade of goods across the country. The transport system in India is among the most dense and complicated networks in the world and has its share of complications related to congestion and pollution, among other issues. The country’s rapid urbanization and growth has further
led to an increase in the demand for mobility, with railways playing an important role in meeting people's needs for improved services. Although rail faces stiff competition from roads and civil aviation, it is still a more energy-efficient, less emission-intensive, and safe mode of transport for ferrying both goods and individuals. According to a World Bank (2018) report, the transport sector contributes 5.5% of India's GDP, with road transport having the majority share. Indian Railways, as per the data recorded in its yearbook for 2018–2019 (Government of India 2020), carried 8.439 billion passengers covering 1.157 trillion passenger-kilometers. On the basis of such encouraging data, the Government of India aims to increase the share of rail to meet 45% of transport demand by 2030, up from the current 36%, by introducing dedicated freight corridors, intensifying electrification of railway routes, and expanding penetration of the mass rapid transit system.

### 19.3 Operational Highlights of the Mumbai–Ahmedabad High-Speed Rail Project

The MAHSR Project, estimated to cost $17 billion, is being executed with financing from an official development assistance (ODA) loan from the Japan International Cooperation Agency (JICA) (JICA and Government of India 2015). Covering a distance of 508.09 kilometers (km) between Mumbai and Ahmedabad in approximately 2.07 hours (with limited stops), connectivity between the two noteworthy financial and industrial hubs of the country will assume a new meaning.

The HSR line will pass through Bandra Kurla Complex in Mumbai, Thane, Virar, Boisar, Vapi, Bilimora, Surat, Bharuch, Vadodara, Anand, Ahmedabad, and Sabarmati, and all stations will be elevated except for the one in Mumbai, which will be built underground.

The Mumbai–Ahmedabad HSR corridor will comprise 463 km of viaducts, 26 km of tunnels, 9 km of bridges, and 13 km of embankment. The longest tunnel, 21 km from Bandra Kurla Complex in Maharashtra including 7 km undersea, will be constructed using a combination of tunnel boring machines and the New Austrian tunneling method.

To provide a broader view, the following are salient features of the MAHSR transport project that make it revolutionary (JICA and Government of India 2015). The feasibility study for the project concluded that 10 train configurations with 24 rakes will be made operational. These numbers are estimated to be sufficient for HSR to
make 35 trips (one way) per day and handle close to 17,900 passengers in one direction. The feasibility study also revealed that three trains can be made operational during peak hours to manage the traffic volume and two trains are sufficient to manage the requirement during off-peak hours. The report is part of a 30-year plan to keep increasing the traffic volume and expanding the project by adding trains, rakes, and routes in order to manage an estimated 92,900 passengers per trip per day by 2053. The operational control center of the project will be headquartered in Sabarmati. Maintenance depots for the rolling stock will be constructed at Thane, Surat, and Sabarmati, in addition to a workshop in Sabarmati. The project has also charted a meticulous maintenance plan, which includes daily, monthly, and yearly inspection and maintenance work of the trains to ensure smooth and safe running, year after year.

Other salient features include the planned construction of 12 traction substations, 2 depot substations, and 16 distribution substations to meet the power supply requirements. The project is estimated to consume 1.1 billion units of energy (kilowatt hours) annually. State-of-the-art signaling, acceleration, and brake control systems will be used to enable trains to run and be controlled at operating speeds of up to 320 km per hour.

Another feature of interest is the use of advanced technology to reach optimum efficiency during project creation. For the first time in India, the project applied technologies like LiDAR (short for light detection and ranging) remote sensing to conduct a topographic survey covering 500 km within a short span of 3 months with an accuracy rate of less than 100 millimeters, as well as static refraction tomography in the construction of an undersea tunnel. Further, advanced methods were used in the design of aerodynamic high-speed trains, improved bogey technology for noise mitigation, pantographs, a special lurch control system, and a pressurized car body system; a continuous automatic train control (known as digital shinkansen-automatic train control, or DS-ATC) system for improving track-to-train transmission, a fallback system, and a digital audio frequency track circuit (DAFTC); and disaster management systems. Such systems are among those being brought together under one umbrella for the successful execution of the railway project. By introducing these new technologies, India is taking the next step toward modernizing its transport system and realizing its long-held HSR dream.

Equipment needs to be installed along the track to ensure that passengers experience safe and comfortable travel (Figure 19.1).
19.4 Adopting Global Technology for Local Impact

A major part of the MAHSR Project revolves around transfer of technology and the “Make in India” platform. Fusing Japan’s technology and India’s quest to create world-class parts could prove to be a boon for the project. As a major step toward being self-reliant, all civil construction packages, contributing to about 70% of the construction cost, are open to Indian contractors. This also includes a 21-km-long large-diameter (13.2 meters) tunnel with a 7-km portion undersea. An important initiative toward technology transfer is the opening of track construction packages to Indian contractors. In consultation with Japanese counterparts, an elaborate facility is being set up at Surat where Japanese experts train and certify contractors’ personnel in shinkansen (bullet train) track technology. About 1,153 personnel will be trained in shinkansen construction technology, as well as operation and maintenance (O&M) procedures.

The project plans to import 18 high-speed train sets from Japan, with six train sets assembled, tested, and commissioned in India. Signaling equipment and power systems for the HSR corridor will be imported from Japan, per the terms of the loan agreement with JICA. By promoting new products for HSR, India will set up manufacturing facilities in the country, generate new jobs, upgrade the skills of its existing workforce, give a boost to allied industries (steel, cement, electrical components, infrastructure, etc.), and get a toehold on new
and upcoming technologies. In order to succeed, talks are ongoing with various indigenous engineering, manufacturing, and technology-based companies to achieve top-level manufacturing standards and fulfill this purpose. These efforts to include local players will help lower the cost of construction and give Indian companies a ready-made global platform to showcase their prowess, inventiveness, and readiness to take on projects of such colossal scope.

### 19.5 The Indian Side of Things

To boost India’s “Atmanirbhar Bharat” (self-reliant India) vision of self-reliance and push indigenous engineering, technology, construction, manufacturing, and other allied industries to enhance their knowledge base and showcase their innovation skills, the “Make in India” aspect of the project is crucial. Through this government initiative, not only will the Indian companies play a major role in meeting the national-level requirements such as creating the parts and fitting the tracks (see examples in Figure 19.2), but also, once complete, the project can be a stepping stone for them to emerge as facilitators.

**Figure 19.2: Items Identified for “Make in India”**

- Traction and telecom equipment
- Auto and distribution transformers
- High-voltage circuit breakers
- Substation switchgears
- Bus ducts
- Overhead equipment poles
- Fiber optic cables
- IP networks
- Wayside protection boxes
- Battery sets
- Generators
- Fasteners for track system
- Depot sleepers
- Track slabs
- Rail turnover prevention devices

*IP = internet protocol.*

*Source: Author.*
19.6 Fostering Indigenous Capabilities through Innovation

The High Speed Railways Innovation Centre Trust set up by the National High Speed Rail Corporation Limited (NHSRCL) has a mandate to undertake targeted, applied collaborative research to solve issues raised by the rail industry to enhance railway safety, reliability, productivity, efficiency, and sustainability while ensuring customer satisfaction.

The trust leverages Indian technical capabilities and develops indigenous capabilities in relevant fields to develop professional expertise in all HSR aspects so as to provide innovative, indigenous, and cost-effective solutions; technical guidance; strategic analysis; advice to the rail transportation industry in the country on significant challenges and opportunities; and eco-friendly, environmentally sustainable solutions. It also contributes to the development of HSR-specific standards in India.

The HSR Innovation Centre, which was registered on 22 January 2019, is managed by its Board of Trustees chaired by the Managing Director, NHSRCL, and supported by the Executive Council. Assisting the management in reviewing the nature of the projects to be undertaken by the center is the Advisory Council, which comprises eminent persons from academia and research institutes both from India and abroad, such as from the Indian Institutes of Technology (IITs), the University of Tokyo, and the Railway Technical Research Institute, Japan. The trust will adopt a collaborative approach for funding, execution of research projects, and other operations.

As a step toward a self-reliant India, the following capabilities in the area of HSR technology are being developed by the High Speed Railways Innovation Centre Trust, in close association with the IITs, the Indian Institute of Science, and other institutes of repute.

19.7 Developing Capabilities in Electrical Systems

All present simulation studies for traction power supply and overhead equipment system design for railway projects in India (metro, dedicated freight corridor, HSR) are carried out abroad. Simulations, with varying degrees of detail, are required at several stages of a project, such as the feasibility stage, detailed project reports, basic design, detailed design, and validation of design modification at any stage and during O&M.
The required software simulation models are being independently developed with active engagement of NHSRCL. The two indigenous simulation models are expected to be developed in the coming 2–3 years and will be applicable to various HSR corridors in India (Table 19.1).

**19.8 Developing Capabilities in Civil Technology Systems**

The following capabilities related to civil technology for HSR systems are being developed in India:

(i) **Geosynthetic reinforced earth retaining wall**: Developing reinforced earth (RE) retaining wall and RE abutments design methods and specifications to suit Indian conditions, based on materials available in India, would help tap the country’s advantages for more efficient railway applications. The use of RE walls on a large scale in HSR has substantial potential to optimize costs. The research and development work in this regard has been undertaken with IIT Gandhinagar with a timeline for completion in 5 years. Once the Indian design standards for RE walls are developed, they can be applied in HSR projects.

(ii) **Cement asphalt mortar**: Cement asphalt mortar (CAM) is a filler material consisting of cement, sand, asphalt emulsion, and admixtures. It is used in between track slabs and reinforced concrete track beds on ballastless
track structures. CAM in semisolid form is poured into a nonwoven bag by gravity flow and inserted below a slab for support and adjustment of the vertical alignment. As suitable material for HSR is not produced in India, a project has been undertaken with IIT Madras and IIT Kharagpur to study the functional and structural requirements of CAM for use in HSR to produce material suited to environmental conditions in India, based on available chemical and cement materials in the country, and to develop alternative material fulfilling the CAM requirements.

19.9 Developing Capabilities in Material Used in High-Speed Rail Systems

A two-phase project studying and analyzing the fire-related properties of materials associated with seat upholstery has been undertaken with the Ahmedabad Textile Industry’s Research Association. In the first phase, the properties of the seat upholstery components used in Japan’s shinkansen will be analyzed by testing as per EN 45545-2 (Railway applications - Requirements for fire behavior of material and components) and the Technical Regulatory Standards on Japanese Railways (Rolling Stock) of the Ordinance of the Japanese Ministry of Land, Infrastructure, Transport, and Tourism (No. 151, as of 31 March 2002). The second phase will establish and set the specifications of all the seat components, identifying two to three sources for developing the components domestically and establishing the supply chain for these.

19.10 Encouraging Upskilling and Learnability through Training

Training is an essential part of any project on the level of the MAHSR Project. Thus, a training center offering advanced modules on cutting-edge technologies is being constructed in Vadodara, Gujarat. The High-Speed Rail Training Institute (HSRTI) campus has been designed to provide an atmosphere conducive to sharing knowledge and promoting a culture of inclusiveness.

State-of-the-art training equipment, such as simulators, model rooms, and slab tracks, is being introduced based on the Japanese HSR training institute at Shin-Shirakawa to ensure Indian HSR employees acquire skills at similar levels.
As a one-of-a-kind educational hub in India for the design, development, and delivery of HSR training programs, the HSRTI will focus on imparting instruction through customized training programs for fields as diverse as construction, project implementation and management, and O&M, besides widening the practical knowledge horizon of the trainees through the use of an in-campus ballastless slab track training line custom-built for training purposes. Simulation-assisted training, next-generation smart classes, and immersive learning experiences will be used to bridge the skills gap and build a future-ready workforce of forward thinkers, solution providers, and doers who are ready to rethink and strategize to prepare for the challenges of today and tomorrow.

19.11 Vocal for Local: A Stimulus for the Development of Satellite Towns

The HSR project could be a key component of India’s economic, social, and financial development in the coming years. Understanding the effects and benefits of the project, therefore, is crucial, as it can influence the long-term urban and regional development policy and planning. The proposed vision of the project has been prepared keeping in mind factors like convenience of transportation, safety, land use, passenger demand, technical aspects, cost, and environmental and social considerations. The entire rail corridor alignment from Mumbai to Ahmedabad is dotted with industrially developed pockets of manufacturing and other economic activities. With several urban agglomerations such as Surat and Vadodara, in addition to the terminal metropolis of Mumbai (and Thane) and Ahmedabad, the whole HSR line will benefit from high-speed passenger train connectivity.

HSR projects in various countries have successfully spurred the revitalization of smaller towns and cities and bridged the gap between metropolitan and lower-tier cities by opening up avenues not just of commuting but also of mixed land use, employment, tourism, and business. In this regard, the MAHSR Project can prove to be a great economic connecter of metropolitan towns such as Thane and Ahmedabad with smaller and less frequented but industrious towns such as Bilimora, Bharuch, Vapi, and Anand. For example, connectivity between Vapi, known as a chemical hub, and bigger cities like Mumbai, Ahmedabad, or Surat brought about by the onset of the MAHSR Project is predicted to improve the ease of doing business, as reaching Vapi will be more convenient and faster than it is now.
19.12 Spillover Effect

The increase in demand for products can spill over to have a positive effect on those directly or indirectly related to the economic and social chain. From human resources to construction industries and from engineering to housing and tourism, all sectors gain when a project of the level of MAHSR is envisioned, planned, and executed, and finally becomes operational.

HSR provides the advantage of faster and more convenient connectivity between cities. To take advantage of this potential, the areas surrounding HSR stations can be developed appropriately. The station area development can be planned in consultation with various stakeholders such as national and local governments and the local community and with a view to promoting existing industrial centers of the city, as well as the new and upcoming industries in the region. This will result in overall improvement in the quality of life of the people in and around the area. With the objective of enhancing the economic and social development along the MAHSR Corridor through transit-oriented development around HSR stations, the Station Area Development Executive Committee was formed, consisting of representatives from concerned government agencies of the state of Gujarat, the state of Maharashtra, and the central government (National Institution for Transforming India, Ministry of Railways, Ministry of Housing and Urban Affairs, and NHSRCL), along with participation of Japanese experts (JICA; Ministry of Land, Infrastructure, Transport, and Tourism; Japan Rail East; and Urban Renaissance). For planning model schemes for station area development, under the guidance and support of JICA's technical experts, two stations have been shortlisted in each state (Thane in Maharashtra and Sabarmati and Surat in Gujarat).

A project of this level requires a multitude of talent. Positive effects of the MAHSR on the Indian economy are predicted given that, going forward, a major surge in job creation through this project alone is estimated at 92,000 jobs (including direct and indirect jobs) during the construction phase. This would include 58,000 direct jobs, of which 51,000 will be for workers (skilled and unskilled) and 7,000 for engineers and supervisors. About 34,000 indirect jobs also will be generated, which would lead to growth and prosperity of the country. Setting aside the personnel requirement purely pertaining to the project, imagine the number of jobs created indirectly in other sectors like hospitality, engineering, manufacturing, real estate, architecture, health care, education, tourism, transportation, logistics, machinery, textiles, exhibition centers, and retail and food. The MAHSR Project's construction plan is not limited to corridor-related construction but
also is likely to include setting up housing societies, hospitals, schools, roads, retail and commercial hubs, parking facilities, multimodal transportation junctions, depots, offices, industrial infrastructure, and so on, along the alignment as HSR stations are expected to serve as destinations rather than just railway stations. In short, the bullet train is believed to bring connectivity that will boost least-developed areas and increase the potential for developing new production bases and townships along the corridor.

Not just the employment market but also the production and manufacturing markets are expected to gain from the project. It is estimated that the demand for raw construction materials will increase as the project construction phase gathers speed. Close to 7.5 million tons of cement, 2.1 million tons of steel, and 0.14 million tons of structural steel will be used in the construction, all of which will be produced in India. Large construction machinery is another market that will benefit greatly from the project. Equipment for excavation and piling (to the tune of 300 and 280 units, respectively), tunnel boring machines, and full-span launchers (more than 20 machines) will be required and are expected to be manufactured domestically.

### 19.13 Environmental Impact

A key element of the case for HSR is that it is more environmentally sustainable than other modes of transport such as cars and airplanes. HSR produces only a third of the carbon emissions of travel by car and a quarter of the emissions of an equivalent trip by air, taking into account the average loadings typically achieved on each mode.

To establish this case further, a study was conducted on HSR and concluded that the carbon footprint of HSR is up to 8.32 times less carbon-intensive than car travel and up to 11.48 times less than aviation travel. Currently, for a 600-km trip, an airplane emits 93.0 kilograms (kg) of carbon dioxide (CO$_2$), a car around 67.4 kg of CO$_2$, and a high-speed train just 8.1 kg of CO$_2$ (UIC n.d.). The significance of these comparative emission factors is that when HSR becomes operational, it will deliver a shift from car and air travel to HSR, which will help to greatly reduce the carbon emissions from the transport sector.

As the HSR project aims for a holistic approach, benefits to the environment are crucial. To minimize the impact of construction work on the environment, a well-thought-out plan has been adopted and efforts are being made to preserve the wildlife and natural habitats. Special arrangements ensure that no harm is caused to the eco-sensitive zones of the Thane Creek Flamingo Sanctuary and surrounding area for which an underground tunnel up to 40 meters below the ground level is
being constructed. An interesting feature of the MAHSR Project is that it will pass through a narrow corridor between Sanjay Gandhi National Park and Tungareshwar National Park. A railway line and a road already exist in this corridor, thus obstructing the natural movement of wildlife, but NHSRCL, in association with other organizations, has undertaken to restore the natural passage for wildlife between the two parks (see Appendix 19.1 for more information).

Furthermore, to ensure minimum to zero disturbance to the natural green cover in areas along the corridor, tree spade technology is being utilized. This will ensure that the uprooted trees are taken to a new plantation site and replanted. NHSRCL so far has transplanted 5,920 trees. Tree planting along the alignment has also been promoted and more than 69,000 trees have been planted so far, with the activity to continue in the future.

19.14 Conclusion

There is no doubt that the MAHSR Project, once completed, will mark the start of a transport revolution in India. From benefiting the regional economy and connecting smaller towns with bigger financial and economic hubs to leapfrogging to the best HSR technology, the project will tick off all the boxes of progress and prosperity. With the advantage of one integrated economic region, chances are that both Maharashtra and Gujarat will script new stories of success in the coming years. For the future, a further seven new corridors comprising a total length of 4,405 km are being studied for consideration (Table 19.2).

<table>
<thead>
<tr>
<th>Corridor Name</th>
<th>Expected Distance Covered (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delhi–Varanasi</td>
<td>865</td>
</tr>
<tr>
<td>Varanasi–Howrah</td>
<td>760</td>
</tr>
<tr>
<td>Mumbai–Nagpur</td>
<td>753</td>
</tr>
<tr>
<td>Delhi–Ahmedabad</td>
<td>866</td>
</tr>
<tr>
<td>Chennai–Mysore</td>
<td>435</td>
</tr>
<tr>
<td>Delhi–Amritsar</td>
<td>459</td>
</tr>
<tr>
<td>Mumbai–Hyderabad</td>
<td>711</td>
</tr>
</tbody>
</table>

Source: National High Speed Rail Corporation Limited (2020).
With the MAHSR Project opening up so many avenues in various sectors, and the likely implementation of more HSR corridors in the future, the country will surely witness unprecedented growth and set the course for the Indian economy’s ascent toward a more prosperous future.
References


Appendix 19.1: Building an Animal Corridor to Provide Safe Passage to Wildlife and Enable Their Smooth Movement

India is home to a unique and rare variety of flora and fauna that not only add to the country’s beauty but also help maintain its ecological balance. To help ensure that this natural uniqueness and beauty remains intact, various animal and green corridors are maintained across the country. But with the growing population, urbanization and a large number of infrastructure projects have become the need of the hour, putting many of these corridors at risk of shrinking.

In Mumbai alone, a large number of infrastructure projects are being planned with most of them connecting the northwest region of Maharashtra with Mumbai. This region is home to two of the densest spots for wildlife: Sanjay Gandhi National Park (SGNP) in Mumbai and Tungareshwar Wildlife Sanctuary (TWLS) in the adjacent Palghar district. The SGNP is a part of the Western Ghats biodiversity and forms almost 20% of Mumbai’s geographical area. It is home to a wide range of birds, mammals, reptiles, amphibians, butterflies, and a staggering number of plant species. It also has two lakes, Vihar and Tulsi. The TWLS is another green area that is a favorite among trekkers during monsoon season. Owing to their vastness and the connectivity they offer with Mumbai, these regions have been identified as spots for the passing of some of the most technologically advanced projects in the country including the Mumbai–Ahmedabad High Speed Rail (MAHSR) Project, Diva–Panvel Rail line, Public Works Department road, and the Multi-Modal Corridor (MMC). While the development in the area would be good news for humans, the common view was that the wildlife might be harmed by the enlargement. Since wild animals are used to living in a certain kind of habitat and away from human intrusion, taking over a part of the forest area to expand construction would have naturally meant robbing most of these animals of a place they have known as their safe sanctuary for centuries and letting them enter areas that could risk their lives.

Aside from the issue of habitat loss, it has also been noted in the past that many animals would cross over to the other side of the forest using roads that would cut through the area. This resulted in a number of accidents in these areas as vehicles passing at high speeds would often miss sighting these animals, which in turn was endangering both human life and the wildlife. In light of these problems, planners decided to require that the projects planned in the area exhibit a sustainable model of development to mitigate the conflict between wildlife and traffic.
The Supreme Court in its judgement dated 9 September 2013 allowed the diversion of 8.05 hectares of forest land falling in Sanjay Gandhi National Park for the construction of dedicated freight corridor track within the eco-sensitive zone of Sanjay Gandhi National Park and Tungareshwar Wildlife Sanctuary, subject to many conditions including construction of four underpasses and chain-link fencing parallel to the railway line.

While multiple rounds of discussions were held between the agencies and stakeholders to come up with a reasonable solution, the team of the National High Speed Rail Corporation Limited (NHSRCL) finally proposed that since the project was in the public interest and no other alternative was feasible, construction of an animal corridor could prove beneficial. Building an animal overpass and underpass would ensure the wildlife in the area was kept protected from any disruption, and the region was converted into a minimum conflict zone by giving a safe and smooth movement passage to the wildlife.

After deliberation and agreement by all the parties involved, the proposal was finally sent to the standing committee of the National Board for Wildlife, where it was given the green light. The board decided to provide 8.05 hectares of the forest land falling in the SGNP for the construction of a dedicated freight corridor as per the rules and procedures decided by the board and the involved parties. As for the MAHSR Project and the MMC Project that is to be built on the forest land falling under TWLS, an animal overpass at a height of 6 to 7 meters above the ground with open spans will be constructed. The 30-meter-wide overpass has been designed in such a way that no obstruction is caused to the wildlife movement in the area. Plans have also been put

**Box 19A.1: Quick Facts on the Wildlife Overpass Planned between Sanjay Ghandi National Park and Tungareshwar Wildlife Sanctuary**

- The overpass will be over the existing Diva–Vasai Line, proposed Dedicated Freight Corridor Corporation of India Limited Line, and Public Works Department road, and it will be below the Mumbai–Ahmedabad High-Speed Rail and Multi-Modal Corridor viaduct.
- The overpass will provide straight connectivity between Sanjay Ghandi National Park and Tungareshwar Wildlife Sanctuary.
- The width of the overpass structure will be 30 meters.
- Headroom of 5.3 meters will be available for the animals below the viaduct of the Mumbai–Ahmedabad High-Speed Rail and Multi-Modal Corridor.
- The combined length of overpass, underpass, and ramp will be 128 meters.
in place by NHSRCL to relocate the existing high-tension transmission line of Mahatransco in the area at a height above the MMC so that it does not hinder the proposed wildlife corridor in any manner.

Other significant points that have been taken into consideration for construction of the wildlife animal overpass:

- The design will be made to match the natural vegetation and habitat of the native species.
- Rocks, logs, expansive stretches of green and water bodies etc. will be included so that animals can feel at home.
- Use of the area by humans for ferrying bicycles, motorcycles, bullock carts, cars, etc. will be prohibited in the area so as to not disturb the natural surroundings and the animal population residing in the area.
- Since the wildlife overpass entry and exit fall entirely within SGNP and TWLS boundaries, adequate funneling and guided fencing of at least a 3-meter height with an additional top portion of 0.5 meter bent inwards has been proposed to ensure animals do not jump over it and wander into unprotected zones.
- High-quality noise barriers will be erected in the area so that noise levels in the wildlife corridor area are within ambient noise limits.
- Restrictions will be put on the use of heavy lighting in this area and light barriers will be maintained so that animal movement is not disturbed during the night.
- The wildlife corridor will have internet-connected closed-circuit television surveillance provisions for its entire length from the entry and exit sides, with a monitoring mechanism from the control rooms of the protected areas involved.
20

Policies and Priorities for Developing Capacity to Build High-Quality Infrastructure

Santhosh Loganathan, Chandra Sekhar Bahinipati, KE Seetha Ram, and Satyanarayana N. Kalidindi

20.1 Introduction

Economic growth gets a major boost from development in infrastructure like roads, railways, and housing, which could have a direct impact on poverty alleviation (Bhattacharya, Sen Gupta, and Sikdar 2020). From 2004 till a few years back, when India saw some of the highest growth rates, the ratio of infrastructure investment to gross domestic product (GDP) kept steadily rising from 4.2% in 2001–2002 to a peak of 8% in 2010–2011 (Bhattacharya, Sen Gupta, and Sikdar 2020), and it is around 9% in 2017–2018.¹ Such investments could have led to reduction of poverty in India (Bhattacharya et al. 2020). Global investments in the construction and maintenance of infrastructure as a share of GDP in 2018 for the People’s Republic of China (PRC) stood at 5%, which is much higher than that of India at 1% (Statista 2020). In other countries like Japan and the United States (US), the share was less than 1% (Statista 2020).

The building of high-quality infrastructure, especially hard physical infrastructure like roads and houses, requires a lot of construction activity, so it makes sense to identify significant factors that positively impact construction productivity. Thus, it is particularly important to find ways to attract labor and improve labor productivity in the construction sector with an aim to increase overall construction productivity. Accordingly, this chapter is divided into five sections. Section 20.2 is

on India’s infrastructure needs and plans. In Section 20.3, we discuss the findings in the literature on improving the construction sector productivity. Section 20.4 discusses ways to increase the productivity in the construction sector, and Section 20.5 provides concluding remarks.

### 20.2 India’s Infrastructure Needs and Plans

A 2011 Government of India report on Indian urban infrastructure and services estimates the requirement of ₹39.2 trillion at 2009–2010 prices over the 20-year period (i.e., till 2031) for the purpose of urban infrastructure development out of which 44% (₹17.3 trillion) would be needed for laying urban roads (Tripathi 2017). Recently, the Government of India launched its National Infrastructure Pipeline for the period of 2020–2025 with ₹111 trillion of projected infrastructure investment in roads, railways, urban infrastructure, energy, etc. to realize the dream of a $5 trillion economy by 2025. The comparison of the infrastructure index with infrastructure expenditure per capita for the years 1991 and 2010 across states of India reveals certain interesting patterns (Mohanty, Bhanumurty, and Dastidar 2017). There are certain states with high endowment of infrastructure, while other states have low endowment of infrastructure. This unequal distribution of infrastructure, where states such as Maharashtra, Gujarat, Punjab, Haryana, Kerala, and Karnataka have high-quality infrastructure and states such as Uttar Pradesh, Odisha, West Bengal, Madhya Pradesh, Rajasthan, and Bihar have low-quality infrastructure, continues from 1991 to 2010 (Mohanty, Bhanumurty, and Dastidar 2017).

Roads constitute 19% of the total projected infrastructure investment under the National Infrastructure Pipeline for the period of 2020–2025. Currently, the share of roads in India in inland freight transport is higher than those in the US, the Russian Federation, and the PRC. The road density of India at 1.66 per square kilometer (km) is higher than that in the Russian Federation at 0.08 per square km, Brazil at 0.18 per square km, the PRC at 0.46 per square km, the US at 0.67 per square km, and Japan at 0.91 per square km (Government of India, Ministry of Finance 2018). In Japan, the modal share of railways is high in passengers, while in the US the modal share of railways is high in freight. The railways in the PRC and India carry a mix of both passengers and freight. However, the National Rail Plan aims to increase the modal share of rail in freight to 45% from 27%. As of 2017, 425 km of metro rail was operational, and another 684 km was under construction in various cities of India (Government of India, Ministry of Finance 2021). Further, it is estimated

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2 In 2011, the Government of India approved the name change of the State of Orissa to Odisha. This chapter reflects this change.
that the urban population of India is going to increase from around 35% to 50% by 2050 with Delhi emerging as the largest city in the world by 2028. As a result, the housing demand in urban areas will increase substantially (de la Maisonneuve and Dek 2020). With an aim to provide a concrete house to every household by 2022, the Pradhan Mantri Awas Yojana-Urban mission as per the economic survey of 2020–2021 has approved the construction of 10.9 million houses out of which 4 million have been already constructed.

20.3 Current Issues in Capacity Building: Construction Labor and Its Productivity

Public expenditure on infrastructure like schools and hospitals rises with a rise in population but spending on infrastructure like roads falls with a rise in population or urbanization (Biehl 1989). The analysis of census data for the period 2001–2011 and the ranking of cities in terms of provision of infrastructure facilities show that bigger Tier 1 cities like Kolkata, Mumbai, Bangalore, Chennai, and Thiruvananthapuram (Tier 2 city) are performing better in terms of infrastructure than the smaller cities (Tier 2 and Tier 3 cities). Even though bigger cities have better infrastructure than smaller cities do, in terms of city population density cities with higher growth of population and higher density of population (as is the case in the bigger cities) have lower-quality infrastructure facilities (Tripathi 2017). In summary, the infrastructure development in India needs a big push. Any major spending on infrastructure requires spending on the construction sector. So, it is imperative to understand the functioning of the construction sector in India, which we do here through a literature review.

In India, 5% of GDP is contributed by the construction sector, which provided jobs to 30 million people as per the Planning Commission in 2008 (Thomas and Sudhakumar 2014). During the period 2000–2012, employment in the construction sector grew at a yearly rate of 9% with the rural construction sector employment growth rate at 12% compared to 5% in urban areas as evident from National Sample Survey Office surveys (Mahajan and Nagaraj 2018). The rural housing construction of solid/concrete houses from hut houses (made of mud and dry leaves) seems to be the major reason behind it (Mahajan and Nagaraj 2017). However, the construction sector’s rise in rural employment seems to have petered out in subsequent years as reflected by the Labour Bureau estimates in 2015–2016 (Sen 2020). The growth rate of wages in the construction sector between 2004–2005 and 2011–2012 was 5.56%, which fell to 1.86 between 2011–2012 and 2017–2018 (Srivastava and Padhi 2020).
20.3.1 Construction Sector Workforce

India is the fourth-largest construction market in the world next to the US, the PRC, and Japan. The construction industry is the second-largest employer in the country, next to agriculture. It employs over 31 million people and is valued at over $126 billion. Table 20.1 shows the employment in India's construction sector by the education level of workers.

Table 20.1: Employment in Indian Construction by Education Level of Workers

<table>
<thead>
<tr>
<th>Category</th>
<th>Total Employment</th>
<th>Percentage of Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unskilled Workers</td>
<td>25.6 million</td>
<td>83%</td>
</tr>
<tr>
<td>Skilled Workers</td>
<td>3.3 million</td>
<td>10%</td>
</tr>
<tr>
<td>Engineers</td>
<td>0.8 million</td>
<td>3%</td>
</tr>
<tr>
<td>Technicians and Foremen</td>
<td>0.6 million</td>
<td>2%</td>
</tr>
<tr>
<td>Clerical Workers</td>
<td>0.7 million</td>
<td>2%</td>
</tr>
</tbody>
</table>


It can be noted from Table 20.1 that about 83% of employment in Indian construction consists of unskilled workers. Given the present employment status, it is crucial to note that 47 million workers are needed over the next decade. Hence, there is a need to increase the skilled construction workforce in the country, given the infrastructure facilities that need to be built.

An empirical study conducted by two of the authors (Loganathan and Kalidindi 2016) on 15 major construction projects across the country indicates the following key findings with respect to the construction workforce in India:

- On average, 15% of organizations managed (in-house) workers, and 85% of labor subcontract workers are engaged in the projects studied. Labor subcontractors, significantly, engage a large proportion of migrant construction workers. In the Indian context, a migrant worker refers to a worker who works on a project site located in a state other than the worker's home state (place of usual residence).
• The percentage of migrant workers ranges from 65% to 95% and averages 89% in the projects studied.
• The majority of the migrant workers were from the states of West Bengal, Bihar, Odisha, Uttar Pradesh, Jharkhand, Andhra Pradesh, Telangana, and Assam.
• In the last 10–15 years, a huge transition in the demographics of construction workers was seen.
• Local and regional workers have been significantly replaced by migrant workers.
• Currently, most of the construction workers are informal seasonal and migrant workers from poorer agricultural states.
• Workers and crews from different regions or states of the country with different socioeconomic and cultural backgrounds work together in a typical construction project.

Box 20.1: A Day in the Life of a Migrant Construction Worker

For Mahadev, a migrant construction worker from Bihar, the day starts at 8am in the project site. He reports to his labor subcontractor (his maistri) to find out his day-to-day activity. While the industry generally follows a 10-hour work shift, Mahadev prefers to work 2–3 extra hours so he is paid overtime wages. He is accommodated near his work site in the contractor’s arranged accommodation. His living hut is just about 100 square feet, and 5–7 of his coworkers are accommodated in the same hut. While Mahadev aspires to live in a building with a concrete rooftop, he is accommodated in a shed covered with tin/asbestos sheets that has a cement or a mud floor. He visits the local Sunday market in the nearby locality and buys food and essential items. People like Mahadev are paid ₹300–₹400 per day. They can make around ₹10,000–₹12,000 per month. By doing extra shifts or overtime duty, they can make it to ₹15,000 per month.

Mahadev visits his village in his home state during festival seasons such as Holi and Durga Puja to spend time with his family and friends. Sometimes he may stay back to work on farmlands as an agricultural worker. He may or may not get back to work with the same labor subcontractor, or with the same contracting company—or even in the same city—the next time, as he is not formally employed in the industry. Mahadev aspires to work in a safer work environment with better living and financial conditions.

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3 In 2011, the Government of India approved the name change of the State of Orissa to Odisha. This document reflects this change.
The study conducted by two of the authors (Loganathan and Kalidindi 2016) also sheds light on the issue of absenteeism and turnover among migrant construction workers by looking at the average age of construction workers in India. The age data of 1,200 construction workers across the country was collected. As Figure 20.1 shows, 56% are under 27 years, 65.3% are under 30 years, and 81% are 35 years of age and under. This further substantiates that there is a lack of experienced construction workers in the industry. Workers quit the industry after a few years and move to other industries. Also, as indicated before, for most of the migrant workers, construction is largely seen as part-time work as some of them return to their hometowns seasonally to work on farmlands.

Figure 20.2 compares the average age of construction workers in India with that in other countries. While the average age of the Indian construction workforce is 28 years, it ranges from 38 to 45 years in other countries. It is evident that workers leave to work in other professions in India due to issues with wages and living and working conditions. A previous empirical study conducted by two of the authors indicated that improper basic facilities, payment issues, and illness and injury are the key reasons for absenteeism and turnover of workers to other professions (Loganathan and Kalidindi 2016).
The construction industry in India has an average annual turnover of ₹3.9 trillion, but poor productivity causes losses exceeding 30% of the revenue in this sector (Dixit, Pandey, et al. 2017). Doloi (2008) finds the labor productivity affects the cost of production and completion of projects on time, which in turn is responsible for poor productivity in the construction sector. It is important to examine the top factors that affect the construction labor productivity of India and compare them with those of other countries, especially those of developed economies.

To this end, we conducted a systematic literature review of research papers published in selected construction and project management journals. The literature search was focused on the period between 1995 and 2020 representing some major developed and developing economies. Table 20.2 provides the outcomes of the literature analysis.

Table 20.2 shows that the key factors affecting construction labor productivity can be grouped under three categories: technical and technological factors, financial factors, and behavioral factors. It is worth noting here that the labor productivity in the construction sector in developed regions of the world is mostly related to technical and
Table 20.2: Comparison of Factors Related to Construction Labor Productivity in India and Other Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Ranking of Top 5 Factors from Various Studies in Different Countries</th>
<th>Authors and Year of Publication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Rework</td>
<td>Hughes and Thorpe (2014)</td>
</tr>
<tr>
<td></td>
<td>Incompetent supervisor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incomplete drawing</td>
<td></td>
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<tr>
<td></td>
<td>Work overload</td>
<td></td>
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<tr>
<td></td>
<td>Lack of material</td>
<td></td>
</tr>
<tr>
<td>Chile</td>
<td>Materials</td>
<td>Rivas et al. (2011)</td>
</tr>
<tr>
<td></td>
<td>Tools</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rework</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Equipment and trucks</td>
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<tr>
<td></td>
<td>Absenteeism</td>
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<tr>
<td>Egypt</td>
<td>Incentive programs</td>
<td>El-Gohary and Aziz (2014)</td>
</tr>
<tr>
<td></td>
<td>Availability of materials and their ease of handling</td>
<td></td>
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<tr>
<td></td>
<td>Leadership and competency of construction management</td>
<td></td>
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<tr>
<td></td>
<td>Competency of labor supervision</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Planning, workflow, and site congestion</td>
<td></td>
</tr>
<tr>
<td>Kuwait</td>
<td>Clarity of technical instructions</td>
<td>Jarkas and Bitar (2012)</td>
</tr>
<tr>
<td></td>
<td>Extent of variation/change during execution</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coordination among agencies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lack of labor supervision</td>
<td>Proportion of work subcontracted</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Material shortage</td>
<td>Kadir et al. (2005)</td>
</tr>
<tr>
<td></td>
<td>Nonpayment to suppliers causing stoppage of materials</td>
<td></td>
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<tr>
<td></td>
<td>Change order by consultants causing project delay</td>
<td></td>
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<tr>
<td></td>
<td>Late issuance of construction drawing by consultants</td>
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<tr>
<td></td>
<td>Incapability of contractor’s site management to organize site activities</td>
<td></td>
</tr>
<tr>
<td>Oman</td>
<td>Errors and omissions in design drawings</td>
<td>Jarkas, Al Balushi, and Raveendranath (2015)</td>
</tr>
<tr>
<td></td>
<td>Change of orders during execution</td>
<td></td>
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<tr>
<td></td>
<td>Delay in responding to requests for information</td>
<td></td>
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<tr>
<td></td>
<td>Lack of labor supervision</td>
<td></td>
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<tr>
<td></td>
<td>Clarity of project specifications</td>
<td></td>
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<tr>
<td>Spain</td>
<td>Shortage or late supply of materials</td>
<td>Robles et al. (2014)</td>
</tr>
<tr>
<td></td>
<td>Clarity of the drawings and project documents</td>
<td></td>
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<td></td>
<td>Clear and daily task assignment</td>
<td>Tools or equipment shortages</td>
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<tr>
<td></td>
<td>Level of skill and experience</td>
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<tr>
<td>United Kingdom</td>
<td>Ineffective project planning</td>
<td>Naoum (2016)</td>
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<td></td>
<td>Delay caused by design error and variation orders</td>
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<td></td>
<td>Communication system</td>
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<td></td>
<td>Work environment</td>
<td></td>
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<tr>
<td></td>
<td>Constraints on a worker’s performance</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>Tools and consumables</td>
<td>Dai et al. (2009)</td>
</tr>
<tr>
<td></td>
<td>Materials</td>
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<td></td>
<td>Engineering drawing management</td>
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<td></td>
<td>Communication</td>
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<tr>
<td>India</td>
<td>Labor personal problem</td>
<td>Agarwal and Halder (2020)</td>
</tr>
<tr>
<td></td>
<td>Improper managerial skills</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scheduling of work</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High/low temperature; Schedule compression</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Labor dissatisfaction</td>
<td></td>
</tr>
</tbody>
</table>

Legend
- Technical and technological factors
- Financial factors
- Behavioral factors

Source: Compiled by authors.
technological factors but in India this is related mostly to behavioral factors. As can be seen in Table 20.2, the study by Agarwal and Halder (2020) in India identifies labor personnel problems as the top factor affecting productivity, which is unique when compared with other countries. As mentioned, this is related to the better wages and living and working conditions of the workers in the other countries. Also, construction in developed countries is more technology driven and less labor-intensive, while in countries such as India it is heavily dependent on workers. There is a great scope to bring more technology and to upskill construction workers to improve productivity. A few observations from the micro-level empirical studies are given in the following paragraph.

A study by Thomas and Sudhakumar (2014) based on the perspectives of project managers, site engineers, supervisors, and craftsmen at construction sites in Kerala finds that while project managers rank poor project planning and scheduling and improper project coordination as major factors, the craftsmen rank poor pay as the most important factor affecting productivity in the construction sector. Karthik and Rao (2019), based on a survey at the construction site of a multistory residential building in Telangana State, find that construction sector labor productivity is lost by 15% due to problems in organizational characteristics, worker management, and safety of work, and an additional 11% loss is due to factors like insufficient materials and equipment delay. Most of the studies that identified factors affecting construction productivity are based on the perspective of managers or executives (Hamza et al. 2019). Even globally, project teams consist of 80% labor and labor accounts for 40% of total costs (Sherekar, Tatikonda, and Student 2016), so it is imperative that in a country like India, where the construction sector is highly dependent on labor, more research is done on labor productivity in the construction sector from the perspective of workers.

20.4 Way Forward: Better Construction Labor Productivity

Analysis of the relationship between construction productivity measured in terms of gross value added per worker and skill measured in terms of qualification and training over the period of 1999 to 2010 finds that skill development contributes a significant improvement in productivity. The recent national policy on skill development, by 2022, aims to prepare 105 million individuals and develop skills in another 460 million through training, retraining, and upskilling (Dixit, Mandal, et al. 2017). As mentioned before, the construction industry is the second-largest job
provider in the country with 32 million workers. During 2000–2012, it grew on an annual average of 14.6% but contributed around 8% to GDP in 2011–2012 (Soundararajan 2013). However, workers in this industry are poorly paid with almost no job training or job security. Around 90% of the workers in the construction industry are casual workers. In 2009–2010, 52% of workers in the construction industry received less than minimum wage (Soundararajan 2013).

In a monopsonistic labor market like the construction sector in India, prevailing wages are often set below the marginal revenue product so if the minimum wage is set above the prevailing wages and equal to the marginal revenue product, this will lead to an increase not only in wages but also in employment (Soundararajan 2014, 2019). Soundararajan (2014) shows that the enforcement of a minimum wage in the construction sector has increased the wages and increased employment. So, the payment of a higher minimum wage may help raise productivity in the construction sector through better nutrition or human development of laborers and through incentivizing job training by employers (Soundararajan 2013).

Based on the above discussions, four key directions are suggested to improve the engagement and management of the construction workforce in India. These are derived by the authors based on the interviews conducted with construction workers, labor subcontractors, construction project teams, and discussion with a few industry experts. These are the four key directions:

• quasi-formalization of the workforce;  
• making the construction sector aspirational;  
• initiatives to train and retain workers as permanent workers; and  
• minimum wages related to marginal revenue product and linked to productivity.

These recommendations are discussed in brief.

20.4.1 Quasi-Formalization of the Workforce

Quasi-formalization of the workforce refers to monitoring of the workforce, not just the overall management of the workforce by the main contractor. Here, the main contractor monitors wages being given to construction workers. By so doing, the main contractor ensures that the last mile worker receives the right payment and that it is given on time. In the current practice, workers are fully managed by the labor subcontractors. Digitalization of labor attendance and payments can be adopted by the contracting organizations. This would ensure correct calculation of overtime payments as against inflated head counts made
by the labor subcontractors. Given the numerous labor transactions that need to be made in a project, digital payments will also bring more transparency in the system.

As per the study conducted by International Data Corporation and automation major Autodesk in 2020, 66% of construction companies in India are prioritizing digital transformation. Companies such as Larsen & Toubro adopt technologies to monitor and manage the processes related to construction labor in their large and megaprojects. However, it is critical to note that the motivation to effectively adopt such innovative technologies in India is primarily driven by the construction clients or owners (Loganathan et al. 2017).

20.4.2 Making the Construction Sector Aspirational

India having one of the world’s largest young populations, the youth (both rural and urban) aspire to have decent work conditions, high-morale work environments, and potential for advancement in addition to wage considerations. Now, most of the construction organizations do not provide good living and working conditions. Payments to workers are often delayed. As mentioned earlier, the study by Loganathan and Kalidindi (2016) found lack of basic facilities, payment issues, illness, and injury as the top reasons for absenteeism and turnover of workers. The average age of the Indian construction workforce, as pointed out, is 28 years—for all the above reasons. To retain workers and make the construction sector aspirational, organizations should invest in arranging better facilities, improve work environments, and mechanize unskilled work. People should opt to work in construction rather than have it as a last choice as a career.

20.4.3 Initiatives to Train and Retain Workers as Permanent Workers

A few construction industry organizations have set up initiatives to train construction workers. However, these initiatives are currently inadequate given the large number of workers needing formal skills training.

The PanIIT Alumni Reach for India (PARFI) Foundation provides holistic skill development and employment among Indian youth. It sets up blue collar technical skill training centers (called gurukuls) across the country and trains youth on vocational skills such as carpentry, masonry, and painting. The aim is to support poor and undereducated youth. Typically, after training with PARFI, the candidates join an employer
(with support from PARFI) and pay a nominal equated monthly installment (EMI) to the finances sourced by PARFI—which supported the candidate to enroll with PARFI training. This creates a model of sustainable skill development. Large construction companies such as Larsen & Toubro have skills training institutes within their organization and provide training to rural youth and maintain them as permanent workers. Such models can be adopted by other organizations too. Certain foreign contractors set benchmarks in retaining construction workers. For instance, Leighton Welspun (an Australian construction major) and Tata Realty completed a project in Kochi, Kerala based on alliance contracting. Based on a case study conducted by the authors, the project witnessed less turnover of construction workers as wages and living and working conditions of workers were better when compared to typical Indian project sites.

### 20.4.4 Minimum Wages Related to Marginal Revenue Product and Linked to Productivity

There is a need to develop scientific measures to assess the skill levels and productivity of workers. Such measures must aim to benchmark and link worker wages to skill and productivity levels rather than minimum wages fixed by the government. Such an approach is viable and cost-effective in construction. Here, the focus is not only on the mechanization aspects of the sector to reduce consumption of personnel.

A study conducted in the US analyzing the annual road construction expenditures over a 9-year period found no significant relationship between average hourly wages and higher construction costs (Poupore 2004). Using Federal Highway Administration statistics, the study categorized the US into low- and high-wage states. Although the average hourly wage was higher in high-wage states than in low-wage states, a 35.2% reduction in consumption of hours per mile was seen in high-wage states, indicating higher productivity (Poupore 2004). Further, total cost per mile was 3.9% lower in high-wage states when compared with low-wage states (Poupore 2004). This substantiates the claim that there is no significant relationship between higher labor costs and higher construction costs; rather, an increase in productivity was associated with lower total construction costs. Skills and productivity have a major influence on cost aspects of the projects, a relationship that needs to be addressed in labor-intensive markets such as India.

In the Indian context, the current practice is to use either a rate-based contract or a wage-based contract. In a rate contract, the performance risks are fully transferred to the labor subcontractors and
the main contractors carry zero risks. However, the labor subcontractors ensure only minimal loyalty, so a worker who expects to make a loss in the current project site will move to a new project site. In a wage contract, there is zero performance risk to the labor subcontractor and the risks are completely transferred to the main contractors. Hence, to accommodate the limitations of both types of contracts, a productivity-linked composite wage metric can be proposed. Here, the government-set minimum wage can be considered as a fixed component and the productivity-linked incentive amount as a variable component. Such measures would aim to improve both skills and productivity.

20.5 Conclusion

The need for infrastructure growth is evident in India. In this chapter, we have provided four key suggestions to improve the quality of construction and labor: quasi-formalization of the workforce, making the construction sector aspirational, initiatives to train and retain construction workers, and minimum wages related to marginal revenue product and linked to productivity. As the study of Soundararajan (2014), for instance, suggests, if the minimum wages are appropriate—for example, in tandem with marginal revenue product—this would even increase the productivity of labor in the construction sector. Any improvement in the productivity of the construction industry will help in building high-quality infrastructure in the country, as the construction sector is the backbone of the infrastructure industry.

Finally, scant research has been conducted on improving construction productivity, especially on-site productivity. Therefore, there should be more focused research projects from the perspective of labor on improving productivity in the construction sector, which is important for countries such as India that depend heavily on labor.
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21

Artificial Intelligence-Based Spatial Exploration for Computer-Aided High-Speed Rail Alignment Development

Sandeepan Roy and Avijit Maji

21.1 Introduction

Alignment design is a complex transportation problem where planners aim to connect endpoints at the minimum possible cost subject to geometrical design, environmental, and other location-specific constraints (Jha and Maji 2007). In practice, the planners typically fix and design the horizontal alignment and then develop suitable vertical alignment along the designated horizontal alignment (Lee and Cheng 2001; Lee, Tsou, and Liu 2009). The primary purpose of the horizontal alignment is to connect desired end locations while avoiding obstructions and other restricted areas. Since two endpoints can be connected by an infinite number of possible alternative alignments, a traditional alignment development process, primarily based on human judgment, may overlook many potential good alternatives (Chew, Goh, and Fwa 1989; Li et al. 2013). Various computer-aided automated methods have been developed to consider all possible alternative routes and reduce human effort. Heuristic-based optimization algorithms do not need explicit mathematical formulation and, hence, are more suited for expressing complex terrain, constraints, and real-world conditions associated with alignment design. These algorithms include neighborhood search heuristics with mixed integer programming (Cheng and Lee 2006; Lee, Tsou, and Liu 2009), nonlinear mesh adaptive search (Mondal et al. 2015), particle swarm optimization (PSO) (Shafahi and Bagherian 2013; Bosurgi, Pellegrino, and Sollazzo 2013; Pu et al. 2019; Zhang et al. 2020), simulated annealing (Costa et al. 2013), modified motion planning

In earlier alignment design studies, the decision variables, i.e., points of intersection (PIs) of the alignment, were determined from a set of points generated on equally spaced orthogonal cut sections perpendicular to the line joining the desired terminal points. A few recent studies (Mondal, Lucet, and Hare 2015) used offset data points as potential PIs across a given initial alignment to establish a corridor, which was used to optimize the alignment within its boundaries. The limitations on PIs were improved upon in the later works (Li et al. 2017; Pu et al. 2019; Zhang et al. 2020) using bidirectional distance transform algorithms, where a layer of uniform lattices or grids was generated over the study area, and the center of the grids was considered as the potential PI location. In summary, the available algorithms considered preselected orthogonal planes, offset data points, or grids as the potential PI locations. However, in a real-world application, the PIs cannot be prefixed or bounded and should be problem-dependent. Also, a study area may have multiple restricted zones. Due to the restrictions on PI locations, the generated alignment might overlap such zones and may not satisfy the location and design constraints, an outcome that would result in infeasible alignments or nonoptimal solutions.

A handful of studies have focused on the railway alignment optimization problem. These studies can be classified as per various rail modes, i.e., urban rail transit (Samanta and Jha 2011, 2012; Lai and Schonfeld 2012, 2016), mountain rail (Li et al. 2017; Pu et al. 2019; Zhang et al. 2020) and high-speed rail (HSR) (Costa et al. 2013). There is a variation in geometrical guidelines and constraints for the alignment design of different railway modes. Thus, existing methods cannot be explicitly implemented for HSR. This study is, therefore, motivated by the need for a methodology that overcomes specifically the discussed limitations in alignment development (i.e., PI location, geometric design constraints, and alignment infeasibility) and reduces the possibility of human error in HSR alignment development. Hence, the objective of this study is to develop a point sampling–based ant colony optimization (ACO) approach for a computer-aided automated HSR alignment development methodology. It improves the potential PI location search, considers geometric design constraints in HSR alignment design, and reduces the infeasible alignment evaluation possibility. Thus, the proposed methodology would assist the planners in exploring and
selecting the best possible horizontal HSR alignment, which can then be integrated with an appropriate vertical profile for holistic alignment development for a given study area.

21.2 Horizontal Alignment Formulation and the Objective Function

The circular curves, spiral curves, and tangent sections from the given PIs and the associated radius of curvature are necessary to determine the horizontal alignment. Let the number of PIs in the horizontal alignment between given endpoints \((a, b \in \mathbb{R}^2)\) be \(N_H\) such that \(PL_i = (x_i, y_i), i = 1, \ldots, N_H\) where \(PL_i \in \mathbb{R}^2\), the radius, central angle of curvature for the circular curves corresponding to the PIs can be represented as \(R_{Ci} \geq 0 (R_{Ci} \in \mathbb{R}\) and \(i = 1, \ldots, N_H)\), and \(\theta_i \geq 0 (\theta_i \in \mathbb{R}\) and \(i = 1, \ldots, N_H)\), respectively. Therefore, for each \(PL_i\), two tangent points \((TS_i, ST_i)\) and points of transition from spiral to circular curve and vice versa \((SC_i, CS_i)\) for the selected radius of curvature must be found. There should be \(N_H + 1\) tangent sections for \(N_H\) number of PIs. Coordinates of the PIs are determined first to formulate the alignment. Then the coordinates for \(TS_i, SC_i, CS_i,\) and \(ST_i\) are determined. The coordinates of the points can be computed as per the equations given in Lai (2012). Figure 21.1 shows the details of the horizontal curves.

![Figure 21.1: Geometrical Components of the Horizontal Curve](image)

- \(R_{Ci}\) = The radius of the circular curve between \(SC_i\) and \(CS_i\)
- \(\theta_i\) = The angle of curvature for the circular curve between \(SC_i\) and \(CS_i\)
- \(\theta_{PI_i}\) = Deflection angle at \(PL_i\)
- \(\theta_{Si}\) = The central angle of the spiral arc \(L_{Si}\) called “spiral angle”

Source: Authors.
Hence, the total length of the feasible horizontal alignment having $N_H$ PIs is given by equation 1.

$$L = L_{T1} + \sum_{j=1}^{N_H} (2Ls_j + Lc_j + L_{Tj+1}), \text{where } N_H \in \mathbb{N}, \quad (1)$$

where

- $L_{T1} = \text{Length of the tangent section between the start point and } PI_1$,
- $Ls_j = \text{Length of the spiral curve section for } PI_p$,
- $Lc_j = \text{Length of the circular curve section for } PI_p$,
- $L_{Tj+1} = \text{Length of the tangent section between } PI_j \text{ and } PI_{j+1}$.

Each PI can be collectively represented as $(PI_p, R_c, \phi_i)$. The start and end points can be denoted as $(PI_0, 0, 0)$ and $(PI_{N_H+1}, 0, 0)$. Thus, for each $N_H \in \mathbb{N}$, the combined horizontal alignment decision variables can be defined as the following equation 2.

$$HA = [(PI_0, 0, 0), (PI_1, R_{C1}, \phi_1), \ldots, (PI_{N_H}, R_{C_{N_H}}, \phi_{N_H}), (PI_{N_H+1}, 0, 0)] \in \mathbb{R}^{4N_H} \quad (2)$$

### 21.2.1 Geometrical Constraints for High-Speed Rail Alignment

The generated alignment between given endpoints must also satisfy various geometrical requirements for HSR, which are based on engineering practice, passenger safety, and comfort (UIC 2010; CA HSR 2012; AREMA 2013). These geometrical constraints are discussed in the following subsections.

**Segment Length due to Attenuation Time.** All alignment segments, including circular and spiral curves, and tangent sections between curves should have a minimum length sufficient to attenuate or adjust changes in the motion of the rolling stock (UIC 2010; CA HSR 2012; AREMA 2013). If the total number of segments in alignment is $N_{sg}$, the desirable minimum segment length for the $n^{th}$ segment is constrained as in equation 3.

$$L_{sm,n} \geq L_{smin} \forall \ n = 1,2,3,4,\ldots, N_{sg} \quad (3)$$

**Cant or Superelevation.** Assuming the total number of horizontal PIs is $N_p$, the applied cant $e_{Amn,i}$ and cant deficiency $e_{Dmn,i}$ for a circular curve corresponding to $PI_i$ is constrained as in equations 4 and 5.
$$e_{Amm,i} \leq e_{Amax} \forall i = 1,2, \ldots, N_H$$ (4)  

$$e_{Dmm,i} \leq e_{Dmax} \forall i = 1,2, \ldots, N_H$$ (5)  

**Circular Curve Radius.** A desirable minimum circular curve radius is essential when designing an alignment. It is expressed in equation 6.  

$$R_{Ci} \geq R_{Cmin} \forall i = 1,2 \ldots N_H$$ (6)  

**Spiral Curves.** Spiral curve length should be the longest lengths determined by calculating the length requirements (CA HSR 2012; AREMA 2013), which are as follows:  
- Minimum segment length to achieve attenuation time $L_{smin}$  
- Length determined from the allowed rate of change in applied cant (also called roll rate $Ro$) $L_{sroli}$  
- Length determined from the allowed rate of change in cant deficiency (also called jerk rate $Jr$) $L_{srj}$  
- Length determined from the allowed rate of change in cant (or runoff rate $Rr$) $L_{sr}$.

Hence, the minimum spiral curve length corresponding to can be formulated as equation 7.  

$$L_{Si} \geq MAX(L_{smin}, L_{sroli}, L_{srj}, L_{sr}) \forall i = 1,2 \ldots N_H$$ (7)  

Horizontal alignment cost primarily comprises location-dependent costs and length-dependent costs. The location-dependent costs include costs associated with the acquired land to build the HSR alignment. Let $A_i$ be the fraction of the area acquired by the HSR alignment and $C_{LOi}$ be the unit penalty cost of the representative land parcel. Assuming that the total number of land parcels within the study area is $TPL$, the total location-dependent cost $TC_{LO}$ can be estimated as given in equation 8 (Lai 2012; Lai and Schonfeld 2012, 2016).  

$$C_{LO} = \sum_{i=1}^{TPL} C_{LOi} \times A_i$$ (8)  

Construction and maintenance costs for the HSR track mainly constitute the length-dependent costs for the horizontal alignment. The length-dependent cost $C_{LP}$ can thus be evaluated as a product of the total length of the alignment and unit length-dependent cost $UC_{LP}$, shown in equation 9.
\[ C_{LD} = L \times UC_{LD} \]  

(9)

Impact on environmentally sensitive landcover and other restricted zones can be modeled by evaluating or calculating all the fractional land parcels acquired during land acquisition, which can then be converted into monetary value using a suitable penalty cost. Let \( FA_f \) be the fractional area acquired by the alignment from land parcel \( f \) and \( C_{LP} \) be the unit penalty cost of the representative land parcel. Assuming the total number of environmentally sensitive land parcels and restricted zones within the study area as \( TEL \), the aggregated impact, \( EI \), measured in monetary terms, can be estimated as given in equation 10.

\[ EI = \sum_{f=1}^{TEL} C_{LP_f} \times FA_f \]  

(10)

21.2.2 Problem Formulation

The overall objective function is to minimize the total construction cost of the horizontal alignment \( TC \), which is a function of the curved path \( C_{HA} \) (determined from the set of decision variables \( HA \)), by minimizing the weighted summation of the total location- and length-dependent cost of alignment while limiting the environmental impact, as shown in equations 11 and 12.

\[
\text{Minimize } TC(C_{HA}) = TC(f(HA)) \\
= TC\left(f\left([[R_{C1}, \emptyset_1], (R_{C2}, \emptyset_2) \ldots \ldots (R_{C_{N_H}}, \emptyset_{N_H})]\right)\right) = C_{LO} + C_{LD}, \quad (11)
\]

subject to

\[ EI = 0. \quad (12) \]

Geometrical constraints for HSR alignment are indicated by equations 3–7.

21.3 Methodology

The proposed methodology, called sampling-based ACO, has two stages. The first stage involves an explicit exploration of the study area for feasible \( PI \) locations using point sampling. The second stage consists of
joining suitable $PI$ locations to develop an optimized railway alignment using ant foraging behavior. Detailed discussion on the proposed methodology is provided in the subsequent sections.

### 21.3.1 Stage 1: Point Sampling for Space Exploration

The $PI$ locations are identified from points generated using a low discrepancy–based sampling sequence called a Halton sequence (Halton 1960). The low discrepancy–based sampling techniques ensure the equidistribution of points within a given space (Halton 1960) and, thus, facilitate better exploration of the study area for possible $PI$ locations. Coprime numbers are used in the Halton sequence as a base to generate quasi-random points (LaValle 2006). Figure 21.2 shows a representative Halton point set in 2D space. These points in $[0,1]$ are developed using equation 13 and are spread throughout the study area.

\[
r(i, p) = \frac{a_0}{p} + \frac{a_1}{p^2} + \frac{a_2}{p^3} + \frac{a_3}{p^4} + \cdots + \frac{a_{i-1}}{p^i},
\]

where, $i = a_0 + p a_1 + p^2 a_2 + p^3 a_3 + \cdots + p^i a_i$, $p$ is prime number, and $a$ is an integer.

![Figure 21.2: Representation of Halton Point Set Superimposed over a Real-World Map](image)

*Source: Authors.*
21.3.2 Stage 2: Development of Alignment Using Ant Colony Optimization

Ant algorithm (also called ant colony optimization or ACO) is an agent-based stochastic search algorithm inspired by ants’ foraging behavior and involves the indirect communication between the ants utilizing chemical pheromone trails to find the shortest path to the nearest food source (Dorigo, Caro, and Gambardella 1999; Dorigo, Bonabeau, and Theraulaz 2000). The ACO exhibits faster convergence in finding an optimal solution over other artificial intelligence–based heuristics algorithms like PSO, shuffled frog leaping algorithms, and GA in spatial optimization problems like the traveling salesman problem (Brucal and Dadios 2017; Saud, Kodaz, and Babaoğlu 2018).

The alignment development starts by placing the number of ants, \( k = 1, ..., n_b \), at the start point or terminal node of the alignment. Let \( IZ_f \) be the \( f^{th} \) environmentally sensitive or restricted zone and \( TEL \) be the total number of environmentally sensitive or restricted zones within the study area. Let \( \sigma_j \) indicate whether the tangent between points \((i, j)\) overlaps infeasible zones, and let \( \Delta \) be the minimum tangential section distance between subsequent sections for an HSR alignment. The \( N_i^k \) represents the set of potential \( j^{th} \) PIs that do not overlap the infeasible zones (i.e., \( \sigma_{ij} = 0 \)) when connected with a tangent to the preceding \( i^{th} \) PI and are at least \( \Delta \) distance away from the \( i^{th} \) PI (Figure 21.3). Each ant, \( k \),
at $i^{th}$ PI will choose the following $PI$ from the feasible neighborhood $N^k_i$. If ant $k$ is currently located at $i^{th}$ $PI$, then it moves to $j \in N^k_i$ based on the transition probability $P^k_{ij}(t)$ presented in equation 14.

$$P^k_{ij}(t) = \begin{cases} 
\frac{[\theta_{ij}(t)]^\beta [\delta_{ij}(t)]^\gamma}{\sum_{u \in N^k_i(t)}[\theta_{iu}(t)]^\beta [\delta_{iu}(t)]^\gamma} & \text{if } j \in N^k_i(t), \\
0 & \text{if } j \notin N^k_i(t)
\end{cases} \tag{14}$$

where

- $\theta_{ij}$ = Pheromone intensity between $i^{th}$ and $j^{th}$ PIs,
- $\delta_{ij} = 1/(e^{\sigma_{ij}} + d_{ij})$ represents the feasibility attractiveness of $j^{th}$ $PI$ from the $i^{th}$ $PI$, $d_{ij}$ = Distance between $i^{th}$ and $j^{th}$ PIs,
- $\beta$ = Positive constant to amplify the influence of pheromone intensity,
- $\gamma$ = Positive constant to increase the feasibility, attractiveness, or desirability toward the other points.

Once tangent sections are established between PIs, horizontal curve sections, including circular and spiral curves, are fitted. Initially, a small random value of pheromone concentration within the range of $[0, \delta_0]$ is deposited on each segment. The $\delta_0$ is a known positive constant. An ant $k$ chooses the next $PI$ and incrementally progresses toward the endpoint or terminal to develop the complete path. Let $T^k(t)$ denote the alignment created by the ant $k$ at time step $t$. The ants deterministically retrace their movement to the starting terminal station and deposit pheromone along each segment of the corresponding alignment, $T^k$. Alignments with a shorter length, lesser location cost, and no overlap with environmentally sensitive or restricted zones should have a significant pheromone trail as more ants will tend to choose it. Let $C^k_{LD}(t)$, $C^k_{LO}(t)$, and $EI^k(t)$ be the length-dependent cost, location-dependent cost, and aggregated impact, respectively, for the alignment traced by the ant $k$ at time step $t$. The pheromone trail is estimated using equation 15.

$$\Delta \theta^k_{ij}(t) = 1/(C^k_{LD}(t) + C^k_{LO}(t) + EI^k(t)), \forall (i,j) \in T^k(t) \quad (15)$$

The pheromones deposited by the ants also evaporate with time. Thus, the updated total pheromone intensity on each tangent $(i,j)$ at time step $t$ after pheromone deposition and evaporation can be estimated with a constant evaporation rate of $\mu$ ($0 \leq \mu \leq 1$) using equation 16.

$$\theta_{ij}(t+1) = (1 - \mu) \theta_{ij}(t) + \sum_{k=1}^{n_k} \Delta \theta^k_{ij}(t) \quad (16)$$
The pheromone concentration is updated iteratively until all the ants pass through the best $n_l$ alignments. These paths are short-listed with each generation. In the next iteration, the ants are again placed on the start point or terminal. In this way, the ants explore new feasible paths or alignments. With an increase in generations or iterations, a larger search space is sampled for better possible alignments. The process continues until the following termination conditions are met:

- The maximum number of iterations, $t_{\text{max}}$, has been exceeded,
- All ants (or most of the ants) converge on the same alignment.

### 21.4 Case Study

A real-world case study is considered for generating a high-speed railway alignment between two cities, Surat and Bilimora, in Gujarat, India. Both cities are part of the Mumbai–Ahmedabad HSR corridor. Land-use data in the form of raster maps (GeoTIFF format) were downloaded from the Bhuvan web portal (Bhuvan n.d.). Property value data was downloaded from property brokerage websites (99acres.com n.d.) and was used to generate a land cost data set (Roy and Maji 2019). Environmentally sensitive land parcels were extracted in a shapefile using ArcMap 10.4 (2017). A Python ArcGIS MATLAB–based approach is developed for the proposed methodology. The cost data are extracted

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
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<td>Width of cross-section</td>
<td>29.1 m (2-track formation width of 11.3 m and 8.9-m embankment width on either side)</td>
</tr>
<tr>
<td>Design speed $V_{\text{high}}$</td>
<td>300 km/hr</td>
</tr>
<tr>
<td>Attenuation time $T_{\text{att}}$</td>
<td>3.1 sec</td>
</tr>
<tr>
<td>Minimum segment length $L_{\text{min}}$</td>
<td>258 m</td>
</tr>
<tr>
<td>Maximum applied cant $e_{\text{A,max}}$</td>
<td>150 mm</td>
</tr>
<tr>
<td>Maximum cant deficiency $e_{\text{D,max}}$</td>
<td>75 mm</td>
</tr>
<tr>
<td>Minimum radius of curvature</td>
<td>4,450 m</td>
</tr>
<tr>
<td>Price of track construction</td>
<td>$300/m</td>
</tr>
<tr>
<td>Penalty cost for impacted area</td>
<td>$100/m^2</td>
</tr>
</tbody>
</table>

Table 21.1: Input Parameters for Railway Alignment Design and Ant Colony Optimization
from the raster maps using a Python-based geoprocessing script in the ArcGIS 10.4 (ArcGIS 2017) environment. The alignment optimization using ACO is handled in MATLAB 2014b (MATLAB 2017). Table 21.1 shows the HSR alignment design and ACO parameters used as input in this case study.

### 21.5 Results and Discussion

The proposed methodology was run for a maximum number of 200 iterations. In each iteration, 20 potential solutions or alignments were generated and evaluated. Figure 21.4 shows the generated optimized alignment and generated PIs along with the horizontal curve sections for the given study area. Table 21.2 shows the breakdown of the objective functions values, central angle ($\phi_i$), circular and spiral curve length ($L_{Ci}, L_{Si}$), applied cant $e_{Amm,i}$, cant deficiency $e_{Dmm,i}$, and tangent length $L_{Ti}$ for the alignment shown in Figure 21.4. A constant radius of curvature was assumed for this case study. In this case study, the computation time for generating a single feasible alignment was around 3 seconds of CPU time. Figure 21.4, Panels B–E shows that the generated alignment is avoiding the infeasible zones in the study area. Hence, the environmental impact of the alignment generated is nil.

From Table 21.2, it can be observed that alignment A1 does not have a constant value for the optimum central angle $\phi_i$ for all the PI locations.
A variable central angle ensures that the alignment design is less restrictive. It can be observed that $PI_3$ has the largest central angle $\phi_3$ followed by $\phi_1$ and $\phi_2$. A similar trend is observed for the circular curve length $L_{Ci}$. From Table 21.2, it can be seen that the length for each of the
Table 21.2: Objective Values of Representative Alignment Optimization Solutions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Alignment A1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of HSR alignment line $L$</td>
<td>47.77 km</td>
</tr>
<tr>
<td>Length-dependent cost $T_{C_{LNC}}$</td>
<td>$14.33 \text{ M}$</td>
</tr>
<tr>
<td>Location-dependent cost $T_{C_{LO}}$</td>
<td>$14.85 \text{ M}$</td>
</tr>
<tr>
<td>Environmental impact area</td>
<td>0 m²</td>
</tr>
<tr>
<td>Total construction cost $T_C$</td>
<td>$29.18 \text{ M}$</td>
</tr>
<tr>
<td>Central angle $\emptyset_i$</td>
<td></td>
</tr>
<tr>
<td>$\emptyset_1$</td>
<td>24.39°</td>
</tr>
<tr>
<td>$\emptyset_2$</td>
<td>4.79°</td>
</tr>
<tr>
<td>$\emptyset_3$</td>
<td>32.15°</td>
</tr>
<tr>
<td>Circular curve length $L_{Ci}$</td>
<td></td>
</tr>
<tr>
<td>$L_{C1}$</td>
<td>1,943.90 m</td>
</tr>
<tr>
<td>$L_{C2}$</td>
<td>403.52 m</td>
</tr>
<tr>
<td>$L_{C3}$</td>
<td>2,727.46 m</td>
</tr>
<tr>
<td>Spiral curve length $L_{Si}$</td>
<td></td>
</tr>
<tr>
<td>$L_{S1}$</td>
<td>365.05 m</td>
</tr>
<tr>
<td>$L_{S2}$</td>
<td>345.04 m</td>
</tr>
<tr>
<td>$L_{S3}$</td>
<td>342.04 m</td>
</tr>
<tr>
<td>Applied cant $e_{Amm_i}$</td>
<td></td>
</tr>
<tr>
<td>$e_{Amm_{1}}$</td>
<td>150 mm</td>
</tr>
<tr>
<td>$e_{Amm_{2}}$</td>
<td>145 mm</td>
</tr>
<tr>
<td>$e_{Amm_{3}}$</td>
<td>145 mm</td>
</tr>
<tr>
<td>Cant deficiency $e_{Dmm_i}$</td>
<td></td>
</tr>
<tr>
<td>$e_{Dmm_{1}}$</td>
<td>72 mm</td>
</tr>
<tr>
<td>$e_{Dmm_{2}}$</td>
<td>65 mm</td>
</tr>
<tr>
<td>$e_{Dmm_{3}}$</td>
<td>64 mm</td>
</tr>
<tr>
<td>Tangent length $L_T$</td>
<td></td>
</tr>
<tr>
<td>$L_{T1}$</td>
<td>1,370 m</td>
</tr>
<tr>
<td>$L_{T2}$</td>
<td>10,520 m</td>
</tr>
<tr>
<td>$L_{T3}$</td>
<td>4,517.5 m</td>
</tr>
</tbody>
</table>

HSR = high-speed rail, km = kilometer, m = meter, M = million, mm = millimeter.
Source: Authors.

alignment segments (tangent, circular curve, and spiral curve sections) satisfies the minimum segment length $L_{smin}$ criteria for all the mentioned alignments. Also, the values for applied cant $e_{Amm_i}$ and cant deficiency $e_{Dmm_i}$ at each PI location are less than the maximum values for both applied cant and cant deficiency. Thus, the generated alignment satisfies the required geometrical criteria necessary for a feasible HSR alignment.
Figure 21.5 shows the variation of the total cost with the number of iterations. The algorithm was executed with the same set of parameters for multiple runs to observe the convergence trend. Figure 21.5 also shows that even for multiple runs, the convergence trend does not show a significant change. It can be attributed to the efficiency of the ACO, which has shown the ability toward faster convergence for other types of problems. Also, the inclusion of a feasible neighborhood in the selection of PIs ensures the generation of feasible alignments. Thus, the computation efficiency is improved as the proposed algorithm does not consider infeasible solutions for further evaluation in the optimization process.

![Figure 21.5: Variation of the Total Construction Cost with the Number of Iterations](image)

Source: Authors.

### 21.6 Conclusion

The development of computer-aided heuristic-based optimization algorithms has helped researchers to extensively evaluate the potential alternatives and identify the best alignment for the real-world conditions. However, these methods assumed the decision variables or PIs to be located on preselected orthogonal cut sections, offset points, or grids. The restriction on PI locations affects the quality and feasibility
of the alignment generated. In the case of railways specifically, existing studies have only focused on urban and mountain rails, so results may not apply to other modes like HSR and conventional long-distance rail due to variation in geometrical guidelines and constraints. The proposed method uses the capability of the ant algorithm to develop a point sampling–based ACO approach to overcome the aforementioned limitations. The low-discrepancy point sampling helped in selecting PIs at suitable locations, the horizontal curve fitting satisfied the geometrical design requirements for an HSR, and transition probability–based PI selection eliminated the need for infeasible solution evaluations. A real-world case study was used to show the applicability of the approach. Obtained results were promising. The proposed method would benefit the planners in exploring and selecting the best possible horizontal railway alignment. The scope of this study was limited to the optimization of horizontal PI locations and curve-related geometric design constraints for the HSR alignment design. Also, in this study, the alignments were generated using a constant radius of curvature and a single value of sampling points. However, the radius of curvature and the required number of sampling points may vary according to the nature of the study area. Thus, further examination of the effect of this parameter shall be investigated in the future. Further, the extension of this study would include ACO for vertical profile optimization and simultaneously optimizing both the horizontal alignment and vertical profile for highways and railways. Also, the application and efficiency of other low-discrepancy point sequences such as Sobol and Hammersley sequences can be compared with the Halton sequences.
References


22

Estimating Direct, Indirect, and Induced Employment from Highway Construction in India

Vinod Vasudevan, Sudhir Misra, Tanika Chakraborty, Prasanna Kumar Behera, and Ayushman Bhatt

22.1 Introduction

When local, state, and national governments invest in transportation infrastructure, they expect their investment to generate substantial employment. Employment can be classified as direct, indirect, and induced. Direct employment results from the construction activity itself, indirect employment occurs in industries that support construction, and induced employment is only possible upon completion and operation of the new infrastructure. While it is fairly straightforward to estimate direct and indirect employment data through payroll information from construction contractors, materials suppliers, etc., induced employment data must be obtained through primary surveys. Despite policy makers’ interest in estimating employment generated from transportation infrastructure projects, there has been a dearth of studies on this topic conducted in India. Researchers in the United States (US) and other developed countries have, to some extent, conducted such studies (Keane 1996), but these studies are largely inapplicable to India and other developing countries due to substantial differences in the requirement of labor in particular and the environment of the

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1 The findings in this chapter are based on data collected for a project sponsored by the Transport Research Wing of the Ministry of Road Transport and Highways (India). The authors would like to acknowledge the support of various officials including Babni Lal, Kirti Saxena, K. Guite, A. K. Sadhu, Ranjan Mukherjee, and Shirley M. Daniel for their continued support throughout the project. We also thank the officers and consultants who provided us with the required data.
construction industry in general. This chapter attempts to fill that gap by building a framework for estimating direct, indirect, and induced employment amounts generated from transportation infrastructure projects in India.

Data were collected on a total of eight infrastructure projects in India from the states of Uttar Pradesh and Maharashtra. Four were ongoing projects for estimating direct and indirect employment and four were completed projects for estimating induced employment. Although this is too small a sample for extrapolating to get generalized estimates of direct, indirect, and induced employment resulting from other infrastructure projects in India, the methods used to obtain these estimates could be imitated. As future studies collect more data, it will become possible to conduct a meta-analysis to develop generalized rules for estimating employment.

The framework developed for this study delivers relatively conservative employment estimates. The following direct, indirect, and induced employment data were not considered: government employees working in organizations such as the National Highways Authority of India, post-construction activities such as regular and periodic maintenance, the reconstruction of buildings that were displaced by the infrastructure projects, the manufacturing of vehicles and construction equipment, and induced employment created outside of a 2-kilometer (km) radius from the completed projects. A conservative estimate is likely of greater value to policy makers than a liberal estimate would be because it may prevent policy makers from “overselling” potential employment opportunities to their stakeholders and constituents.

There is a commonsense agreement that large infrastructure projects generate employment, but policy makers should be able to rely on more than common sense. This chapter is a first step toward being able to offer Indian policy makers an approximation of the value, in terms of generated employment, of highway infrastructure investments. When weighing the value of one project versus another, the framework described in this chapter could become an important tool in cost-benefit analyses, though of course it must be borne in mind that monetizing benefits to quantitatively establish this ratio is quite a challenge and is not being addressed in this study.

### 22.2 Definitions

*Direct employment* includes any employment generated in direct relation to the construction of an infrastructure project. Construction activities such as building new roads, adding lanes, and building new
bridges or interchanges all require huge deployment of labor. These data can be gathered from the concessionaires, the private firms that were contracted by the government.

*Indirect employment* includes any employment generated in supporting industries to meet increased demand during the construction period. These data can be gathered from materials suppliers, equipment suppliers, and other vendors.

*Induced employment* includes all employment directly or indirectly attributable to creation or improvement of the transportation infrastructure. For example, businesses may grow because of the increased demand caused by a nearby highway or the improved access to urban centers. These data are particularly difficult to collect because every business in the vicinity of the project, no matter how small or large, could experience induced employment. Further, it is likely that some new businesses may also be added due to the existence of constructed highways.

*Person-days* are the key unit of analysis used in this study. One person-day has been considered to be equal to 8 hours of labor, regardless of whether that labor was conducted by one employee or multiple employees. Another common unit of analysis for labor is full-time equivalent employment, but this unit can vary depending on individual firms' position requirements. For instance, one full-time equivalent employee may be equal to 365 person-days or, if paid time-off is standard for the position, it may be equal to less than 365 person-days.

### 22.3 Literature Review

Few studies have looked at the effect of transportation infrastructure investment on employment, per se, but several studies have investigated the effect on the overall regional economy. However, even fewer of these studies were conducted in India.

Regional econometric models are frequently used to assess the impact of transportation investment on regional economic activity. These models typically examine the effects of transportation investment on industry output and employment. Carlino and Mills (1987) examined various factors, including different measures of employment, which affected the country population growth in the US during the 1970s. Andersson, Anderstig, and Hårsmans (1990) analyzed relationships between infrastructure and regional productivity in Sweden and identified specific variables, such as the existence of roads, that contributed to regional productivity. However, there is evidence from these studies and others that while highways may stimulate the economy in urban and suburban areas, underdeveloped areas may be
negatively affected. A location decision analysis conducted by Calzonetti and Walker (1991) indicated that market accessibility (i.e., highway access, airport access, etc.) is an important factor influencing industry locations. This study suggested that improving highways and interstate access is one of the major parameters affecting the viability of sites for industry. These studies support the general concept that investing in transportation infrastructure is often a boon for the local economy, but none of these studies specifically address employment as an effect of infrastructure investment.

Kim et al. (2012) estimated direct employment generated by the construction of expressways in the Republic of Korea using a multiple regression analysis and the ordinary least squares estimation technique. The analysis included 68 sections of expressways, finding that W1 billion ($909,000) could generate 7.27 full-time jobs. In the US, Smith (1978) analyzed 510 federal-aid highway projects, finding an immediate impact on job creation. Similarly, Gorman (1985) conducted a correlation analysis to estimate the job generation rates of road construction projects in the US and found that smaller projects, particularly in rural areas, resulted in larger job generation rates. Jacoby (1995) used a multiple regression analysis to estimate the effect of road construction on employment for 4,612 road construction projects in the US between 1978 and 1992, finding that $1 million could generate an average of 8.35 full-time jobs, but there were regional variations ranging between 5.95 and 10.62 full-time jobs. Studying the effects of the American Recovery and Reinvestment Act (2009) on construction employment in the US state of Texas, Kim et al. (2014) found that an increase in project size increased the demand for person-hours by a factor of approximately 0.5 and that projects in metropolitan areas generated more employment than in rural areas by a factor of 1.3. And according to the job generation formula developed for the American Recovery and Reinvestment Act (New England Council 2008), using the economic impact analysis for planning methodology, an investment of $1 million could create 8.34 direct full-time jobs and 8.63 indirect and induced full-time jobs.

A report by the Executive Office of the President of the US (CEA 2009) illustrated that the macroeconomic methodology used to derive aggregate jobs estimates provides only an imperfect way to separate direct, indirect, and induced employment. The authors assumed direct and indirect output effects moved one-for-one with government spending. That is, each dollar spent goes one-for-one into gross domestic product (GDP). Then the generally accepted theory that a 1% rise in GDP creates 1 million jobs (distributed over three quarters)
was used to estimate the effect on direct and indirect job generation. Induced jobs were then estimated using the difference between total jobs created and the estimate of direct and indirect jobs created. For a typical government spending project, the report found that 64% of job-years created by government spending could be attributed to direct and indirect employment and 36% to induced employment.

The International Labor Organization published a report (Sinha, Prabhakar, and Jaiswal 2015) that used input-output (IO) multiplier analysis, which operates through multi-sector linkages in an economy, to develop employment multipliers that could estimate the effect of infrastructure investment in two Indian states, Gujarat and West Bengal, on the creation of direct, indirect, and induced jobs. Labor enters an IO framework as a factor of production in relation to output generation. The IO tables for Gujarat and West Bengal included 16 sectors typically included in IO tables plus four new infrastructure sectors: national highways, urban-rural roads, buildings, and irrigation canals. The IO multiplier analysis provided information on the quantum of jobs that would be created in the entire economy due to new construction and repair and maintenance work in the infrastructure sectors. The direct and indirect multipliers were estimated by closing the IO model to include the household sector. The induced effect was then estimated by calculating the difference between these employment multipliers from a closed IO model and employment multipliers from an open IO model.

To date, very few studies have attempted to estimate the effect of infrastructure investment on direct, indirect, and induced employment generation, particularly in developing countries like India. Furthermore, there is no single methodology that is generally accepted for this purpose. This chapter attempts to fill this gap in the literature.

22.4 Methods and Framework

This section on methods and framework is broken into two subsections. The first subsection is on the estimation of direct and indirect employment and the second subsection is on the estimation of induced employment. These methods draw on the work of previous researchers, but the ultimate framework for estimating employment generation is original. As mentioned earlier, four ongoing infrastructure projects were used for estimating direct and indirect employment generation and four different, completed projects were used for estimating induced employment generation.
22.4.1 Direct and Indirect Employment

Figure 22.1 shows a diagram of the methodology for estimating direct and indirect employment generation for the four ongoing projects, two each from Maharashtra and Uttar Pradesh. As shown, the process is divided into three steps: data collection, data standardization, and analysis and estimation.

**Data collection: direct employment.** As defined earlier, direct employment includes construction workers and other employees of the firms involved in the construction of transportation infrastructure projects. All projects considered in this study were built under public–private partnerships (PPPs), meaning that the government contracted out many functions related to the infrastructure projects to private firms, known as concessionaires. In India and many other countries, concessionaires are required to keep detailed records of expenses related to contracted projects, including labor.

In two of the infrastructure projects considered for this portion of the study, the concessionaires themselves managed construction activities. In the remaining two projects, construction activities were executed by subcontractors hired by the concessionaires. The appropriate party for each project was approached and data related to pre-construction activities (such as utility shifting), construction activities, and post-construction activities (such as toll operations) were collected for this study. In addition, employment data pertaining to the independent engineering firm, i.e., the third-party firm responsible for objectively monitoring the infrastructure project, was separately collected.

**Data collection: indirect employment.** As defined earlier, indirect employment includes the employment generated in firms that provide support services or materials to the construction company. Every commodity necessarily has a manufacturer and a consumer. In order to
make the commodity available to the consumer (which, in this case, is the concessionaire or subcontracted construction company) from the manufacturer, there may be several “hands” between the two that “touch” the commodity. Employment in every layer between the manufacturer and the consumer contributes to the indirect employment generated on account of government investments in infrastructure projects.

For example, the cement used for construction activities may be procured through a dealer, who obtained it directly from one or more cement factories, which obtained raw materials from yet other companies. Hence, the indirect employment generated in the dealer’s company due to the infrastructure investment is only the first layer, and then the indirect employment generated in the cement factories is the second layer, and so on.

Collecting data related to indirect employment becomes increasingly complicated as one moves down the layers of the supply chain. Further, the employment generation effect of highway construction appears to decrease as the layers move further from the consumer. For these reasons, only firms involved in the first two layers of the supply chain, i.e., only material dealers and manufacturers, were contacted for data collection. This has likely resulted in a conservative estimate of indirect employment generation. But, as mentioned in the introduction, a conservative estimate is likely of greater value to policy makers.

Data standardization. During the data collection process, it became clear that most organizations did not maintain employment records in terms of person-days. This meant that after data collection, it was necessary to standardize the data. This process was done for both direct and indirect employment, and the approach followed for direct employment was slightly different from that for indirect employment.

Since highway construction in India is often a continuous activity, i.e., 24 hours per day, the laborers work in shifts. In all the projects considered for this study, the workday was divided into two 12-hour shifts. A simple calculation was performed to convert the 12-hour shifts into 8-hour person-days. It could be said that each employee worked a total of 1.5 person-days per shift (the quotient of 12 divided by 8). Therefore, direct employment in terms of person-days was determined by the number of employees multiplied by 1.5 and multiplied again by the number of shifts during the construction period.

A similar approach was used for indirect employment generated through the transportation of construction materials from their source. Trip durations were reported in full 24-hour days because of the long distances involved. In these cases, the indirect employment in terms of person-days was determined by multiplying the trip duration by 3 (the quotient of 24 divided by 8).
For other forms of indirect employment, total employment figures were provided by the various firms involved in the first two layers of the supply chain. Since most of these firms provided services or materials to multiple customers and not exclusively for the infrastructure projects considered in this study, it would be incorrect to include all employment figures. In such cases, the indirect employment dedicated to the infrastructure project was estimated by dividing the effort (in terms of services or materials) given toward the construction activity by the total effort during the time under study.

Data analysis. Using the adjusted data in terms of person-days, detailed analyses became possible. Other than estimating direct and indirect employment in terms of person-days, the relationship between employment and type of infrastructure project could also be analyzed. These analyses can provide a better understanding of the employment creation of various activities.

22.4.2 Induced Employment

Initially, an effort was undertaken to use data collected by the National Sample Survey Office, a division of the Indian Ministry of Statistics and Program Implementation. However, the data did not meet the needs of this study because the level of analysis in the National Sample Survey Office data is at the district level and the level of analysis in this study is at the project level. Therefore, the estimate of induced employment generation is based on a primary survey and interviews involving businesses in the areas near four completed transportation infrastructure projects, two each in Maharashtra and Uttar Pradesh.

As already mentioned, because induced employment can only be observed in completed projects, the four projects used for estimating induced employment are different from the four projects used for estimating direct and indirect employment. Since induced employment can only be observed within a number of years after project completion, all four project completion dates were within the last 7 years at the time of data collection.

From the completed infrastructure projects, 10 sections of 5 km each were selected. These sections were chosen in such a way that they were spread out over a considerable distance from each other, yet still logistically manageable within a limited time span for the team of interviewers. Thus, a total stretch of 50 kilometers was selected from each project. In each section, surveyors filled in a list of businesses and conducted interviews using the form shown in Figure 22.2.
Before conducting the interviews, a pilot survey was used to narrow down the list of business types to be considered for the study. Interviews were then conducted for a sample of selected shopkeepers from each of these business categories. The survey included questions about the number of employees on the date of the interview and the number of employees before the completion of the highway project, as recalled by the business owners. The induced employment over the construction period was thus determined from the difference between the two numbers.

As can be seen from Figure 22.2, data were collected separately for different types of businesses. Within a project area, the data collected through the survey about different types of businesses served as the sample, which was then used to extrapolate induced employment for the total number of each business type within the project area. The aggregation over all the stretches then provided an estimate of total induced employment generated in the full 50-km section of each project.
22.5 Results

The results section, just like the methodology section, is broken into two subsections. The first subsection is on direct and indirect employment. The second subsection is on induced employment.

22.5.1 Direct and Indirect Employment

The results are presented in several tables. Where applicable, the four projects are denoted in the tables as MH-1 and MH-2, for the two projects in Maharashtra, and UP-1 and UP-2, for the two projects in Uttar Pradesh. Throughout the analysis, it became apparent that the data for UP-2 were substantially different from those of the other three projects. Because of this, UP-2 was excluded from some comparisons. As previously mentioned, the unit of analysis for labor is person-days.

Table 22.1 shows the direct and indirect employment generated by each of the four projects. The project period is divided into three phases: pre-construction, construction, and post-construction. All labor in the pre-construction and post-construction phases is considered

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Estimate</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MH-1</td>
</tr>
<tr>
<td>1</td>
<td>Length (km)</td>
<td>138</td>
</tr>
<tr>
<td>2</td>
<td>% completion (as on Dec. 16)</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>Pre-construction</td>
<td>127,480</td>
</tr>
<tr>
<td>4</td>
<td>Construction</td>
<td>Direct</td>
</tr>
<tr>
<td>5</td>
<td>Indirect</td>
<td>2,905,654</td>
</tr>
<tr>
<td>6</td>
<td>Post-construction*</td>
<td>21,080</td>
</tr>
<tr>
<td>7</td>
<td>Total employment (person-days as on Dec. 16)</td>
<td>5,620,888</td>
</tr>
<tr>
<td>8</td>
<td>Adjusted total employment</td>
<td>6,988,970</td>
</tr>
<tr>
<td></td>
<td>(for 100% completion)*</td>
<td>50,645</td>
</tr>
</tbody>
</table>

* km = kilometer, MH = Maharashtra, UP = Uttar Pradesh.
* Does not include employment from toll operation and maintenance.
* Estimated using direct projection of construction-related direct and indirect employment.
* Includes employment generated from reconstruction of dismantled buildings.

Source: Authors.
direct employment because those activities do not include any non-negligible work that requires outside vendors. The last row displays the total employment generated per kilometer of constructed highway. It is important to mention that at the time of data collection, three of these projects were not completed. Therefore, the second-to-last row on the right displays the projected total employment with 100% completion of the projects.

Table 22.2 is a summary of the direct employment generated per lane kilometer of the projects. A lane kilometer is defined as one kilometer of road in a single lane—meaning that 1 km on a four-lane highway is equal to 4 lane kilometers. On average, the direct employment generated per lane kilometer of highway construction is roughly 4,406 person-days. The estimation of direct employment per lane kilometer is challenging and requires further explanation.

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Estimate</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MH-1</td>
</tr>
<tr>
<td>1</td>
<td>Length (km)</td>
<td>138</td>
</tr>
<tr>
<td>2</td>
<td>% completion (as on Dec. 16)</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>Total direct employment (person-days as on Dec. 16)</td>
<td>2,715,234</td>
</tr>
<tr>
<td>4</td>
<td>Adjusted direct employment (for 100% completion)*</td>
<td>3,356,902</td>
</tr>
<tr>
<td>5</td>
<td>Adjusted direct employment per km of highway (for 100% completion)</td>
<td>24,325</td>
</tr>
<tr>
<td>6</td>
<td>Effective lane km per km</td>
<td>4.09</td>
</tr>
<tr>
<td>7</td>
<td>Adjusted direct employment per lane km of highway (for 100% completion)</td>
<td>5,948</td>
</tr>
</tbody>
</table>

km = kilometer, MH = Maharashtra, UP = Uttar Pradesh.
Note: Total direct employment number includes those during pre- and post-construction (from Table 22.1).
* Estimated using direct projection of construction-related direct employment.
Source: Authors.

The assumptions made throughout this explanation are based on conversations with the concessionaires and National Highways Authority of India officials who were familiar with similar projects. For most widening projects (2 lanes to 4 lanes, 4 lanes to 6 lanes,
etc.), the addition of service lanes is required during construction. Therefore, two lanes of service roads were added throughout the length of the road. Since the quality requirements of service roads are not as stringent as those of highways, the employment requirements of service roads were also lower. In this case, it is assumed that the resources required to construct one lane kilometer of service road are equal to 70% of those required to build one lane kilometer of highway. At locations where special structures such as bridges, grade separators, or underpasses are present, the entire special structure must be substantially rebuilt irrespective of the quality of the existing structures. This means that, in those stretches of highway with special structures, the number of additional lanes could be assumed to be the same as the total lanes of the newly constructed road.

Although the count of special structures was collected from concessionaires, the length of individual structures was not available. Therefore, assumptions regarding length were made. The average length of major bridges was assumed to be 800 meters (including the approach length on both sides of the bridge), length of minor bridges was assumed to be 400 meters, length of grade separators was assumed to be 800 meters, length of underpasses (vehicle, pedestrian, and cattle underpasses) was assumed to be 50 meters, and length of culverts (box and pipe) was assumed to be 20 meters. The effective lengths of each of the special structures were summed to get the effective length of new highway constructed. This number was then multiplied by the number of lanes of the widened highway to estimate the effective lane width added. In addition, whenever new lanes are added, some maintenance is performed on the existing lanes (other than the lanes that are part of special structures). This includes adding a top layer to ensure uniform riding quality across all the lanes. In this case, it was assumed that for each of the existing lane kilometers, the resources required for maintenance are equal to 10% of constructing a new lane for a highway converted from 4 lanes to 6 lanes and 12.5% for that converted from 2 lanes to 4 lanes. Using these assumptions, the effective lane kilometers per kilometer of highway for MH-1, MH-2, and UP-1 were estimated to be 4.09, 5.29, and 4.66, respectively. UP-2 did not include lane additions, so service lanes were not necessary. Therefore, UP-2 (a two-lane highway) has a value of 2 for effective lane kilometers per kilometer of highway. These values were then used to generate a ratio of direct employment per lane kilometer, as shown in the last row of Table 22.2.

Table 22.3 shows the total direct and indirect employment generated per million Indian rupees invested. As with Table 22.1, it was necessary to project employment for 100% completion of three of the projects.
Table 22.3: Direct and Indirect Employment per Million ₹ Invested

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Estimate</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MH-1</td>
</tr>
<tr>
<td>1</td>
<td>Project cost (₹ million)</td>
<td>19,000</td>
</tr>
<tr>
<td>2</td>
<td>% completion (as on Dec. 16)</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>Total employment (person-days as on Dec. 16)</td>
<td>5,620,888</td>
</tr>
<tr>
<td>4</td>
<td>Adjusted total employment (for 100% completion)a</td>
<td>6,988,970</td>
</tr>
<tr>
<td>5</td>
<td>Estimated employment (person-days) per ₹ million investment</td>
<td>368</td>
</tr>
</tbody>
</table>

MH = Maharashtra, UP = Uttar Pradesh.

a Estimated using direct projection of construction-related direct and indirect employment.
b Does not include employment generated from reconstruction of dismantled houses.

Source: Authors.

Table 22.4 shows the ratio of indirect to direct employment. The weighted average for the indirect-to-direct ratio for MH-1, MH-2, and UP-1 (excluding UP-2 because of its substantial difference from the other projects) is 1.25, meaning that 1.25 indirect jobs are generated for every 1 direct job.

Table 22.4: Ratio of Indirect to Direct Employment

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Estimate</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MH-1</td>
</tr>
<tr>
<td>1</td>
<td>Project cost (₹ million)</td>
<td>19,000</td>
</tr>
<tr>
<td>2</td>
<td>% completion (as on Dec. 16)</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>Construction (person-days) Direct</td>
<td>2,566,674</td>
</tr>
<tr>
<td>4</td>
<td>Construction (person-days) Indirect</td>
<td>2,905,654</td>
</tr>
<tr>
<td>5</td>
<td>Indirect-to-direct employment ratio</td>
<td>1.13</td>
</tr>
</tbody>
</table>

MH = Maharashtra, UP = Uttar Pradesh. Note: Only the construction phase is included because it is the only period in which indirect employment information was available.

Source: Authors.
22.5.2 Induced Employment

As mentioned previously, since induced employment is only possible after the completion of a project, the four projects chosen for analysis of induced employment are different from the four for direct and indirect employment.

Table 22.5 presents the total number of businesses along the project area and the total number of businesses surveyed. In this table, the two Maharashtra projects are denoted as NH 65 and NH 3 and the two Uttar Pradesh projects are denoted as NH 2(A) and NH 2(B).

The surveys captured a variety of data, including type of business (service, retail, or manufacturing), nature of operation, when the establishment was registered, when it started its operations, price of the land before and after the construction of the highway, and impact of the highway on the cost of labor or ease of transportation.

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Highway Surveyed/Details of Enterprises</th>
<th>Number in Population</th>
<th>Number Surveyed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All projects</td>
<td>5,923</td>
<td>383</td>
</tr>
<tr>
<td>2</td>
<td>NH 3</td>
<td>539</td>
<td>103</td>
</tr>
<tr>
<td>3</td>
<td>NH 65</td>
<td>1,728</td>
<td>120</td>
</tr>
<tr>
<td>4</td>
<td>NH 2(A)</td>
<td>2,349</td>
<td>119</td>
</tr>
<tr>
<td>5</td>
<td>NH 2(B)</td>
<td>1,307</td>
<td>41</td>
</tr>
</tbody>
</table>

Source: Authors.

According to the survey results, 354 of the 383 surveyed businesses started their operations after the highways were constructed. Only 29 had been in operation before the construction. This finding alone is staggering and speaks to the potential of induced employment caused by highway construction. The businesses also provided their number of employees before and after construction. However, since most businesses opened after construction, only one number was provided. In those cases, the number of employees before the highway was constructed was entered as zero. The difference between the before and after values is the number derived for induced employment.

The total number of induced employment generated after the construction of the highways can be calculated using the following simple equation:
Employment Generated = Total Number of Enterprises (N) 
  \times \text{Mean Change in Employment (E)}

The results show that highway construction induced a roughly estimated 9,000 jobs in both Maharashtra and Uttar Pradesh. Furthermore, an average of about 90 jobs per 100 km of highway was induced in both states.

As mentioned earlier, the infrastructure projects considered for study were completed 7 years prior to data collection. Hence, the estimate of 90 jobs is the approximate amount of induced employment generated over the 7-year period since the project was completed. However, it is unlikely that all of this employment was immediately generated. Therefore, in order to estimate the overall employment over the years considered, an assumption of the growth rate must be made. If a linear progression is assumed, then the induced employment would be spread over 7 years. In other words, 12,857 jobs were created each year.

To compare induced employment to direct and indirect employment, it is necessary to convert the estimates of induced employment into person-days. To do this, it was assumed that each employee works 6 days per week for a total of 312 days per year. Therefore, the translation into person-days for the first year would be equal to 12,857 multiplied by 312, and then that number would be multiplied by 7 (for the total number of years worked by the year one “cohort”). Then, the year two “cohort” would again be 12,857 multiplied by 312, but then that number would only be multiplied by 6, and so on.

This means that we can use an arithmetic progression technique going from 7 to 1 year(s) of work to estimate the total number of person-days generated per km due to the employment of 90 people over a period of 7 years. This is given by:

\[
(7 \times 312 \times 12.857) + (6 \times 312 \times 12.857) + (5 \times 312 \times 12.857) + \ldots + (2 \times 312 \times 12.857) + (1 \times 312 \times 12.857) \\
= (7+6+\ldots+2+1) \times 312 \times 12.857 = 112,320
\]

That is, an estimated average of 112,320 person-days was induced per kilometer of highway construction. When that number is converted to person-days per lane kilometer, it is reduced to 56,160. (It is divided by two because two lanes were added to each of the highways.) This number may seem high compared to the estimate of direct employment per lane kilometer of highway construction, 4,406 person-days, but it must be remembered that a majority of direct employment person-days occur during construction. Very little direct employment is generated after the highway construction, but induced employment may last for the highway’s full lifetime.
This result means that the ratio of direct employment to indirect employment to induced employment is 1.00:1.25:11.70—with the caveat that the value for induced employment was derived over a 7-year period. However, 7 years is likely a period worthy of consideration for comparing these values. It is enough time for induced employment effects to occur, but not so far into the future that the value loses its pertinence to policy makers and their stakeholders and constituents.

Thus, the study provides direct, indirect, and induced employment estimations for India’s highway construction projects. The methodology adopted in this study can be extended to other transport infrastructure projects, including high-speed rail (HSR) construction. Due to the typical characteristics of HSR projects, like the increased number of unique structures, use of special equipment in the construction, dedicated platform, and routine maintenance staff, it is rational to expect that the estimates of employment would be higher than that obtained in highway projects. However, factual findings on this topic can be obtained only by conducting dedicated research, and this is a subject for further study. The employment numbers obtained in highway construction would motivate policy makers to invest in transportation infrastructure. Furthermore, massive infrastructure projects like HSR also require substantial capacity building in human capital training, equipment building, educational programs, etc. This study’s results help the policy makers understand the massive potential of transport infrastructure projects in boosting the economy and employment so that they can make their capacity development plans accordingly.

22.6 Conclusion

Although highway construction is considered a significant employment sector, few studies are available in developing economies that quantify this. This chapter has presented employment estimation from highways in India. Direct and indirect employment numbers were estimated using data from four projects in two states. Induced employment was estimated using data collected from questionnaire surveys on four different highway segments in the same states. This study estimated that the amount of direct employment from highway construction is 4,406 person-days per lane-km. This study also found that the ratio of direct employment to indirect employment to induced employment is 1.00:1.25:11.70—with the caveat that the value for induced employment was derived over a 7-year period. Although most of the direct employment was considered, some types were not considered. These include the employment in the government sector, employment from the reconstruction of buildings
that were shifted, and employment generated during operation state, including tolling operation and maintenance. For indirect employment, employment until the second layer was considered due to various reasons. Although the numbers are expected to be insignificant, it would be worth exploring employment generated on lower layers. Since this study considered a 7-year period for estimating induced employment, the changes for different years would be worth exploring.
References


PART VI
High-Speed Rail for the People
Key Messages

KE Seetha Ram, Nikhil Bugalia, Ayushman Bhatt, and Veronica Ern Hui Wee

Arriving at the end of the previous five parts comprising papers submitted for the ADBI-Chubu University conference, and after witnessing the various lessons learned from them, it is time to reflect on some final important remarks and envisage the agenda for the future direction of this research. The key messages from each of the previous five parts of this edited volume have already conveyed highlights of the important agenda for future work, so we do not aim to repeat them here. Instead, we adopt a different approach to discuss these highlights. Our aim is that this part can further complement the earlier acknowledged topics and scholarly works discussed in the conference by presenting some of the themes that emerged during the conference but could not be sufficiently stated earlier due to their rather abstract evidence in the current literature. However, these themes were actively identified and acknowledged by various panelists during the deliberations and discussions, hence comprising an important part of the future agenda.

The next three chapters, therefore, discuss some topics that were documented with the enthusiastic support of a few panelists.

Chapter 23 by Pagliara, Hayashi, and Seetha Ram promotes new research to resolve questions related to the interaction between land use and transport that arise during high-speed rail (HSR) development. They identify and highlight seven specific topics that require future attention from the HSR research fraternity. These topics are: (i) How does mode choice model at the national scale, taking into account the impact of HSR at the country level rather than on single corridors? (ii) Over short distances, HSR can foster the formation of megacities. The current literature has done very little to quantify this phenomenon. It will be useful to estimate a theoretical model to explain the mechanisms through which metropolitan areas integrate into megalopolises and to identify the role of HSR systems in this respect. (iii) The link between HSR systems and the tourism market is a hot topic still in need of

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1 Partly drawn from the deliberations and discussions held during 12–16 October 2020 at the ADBI-Chubu University Conference (virtual) on Transport Infrastructure Development, Spillover Effects, and Quality of Life.
research in terms of modeling to clarify how HSR affects the tourism market. (iv) How does HSR impact temporary office location choice? (v) What are the effects of long-distance rail accessibility, such as HSR, on the property market? (vi) What is the link between HSR systems and equity issues? (vii) As stakeholder engagement in HSR evaluation projects is neglected, guidelines for quantifying the costs and benefits of stakeholder engagement in HSR projects should be provided.

Chapter 24 by Bugalia and Alvarez discusses the proceedings from the first graduate students’ colloquium on rail infrastructure development, which drew the participation of students from various universities of repute located in Germany, the United Kingdom, India, the People’s Republic of China, Bangladesh, the Philippines, and Japan. The authors echo one of the key lessons learnt from Part V of this edited volume by highlighting that the research required for the development and improvement of HSR relies upon the collaboration of experts who belong to different disciplines pertinent to HSR development. A new beginning in an attempt to realize such collaborations among future generations of leaders was made through this colloquium during the conference. In addition to the feedback the participating students received from senior researchers and policy makers, the students experienced an opportunity to share, develop, and explore their research interests and potential prospects of collaborative work among likeminded peers. A few topics that were found to be of interest during the colloquium, being aligned with ones discussed in the previous chapters of this edited volume, verified the relevance of the overall theme of HSR and quality of life. Some additional topics emerged to complement this theme in future agendas. Such topics include “freight railway and HSR,” “technical know-how and maintenance,” and “HSR is not a one-size-fits-all solution.”

Chapter 25 by Jayal summarizes a high-level policy dialogue for countries that plan to undertake HSR projects. This dialogue was observed during a session in the conference called “Policy and Innovation for Transport 2.0—Building a National Network of HSR in Asian Countries.” This contribution highlights the necessity and potential of HSR development in Asian regions, even in a world after the coronavirus disease (COVID-19) pandemic, and echoes the pertinence of continuous research and evidence-based policy making in HSR development.

In addition, some important suggestions were made by the panelists, notably the chairs of the 10 sessions in the conference. These include the need to:

- Integrate HSR development with secondary rail networks (such as local, regional, and suburban rails) to address spatial equity issues.
• Embrace the systems view in planning and focus on a wider impacts perspective of the integrated transportation network during the evaluation stage, instead of evaluation based on a single corridor or a project using narrow surplus-based approaches.

• Investigate the link between the growth of the knowledge economy and HSR development, which can lead to longer-lasting productivity effects.

• Integrate the passenger transport service provided by HSR with a logistics service in its planning, considering the high amount of growth in the segment of parcel services in the transportation sector. This can make the adoption of HSR projects much more viable and would simultaneously contribute to meeting the fast-growing demands of the parcel service industry. Ishii (2020), for instance, presented the successful trial made by the Kyushu Shinkansen in promoting the facilitation of logistics services through bullet trains during the pandemic in Japan.

• Develop a better understanding of the process of political decision making considering its large role in the development of large infrastructure projects.

• Enhance international data sharing and develop governance policies for the use of emerging technology in the transportation sector. For instance, in order to meet the remarkable demands of parcel volumes and their deliveries, the realization of strategies like just-in-time delivery would be much more critical and would also require the large-scale use of emerging information communication technologies. Research on the governance policies of such technologies and their management would hence be necessary to ensure that the concerns of data privacy and the concentration of market power are also addressed for the well-being of society (Kinra 2020).
References


Kinra, A. 2020. Discussant's remarks during the session titled “Policy and Innovation for Transport 2.0—Building a National Network of HSR in Asian Countries.” ADBI-Chubu University Conference on Transport Infrastructure Development, Spillover Effects, and Quality of Life. 15 October. ADBI, Tokyo (Japan).
23.1 Introduction

The Asian Development Bank Institute (ADBI) hosted a conference on the spillover effects of high-speed rail (HSR) and quality of life in November 2018 in Tokyo, as well as five special sessions on transport and quality of life at the 15th World Conference on Transport Research (WCTR) during 26–31 May 2019 at the Indian Institute of Technology in Mumbai. Also in 2019, ADBI in association with the WCTR Society formed a special interest group on policy, investments, and impacts related to high-speed rail to address the need for emerging research on HSR policy. Together, the conference and special sessions highlighted critical issues and delivered key messages on broad research on HSR and quality of life. ADBI also published selected papers from these activities in the Handbook on High-Speed Rail and Quality of Life released during the Virtual Conference on Transport Infrastructure Development, Spillover Effects, and Quality of Life in March 2020. During May–June 2020, ADBI in association with the WCTR Society special interest group and Chubu University hosted a series of three webinars on HSR, illustrating and discussing a wide range of pertinent topics for future research, such as land-use and transport interactions with HSR, sustainability and resiliency of transportation and living work systems in the context of the coronavirus disease (COVID-19) outbreak.

1 We thank Ayushman Bhatt (Asian Development Bank Institute) for helping to coordinate this joint research.
and spatial scenarios for the European Union 2050. Following the rich and diverse discussions during these webinars and to envision future directions for research, this chapter highlights new research topics as well as the need to address unresolved questions related to land-use and transport interactions in the development of HSR.

### 23.2 Interactions between the Transportation and Activity Systems

Urban systems include households, workplaces, services, transportation facilities, and regulations. Several subsystems include the activity and transportation systems (Cascetta, Pagliara, and Papola 2007; Cascetta 2009) (Figure 23.1). The activity system of an urban area can be further broken down into several subsystems consisting of households divided by category, economic activities divided by sector, floor space available for various uses, and the corresponding property prices.

![Figure 23.1: Relationship between the Transportation and Activity Systems](image)

Source: Cascetta (2009).
The characteristics of transportation services depend on the transportation supply, comprising facilities, services, regulations, and prices, which induce travel opportunities. Transportation performance influences the relative accessibility of different urban zones by determining for a given zone the “cost” of reaching other zones (“active” accessibility) or being reached from other zones (“passive” accessibility), both of which influence the location of households, economic activity, and the property market (Cascetta 2009).

The same interactions can be adapted at the regional and national levels. The transportation facilities and services dealt with in this chapter relate to HSR systems.

Over the last 6 decades, countries around the world have made significant investments in HSR systems (Pagliara 2014a). Spending public money to construct HSR lines yields several benefits, such as time savings, increased comfort, induced demand, and reduced congestion, as well as wider economic benefits such as the development of less developed regions (Pagliara 2016). In pointing out the huge need for infrastructure investment in Asia and the Pacific, Yoshino, Xu, and Seetha Ram (2020) also argued that there is a large investment gap in terms of financing from tax revenues in many regions of Asia and the Pacific. In addition to this large need for infrastructure and public financing bottlenecks, there is also a dearth of studies that estimate the economic impacts of such investments.

This chapter aims to resolve certain questions related to the analysis of the impacts of HSR systems on activity systems. It is meant to help academics, professionals, and consultants promote further research on interactions between HSR systems and activity systems.

### 23.3 Ex Post Evidence for Mode Substitution and Induced Demand after the Inauguration of High-Speed Rail

High-speed trains can be used to solve two different accessibility problems. First, where a point-to-point link is dominant, each train can be a substitute for an air connection between two cities by connecting cities or central business districts over long distances via a direct train connection. The high-speed train links between Paris and Lyon, Paris and London, Tokyo and Osaka, and Madrid and Barcelona are examples of this type of train connection (Pagliara, Vassallo, and Román 2012). “In this case the train trip together with access and egress times should be compared with the competing solution which consists of the air trip plus..."
the trip to the airport at the trip origin and the trip from the airport at the trip destination” (Pagliara, Vassallo, and Román 2012: 636). Second, in countries with a dominant high-speed network, the train system links together many cities and central business districts, creating a new type of region with high intra-regional accessibility sharing a common labor market and a common market for household and business services. In this case, the high-speed train binds cities together in a band, with each pair of cities at a time distance of 20–55 minutes from each other, which enables daily commuting.

Givoni and Dobruszkes (2013) focused on mode substitution and induced demand effects on specific HSR corridors from Europe to Asia. Their review analyzed the ex post demand for HSR services, of which 10%–20% was induced demand for HSR a few years after inauguration, with the rest attributed to mode substitution. In most cases, the majority of HSR passengers had previously used conventional rail, and substitutions from aircraft, car, and coach traffic were generally modest.

This work demonstrates that the literature lacks contributions that look at national-scale models. One exception is the case of Italy. Cascetta and Coppola (2017) provided an overview of the dual effects of the inauguration of the new HSR line, with a single state operator (Trenitalia) between 2010 and 2012 and the entry of a new private operator (Nuovo Trasporto Viaggiatori, or NTV) in 2012. This case is unique because before- and after-effects on supply, demand, and prices were reported, making it possible to analyze the evolution of new HSR services on the multimodal intercity travel market and evaluate the competition within a typically monopolistic market. An integrated modeling system was developed to assess the effects of timetables, services, and prices in terms of HSR, and the analyses used competing modes (air, automobiles, and railway).

Researchers should estimate national-scale models instead of models on single corridors, to consider the effects of the entry of HSR on the whole country. We suggest this as a future line of research that should be promoted among academics, researchers, and consultants.

23.4 High-Speed Rail Shrinking Spaces, Shaping Places: High-Speed Rail and Megalopolis Formation

Cities are pushing beyond their limits and merging into new physically and economically linked conurbations called megalopolises. The implementation of HSR lines plays an important role in reshaping people’s travel patterns and activities, and consequently changing how
cities develop (Pagliara et al. 2013). Indeed, HSR systems have also fostered the promotion of economic growth and regional development in many countries. A megalopolis is an integrated economic urban complex created by the fusion of multiple cities connected at high speeds (200–300 kilometers [km] per hour). Megalopolises can have many positive economic impacts stemming from larger labor markets, larger commercial markets, and expanded individual daily activity zones, among others (Sussman 2011). HSR can change the geography of a country, bringing regions and cities closer to each other by increasing accessibility. These benefits in turn can be the basis for promoting economic development, justifying the high cost of HSR investments.

For Japan, Kobayashi and Okumura (1997) proposed a dynamic multi-regional growth model simulating the dynamic processes of economic development of city systems. Such an economic system consists of multiple cities interconnected by HSR systems, with each city comprising one production sector as well as residential land use. The model emphasizes how differences in the geographic and qualitative factors of HSR systems could affect regional economic development.

Perl and Goetz (2015) identified three models of HSR deployment: (i) exclusive corridors (e.g., Japan); (ii) hybrid networks, both national (e.g., France and Germany) and international (e.g., the European Union); and (iii) comprehensive national networks (e.g., the People’s Republic of China [PRC] and Spain). In the first model, HSR systems serve as corridors 480–560 km long connecting two megacities. The second model is a “hybrid system that blended high speed travel across new dedicated trunk line infrastructure together with operation at conventional speeds along interconnected branch lines shared with regular trains” (Perl and Goetz 2015: 135). This hybrid strategy multiplies the number of origins and destinations that can be served by HSR. The third model serves major cities and mid-sized communities across countries such as the PRC and Spain. In the PRC, four east–west and four north–south HSR lines connect many large cities, covering routes up to 1,600 km long.

Ureña, Menerault, and Garmendia (2009) proposed large intermediate cities along HSR lines and examine HSR’s capacity to change time distances and accessibility. They highlighted the role of HSR in promoting new opportunities for Cordoba and Zaragoza in Spain, and Lille in France. Introducing regional HSR services transformed the connections and time distances from certain smaller cities to metropolitan areas and large intermediate cities. This contribution demonstrated the power of HSR to change the balance and hierarchy of
the established city system, by improving the regional centrality of large intermediate cities with respect to certain smaller regional cities.

Zheng and Kahn (2013) claimed that the PRC’s bullet trains play a significant role in the development of the country’s growing megacities, which are facing several different problems. High levels of traffic congestion and pollution are primary factors degrading quality of life. Transportation technology that allows individuals to access a megacity without living within its boundaries provides large benefits by enabling people to enjoy the advantages of urban agglomeration without paying megacity real estate rents and urban social costs. In 2007, the PRC introduced bullet trains connecting megacities such as Beijing, Shanghai, and Guangzhou with nearby cities. By facilitating market integration, bullet trains stimulated the development of second- and third-tier cities and helped protect the growing urban population’s quality of life.

Ross and Woo (2012) analyzed the HSR programs proposed by the United States Department of Transportation’s Federal Railroad Administration and found that most HSR routes with high investment priority are located within mega-regions and across state boundaries. They also found that the released federal HSR programs consider multijurisdictional interactions when allocating HSR funds. Their results imply that mega-regions are an appropriate scale for developing HSR in terms of the benefits and effectiveness of implementation.

However, there is still a lack of studies concerning the building of a framework for understanding and exploring the relationship between the phenomena of megalopolis formation and HSR, as well as studies determining the possibility and magnitude of associated impacts on regional development. This is a real challenge! It is necessary to introduce new variables, such as commuting flows between two cities served by an HSR section or proxies thereof, such as the number of tickets sold. Other variables to be included are changing property prices and salaries in the two destinations served by an HSR line. HSR creates new value. We suggest this as a future area of study by researchers, academics, and consultants, to better model the phenomena of HSR and megalopolis formation.

It is necessary to estimate a theoretical model to explain the mechanisms through which metro areas integrate into megalopolises and to understand the role of HSR systems in this respect. Pagliara (2020) attempted to estimate, where two corridors (the Turin–Milan line in the north of Italy and Rome–Salerno line in the south) have been chosen, regions that have high potential to become megalopolises supported by HSR. The model estimation provided interesting results that highlight the need to plan on a new spatial scale with new boundaries and linkages.
23.5 The Impact of High-Speed Rail Systems on the Tourism Market

The transportation industry is a global industry that aims to move passengers and freight as efficiently as possible (Delaplace, Bazin, et al. 2014). It is often observed that a country with a good transportation system can be considered a tourist destination. Increased accessibility to a given tourist destination thanks to new interventions in the transportation system is an important factor in tourism development. The introduction of new technologies in the transportation system, such as HSR systems, has benefited the tourism market in terms of increased tourist flows.

Some examples of international studies that investigate the link between HSR and the tourism industry are Khadarooa and Seetanah (2008); Chen and Haynes (2012); Coronado et al. (2013); Kurihara and Wu (2016); Pagliara, Mauriello, and Garofalo (2017); and Pagliara and Mauriello (2020). In general, tourists perceived decreased travel time brought about by HSR as a good reason to choose a destination connected with this service (Delaplace, Pagliara, and Aguilera 2014; Pagliara 2014b; Pagliara, Delaplace, and Vassallo 2015; Pagliara, La Pietra, et al. 2015). Kang, Kim, and Nicholls (2014) examined the changing distribution of domestic tourism in the Republic of Korea in 1989–2011 and found that while domestic tourism activity became less concentrated at the macro level during this period, at the micro level this deconcentration clearly occurred in a clustered manner. Thus, while the traditional emphasis on Seoul and the southeast appears to have declined, tourism benefits are still unevenly distributed.

Examples of transport infrastructure investment have been scrutinized to investigate the spillover effects of infrastructure investment and provide a deeper understanding of these effects. The first example applies the difference-in-difference method to a highway project in the Philippines (Yoshino and Pontines 2015), and the second to an HSR project in Kyushu, Japan (Yoshino and Abidhadjaev 2016).

To clarify the impact of the shinkansen (bullet train) network extension on tourism development in Japan, Kurihara and Wu (2016) investigated changes in tourism demand and tourist behavior in the Tohoku and Kyushu regions. The results suggested that tourist arrivals increased significantly in cities connected by the extended shinkansen network. Shorter distances from an HSR station resulted in increased tourism demand to a given destination. The simultaneous operation of shinkansen and scenic trains would significantly increase tourism demand.
The link between HSR systems and the tourism market is a hot topic at the international level, and there is still much to do in modeling this relationship to understand how HSR can affect the tourism industry. We encourage research in this direction (Yoshino and Abidhadjaev 2016).

### 23.6 The Impact of High-Speed Rail Systems on Temporary Office Location Choice

The international literature has not yet modeled the impact of HSR on temporary office location choice.

In Italy, HSR nodes have become centers for services and urban renewal. The HSR stations in the major metropolitan nodes of Turin, Milan, Bologna, Florence, Rome, and Naples have been renewed or built by well-known architects. Stations are considered as protagonists of significant urban redevelopment operations and the expression of a new architectural language and conceived as spaces not only dedicated to railway activities, but also meeting and communication places. The restyling of Rome Termini and more recently of Milan Central stations are pilot projects of the new way of interpreting stations as city squares (Delaplace, Pagliara, Perrin et al. 2014).

The renewal of Milan Central, centre of urban mobility and a real gateway to the city, also for future visitors to Expo 2015, marks a milestone in the expansion of regional and metropolitan transport and exploits the role of the station as a junction for the new High Speed/High Capacity lines. In Naples, the new HSR station, designed by Zaha Hadid, built in the municipality of Afragola, will be integrated with the major roads and regional railway lines. The four-level building will take up 20,000 [square meters] and Afragola will be a strategic node for local and international traffic and it will be a fundamental junction point for the Naples – Bari line. (Pagliara, Delaplace, and Cavuoto 2016: 109)

In France, central stations have also been renewed and in some cases new ones built outside the city center. For example, in the southeast of the country, renewal of stations that serve only a couple of daily stops has been minimal, whereas in some bigger cities with very good services, the central station has been completely renewed (e.g., Dijon and Chambéry) or a new one built (e.g., Lyon Part-Dieu). In the southwest of the country, a new Novaxis business center has been built near the HSR station (Bazin, Beckerich, and Delaplace 2009). Along the
LGV Nord High-Speed Railway, a new TGV station and business center, Euralille, has been built near the existing rail station. More recently, in the case of the East European High-Speed Line, new stations have been built near the city (e.g., the Champagne-Ardenne station) or outside the city (e.g., Meuse TGV and Lorraine TGV). In bigger cities like Reims, Metz, and Strasbourg, the central stations have been renewed to make them “new places” in the city.

Several authors have studied the influence of an HSR system on firm location. Pagliara, Delaplace, and Cauvuto (2016) submitted a questionnaire to clients of the Regus business center, which is on the sixth floor of a modern, 16-story building in the HSR station in Naples, Italy, to determine their socioeconomic profile and travel choices. In this case, temporary offices inside the HSR station were rented not only by mobile workers (i.e., those without a headquarters), but also by local workers, thus confirming the new trend of working at a third place near home.

There is still much work to do in this direction. Moreover, the current COVID-19 pandemic will foster this trend since more and more workers will need to have meetings in a safe place.

23.7 The Impact of High-Speed Rail Systems on the Property Market

Most studies looking at the impact of rail accessibility on property prices analyze local transit networks. In many Asian countries such as Bangladesh, India, Indonesia, and Thailand, land acquisition is a major issue in infrastructure development that delays the completion of projects and lowers the rate of return of private investment. For instance, 30 years ago Japan had planned an HSR project linking Narita Airport with Tokyo city center; this has not yet been implemented (Nakamura et al. 2019).

Very few studies have looked at commuter rail. Of these, Armstrong and Rodriguez (2006) estimated the local and regional accessibility benefits of commuter rail services in eastern Massachusetts, controlling for proximity-related negative externalities and other confounding influences. They used geographic information system tools to measure both multimodal accessibility to commuter rail stations and distance from the rail right-of-way. Although the overall results were inconclusive, they did show that proximity to a commuter rail right-of-way had a significant negative effect on property values because of local noise and crime effects. In Izmir, Turkey, Celik and Yankaya (2006) claimed that investments in commuter rail had altered the land rent gradient in the vicinity of railway stations. They contended that their empirical results
convinced decision makers in developing countries that railway and transit investments could provide additional economic value beyond direct ticket revenues.

While the literature apart from these studies is very scarce, some information can be collected from websites and reports. For example, Spain’s HSR network (Alta Velocidad Española [AVE]) played a significant role in pushing up property prices throughout the country. To prove this theory, a house price index was developed showing that property prices in towns and cities served by AVE stations outperformed their provincial averages. For example, house prices in Málaga, served by the AVE line, were 24.7% more expensive than in Andalusia and 23.7% higher than the national average. Prices in Seville and Córdoba also showed a similar trend, where properties were within easy reach of AVE stations. People liked living close to transportation, particularly fast and convenient services such as high-speed trains (Trains for America 2008).

Kantor (2008) stated that the introduction of HSR in California’s Central Valley would necessarily lead to higher property values as such real estate becomes more desirable. Both commercial and residential values are predicted to experience price appreciation as businesses move to Central Valley areas conveniently served by HSR, thus putting upward pressure on existing land and housing stocks. However, members of the California High Speed Rail Blog who oppose HSR believe that HSR will cause their property values to crash, and that the government should prioritize protecting their current property values.

Improved accessibility and the changing image of HSR stations can boost property prices in the vicinity of the station. However, very few studies have analyzed the effects of long-distance rail accessibility on real estate prices. Andersson et al. (2010) demonstrated that the opening of an HSR line in early 2007 decreased travel times along Taipei, China’s west coast. Investments in transportation infrastructure affected land price patterns in Taipei, China as well as elsewhere. Regional accessibility and land value maxima shifted from ports and harbors to emerging downtowns around urban stations.

Another case study is the HSR stations of St. Pancras and Stratford in the Camden and Newham boroughs of London, where house prices within walking distance of the station increased. Martinez, Pagliara, and Tramontano (2013) used hedonic price theory to derive a new formulation by assuming that bids for dwellings follow the extreme value Fréchet distribution.² They then compared the proposed formulation

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² The hedonic pricing method is a method for estimating the market value of certain characters or services, based on market prices of goods that incorporate (isolating with multivariate regression techniques) the contribution of a given attribute to the observed price.
(assuming that land is auctioned to the highest bidder) against other usual formulations in the literature to estimate the land price impacts of improved accessibility brought about by the HSR station in the area surrounding the station.

For future research, we encourage an analysis of the effects of long-distance rail accessibility, such as HSR, on the property market. Indeed, there is still much to do.

### 23.8 High-Speed Rail and Equity Issues

Spatial accessibility is a measure of spatial equity and can be represented by the ease of traveling from an origin to a given destination via a given mode or set of transport modes (Pagliara, Biggiero, et al. 2016; Biggiero et al. 2017). The positive social impact of HSR is represented by increased accessibility and the movement and activities of commuting HSR users. HSR improves work trips by providing fast train connections between major cities. On the other hand, users unable to afford HSR or who live far from stations can be socially excluded and have difficulty finding better jobs (Pagliara and Biggiero 2016, 2017).

Pagliara, Biggiero, and Menicocci (2017) investigated the current situation of non-HSR users in Italy, Spain, and the United Kingdom, as well as the factors preventing them from choosing this service. A relationship between social exclusion and HSR was evident, especially in terms of economic and geographical exclusion (due to, for example, the cost of an HSR ticket and low accessibility of the departure and/or arrival station). The fact that low-income travelers were greatly impacted by both criteria was matched with the location of the residences of these classes of travelers. Specifically, with respect to the higher cost of their residences, it was clear that those with higher incomes lived in city centers, which are usually served by good public transport and taxis.

In the current international literature, there is a lack of contributions on the link between HSR systems and equity issues. This chapter highlights several unresolved questions and identifies the following topics as items of special interest that should be developed further:

(i) the concept of social equity in long-distance HSR;
(ii) the socioeconomic profile of HSR users;
(iii) factors excluding non-HSR users from choosing HSR as an alternative transport mode;
(iv) the relationship between HSR and social equity;
(v) HSR pricing policies preventing non-HSR users from choosing this transport mode;
(vi) whether destinations not served by HSR are excluded from the possible development of tourism and other growth factors;
(vii) whether the introduction of more than one railway company competing on the same HSR network (such as Trenitalia and NTV in Italy) can improve social equity; and
(viii) policies to make HSR available to all socioeconomic users (such as new investments in low-cost HSR systems, such as Ouigo).

Surveys and methodologies supporting this investigation should also aim to inform investors in these systems. Before investing large amounts of money in a new HSR infrastructure, investors should ask, who will the users be? Does this infrastructure exclude certain socioeconomic categories, such as low-income people, immigrants, and women?

Italy today presents a unique example of market competition in the HSR sector (Cascetta and Coppola 2015). The history of the liberalization of the Italian HSR market began with the European directive of 1991, which aimed to develop the European railway network. Although only the European First Railway Package (2001) was regulated, this legislation separated the management of rail infrastructure from the supply of transport services, which until then were under a single ownership. In 1997, in response to the European directive 91/440, the Italian Rail Network (RFI) founded the rail service company Italiana Trasporti Ferroviari, renamed Trenitalia in 2000. In 2001, the Government of Italy established the RFI to manage the railway network (supply-side). In 2007, the Italian law DL162/2007 (in response to the European Second Railway Package) established the National Rail Safety Agency for controlling and regulating use of the RFI. In 2007, the Third Railway Package was introduced (implemented in Italy under Law 99/2009), establishing the right to use the international passenger rail network. With the opening of competition in the rail market, in December 2006 NTV was established with an initial investment of €1 billion and no subsidy from the Italian government, becoming Trenitalia’s unique competitor in the HSR market. NTV obtained a railway company license in February 2007 but only supplied the first HSR service in competition with Trenitalia in 2012. Today, Trenitalia runs 213 trains per day while NTV runs 90 trains. This competition has led to a reduction in HSR ticket fares.

23.9 High-Speed Rail Systems Evaluation and Stakeholder Engagement

Stakeholder engagement involves stakeholders in the decision-making process to reach a shared and transparent decision on a given intervention. This chapter provides guidelines for transport projects
to quantify the costs and benefits of stakeholder engagement, which appraisal analyses have largely neglected. It provides a range of examples of the direct (monetary) and indirect (non-monetary) costs and benefits of stakeholder engagement. It also provides guidelines for measuring and monetizing such costs and benefits. These guidelines are a tool for analyzing stakeholder engagement in economic analysis. Broader and more analytical frameworks are necessary to capture participation. Few studies have looked at monetizing the costs and benefits of stakeholder engagement when assessing the technical and economic feasibility phase.

To the best of our knowledge, only five examples in the published literature evaluate the impact of stakeholder engagement in transport projects using cost–benefit analysis (CBA), and only one (Pagliara and Di Ruocco 2018) deals with its impact in monetary terms.

Jenkins (1999) proposed an integrated financial, economic, and distributive analysis with advantages for evaluating both public- and private-sector investments. Specifically, the author identified the role of stakeholders as key components in determining the likelihood of a project’s successful implementation, as well as motivating the authorities to consider redesigning the project to have a more favorable impact on the stakeholders. The stakeholder analysis, which was undertaken by comparing the economic and financial outcomes, identified the groups likely to promote a project and those which would not favor it.

Andersson, Fennell, and Shahrokh (2011) produced a report for Involve, the UK’s leading public participation charity, proposing a consumer focus toolkit to understand the value of engagement by looking at the actual costs and benefits of stakeholder engagement. Good-quality stakeholder engagement should be carefully designed to fit the purpose, context, and people for which it is intended. Poorly planned and implemented engagement could undermine the benefits. This toolkit shows how to build the case for engagement using monetary terms. There is much anecdotal evidence in support of stakeholder engagement and some case study evidence showing that the value of engagement, if done well, exceeds the upfront costs. The toolkit can be used for all kinds of engagement, from small-scale “one off” projects to major exercises across an entire town or wider local authority area. It is aimed at those who manage, design, deliver, plan, or commission stakeholder engagement projects. However, this toolkit presented no transport project.

Chambwera et al. (2012) defined a stakeholder-focused CBA as an extended form of CBA covering the private sector, public sector, households, and (where appropriate) the environment. An analytical framework was proposed with four stakeholder groups feeding into overall decisions about climate change adaptation interventions. The activities considered included stakeholders’ involvement in analyzing
the costs and benefits of an initiative, reflecting on the costs and benefits ascribed to different stakeholders in the analysis and assessing the weight that different stakeholder groups placed on different costs and benefits.

Rangarajan et al. (2013) highlighted the role of stakeholder engagement in developing sustainable rail infrastructure systems in Missouri, in the United States. A stakeholder engagement process assessed the impact of stakeholders’ needs, where data were gathered through interviews, surveys, focus group discussions, and public meetings across the state. The main finding of this study was that stakeholders had high awareness of the benefits of rail service, especially those with easy access to it. Stakeholders considered the investments for improving rail infrastructure in the state and the benefits that the rail could bring to communities as two important factors that required attention. Several players undertook actions in rail settings, with different costs and benefits accruing to different stakeholder groups (Pagliara and Di Ruocco 2018).

Vignetti et al. (2020) provided an ex post evaluation of 10 major transport projects cofinanced by the European Regional Development Fund and the Cohesion Fund during 2000–2013 and located across nine European Union member states. The original contribution consisted of a combination of a traditional ex post CBA and a qualitative analysis. The authors used a retrospective CBA to quantify the costs and benefits of the projects and interviewed relevant stakeholders to reconstruct the project history, discover behavioral patterns, and assess any wider non-quantifiable effects. The authors argued that the ex post CBA, when appropriately implemented and integrated with qualitative evidence, could be a powerful tool for supporting the decision-making process and for identifying policy lessons. Pagliara and Di Ruocco (2018) were among the first to help measure the costs and benefits of participatory activity. They proposed an ex post evaluation analysis for the case study of the HSR Turin–Lyon line and showed that if the costs and benefits of stakeholder engagement had been monetarized and embedded in a CBA, it would have generated a different net present value.

This chapter suggests that governments should:

(i) provide guidelines for quantifying the costs and benefits of stakeholder engagement in transport projects, building on a framework where it is embedded in the general transportation decision-making process; and

(ii) develop guidelines for measuring and monetizing the direct and indirect costs and benefits of stakeholder engagement.
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Graduate Students’ Recent Research on High-Speed Rail

Nikhil Bugalia and Daniel del Barrio Alvarez

24.1 Introduction

High-speed rail (HSR) projects are no longer on the short lists of most economically advanced countries. Beginning with the first commercial high-speed rail established in Japan in 1964, an increasing number of Asian countries followed in building high-speed rail corridors. Some of them, such as the People’s Republic of China, have developed their own HSR systems. The term “systems” is one of the key characteristics of HSR. Their proper functioning is the result of a series of technologies, people, and institutional arrangements perfectly synchronized. To understand the impact of HSR systems on the quality of life, we must consider the social and cultural contexts that surround them.

The research required for the development and improvement of HSR relies upon the collaboration of experts from multiple fields. Academic societies, conferences, and publications tend to be highly transdisciplinary. As more countries are starting to plan and build their own projects, cross-border research collaboration will be more important. Policy makers in Asia will need to be informed by the findings and new knowledge created through this cross-border collaboration. In order to contribute to these two needs, a colloquium between graduate students was held during the conference.¹

The first ADBI graduate students’ colloquium on HSR was organized as an opportunity to share the students’ research interests and progress among their peers, as well as to get feedback from

senior researchers and policy makers. Six students were chosen from different disciplines and parts of Asia, and one was chosen from Europe. Each student prepared a presentation of about 5 minutes that was followed by comments from participants. At the end, some time was allowed for exchanges between students. Due to the coronavirus disease (COVID-19) pandemic, the colloquium was held online, as was the entire conference.

### 24.2 Topics Discussed

The scope of the topics for the graduate school colloquium was kept broad to provide students working on a variety of areas related to HSR and railways an opportunity to seek comments on their work as well as to develop a professional network of people capable of analyzing HSR issues through a multitude of lenses. The contributions thus obtained (as listed in Table 24.1) focused on a range of topics from socio-economic spillover effects of HSR to inter-modal interactions and even the technical aspects of railways. The key themes that emerged are discussed in the remainder of this chapter.

#### Table 24.1: List of Presentations

<table>
<thead>
<tr>
<th>Presenter’s Name</th>
<th>Title of Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Razon Chandra Saha</td>
<td>Challenges to Improve Inland Intermodal Connectivity via Rail in Bangladesh</td>
</tr>
<tr>
<td>Shanaraj VK</td>
<td>Quality of Life Implications of Mumbai–Ahmedabad High-Speed Rail in Mumbai Metropolitan Region</td>
</tr>
<tr>
<td>Ivan Harris Tanyag</td>
<td>Modelling Transport Networks within UNESCO Creative City Networks</td>
</tr>
<tr>
<td>Manuel Weiß</td>
<td>High-Speed Rail and the Role for Commuting of Knowledge Workers in Germany</td>
</tr>
<tr>
<td>Shashwat Gupta</td>
<td>Corrosion of Friction Stir Welded (FSW) Aluminium Alloy</td>
</tr>
<tr>
<td>Jonathan Andrew Lane</td>
<td>Re-evaluating the Economic Benefits of the Lao People's Democratic Republic (Lao PDR)–People's Republic of China (PRC) High-Speed Rail and Its Implications for the Fiscal Stability of the Lao PDR</td>
</tr>
</tbody>
</table>

Source: Authors.
24.3 High-Speed Rail and Quality of Life

HSR and quality of life (QoL) was the theme that received the largest number of papers. Under this broad theme, several unique and emerging aspects of QoL were discussed. QoL and related themes continue to be relevant for countries in developing their first HSR projects and countries with long experiences of developing and operating HSR networks.

For example, the study by Shanaraj VK focusing on the Mumbai–Ahmedabad HSR project in India aims to analyze the stated preference data about several QoL dimensions (about the current no-HSR scenario, as well as the assumed level of HSR service after its completion) as well as the existing commuting patterns in the sizeable megapolitan city of Mumbai. The results of such an exercise may help guide the HSR and the urban railway development process itself such that the socio-economic effects of such a large-scale project can be equitably distributed. While the study results may not be generalizable to all cities considering an HSR connectivity, the framework to analyze the stated preference data can be assessed to identify policies suitable for the local context.

On the other hand, for countries with long-term experience operating HSR, a new area receiving attention is the effects of HSR on the knowledge economy. Along with another full paper submission in the current edited volume, a presentation in the colloquium by Manuel Weiß focused on evaluating the long-term effects of HSR on the knowledge economy. The colloquium presentation focuses on analyzing knowledge economy workers’ commuting patterns for multiple stations spread across Germany. The questions asked in the presentation remain to be answered, such as Do the knowledge-intensive firms gain from HSR accessibility? How long does it take to accrue the benefits? What urban and regional factors determine the level of gain? Answers to such questions will inform critical policy decisions about investments in HSR, an often cost-intensive infrastructure project. The topic is also expected to be relevant considering the recent COVID-19 pandemic, which is expected to have a long-lasting impact on the commuting patterns and travel behavior of knowledge-economy workers and firms. Hence, the topic is expected to continue to be academically and practically relevant.

Another colloquium presentation by Ivan Harris Tanyag highlights scarcely discussed aspects of QoL related to creative tourism, where the travel patterns related to creative experience and participation are studied through formal academic approaches. Creative economic activities related to arts and other creative activities have been recognized as an essential theme under the Sustainable Development Goals of the United Nations. This theme is new and the work is also
in a nascent stage. Some early-stage questions relate to planning and designing transit-oriented development frameworks at a city level considering the creative economy’s aspects. The area is academically novel and has the potential to be developed further.

### 24.4 Freight Railways and High-Speed Rail

Several presentations in the colloquium also emphasized the continued importance of railways (not only HSR) as an essential transport mode for developing economies. The conference discussions and the colloquium point toward a renewed momentum for freight transport using railways.

For example, the government of the People’s Republic of China has a strong emphasis on significantly reducing cities’ carbon emissions. Freight transport using railways is deemed a suitable method for achieving this goal. According to the presentation by Yueqi Zong, to continually improve the policies for achieving the sustainability visions set by individual countries, we will need empirical evidence about the effectiveness of policies considering the inter-modal interactions.

While evaluation of policy is essential, often countries suffer from poor policy implementation. A similar case study for freight railway in Bangladesh, presented by Razon Chandra Saha, was also highlighted in the colloquium. Bangladesh suffers from a problem of a low modal share of railways in container transport. Hence, the real benefits from several port-capacity enhancement projects are yet to materialize. To solve such practical issues, a microscopic approach to understanding the techno-managerial realities was deemed necessary. Without a comprehensive implementation plan adequately reflecting such on-the-ground realities, the gap between proposals and implementation will continue to widen. From the academic perspective, the current need is also for researchers to understand the complex nature of problems facing the various transportation systems and adopt a systems thinking perspective for solutions.

Even though it was not deeply discussed in the colloquium, the importance of considering HSR as a potential mode for freight transport was mentioned several times in the conference. While the conference gathered a myriad of evidence of the socio-economic spillover effects of HSR, the cost structure of the HSR development makes it difficult to identify financially viable projects only relying on passenger revenues, as seen in the presentation by Jonathan Andrew Lane. Even for countries having HSR operating experience, the socio-economic context has started to favor usage of HSR as a potential mode of freight transportation. Authors recognize this as an emerging area for research.
that should be examined from perspectives of economic feasibility and technical and managerial feasibility.

24.5 High-Speed Rail Not a One-Size-Fits-All Solution

The conference theme and most of the presentations at the colloquium took a positive outlook toward HSR experiences worldwide. However, the fact remains that HSR is not a one-size-fits-all solution for all socio-economic problems of a country, and it should not be promoted as such. Like with any other infrastructure project, the rationale for developing HSR should be justified using unbiased systematic evaluation approaches as much as possible. If megaprojects such as HSR are developed due to political and other influences, low- and middle-income countries can even face a severe crisis. This risk was demonstrated through a case study presented by Jonathan Andrew Lane for the Lao People’s Democratic Republic, where the economic feasibility of the HSR development could be justified only by unrealistic assumptions, and the project being implemented posed a severe economic threat to the country. Such results highlight the importance of solutions specific to a country’s context for developing HSR. Academic studies focusing on such themes will be relevant from an academic and practical perspective, given the recently renewed momentum on HSR development around the world.

24.6 Technical Know-How and Maintenance

Unlike the leading conference’s focus, the colloquium also included topics rooted in engineering aspects of HSR. Experience from countries with long-term HSR operation experience suggests the importance of efficient operation and maintenance strategies for HSR system components. The various system components expected to last a long time need to be well maintained HSR services to be reliable and safe. However, in the long run, such maintenance is costly. Research must continue in areas such as new technology development to reduce the cost and improve the quality of the maintenance methods. The presentation by Shashwat Gupta focused on assessing the effectiveness of a new welding method potentially useful for HSR rolling stock. While it focused on a technology being developed in Japan, the research also indicates the relevance of technology transfer for HSR development in developing economies. The researchers aim to assess the potential application of Japanese technology to the Indian context, where the first HSR project is being developed with Japan’s financial and
technical support. This overall theme is related to capacity building and training at multiple levels in the organizations and countries importing sophisticated technology such as HSR. Such a theme, then, is also essential from a policy research perspective.

24.7 Forthcoming

The first graduate school colloquium was a starting point for building fruitful collaborations across disciplines, countries, and generations. These collaborations will provide insights for students to guide their research toward better impact in the real world and for practitioners to be informed of the most recent and advanced discoveries on high-speed rail. The colloquium also established connections between the participants and gave students an opportunity to showcase their progress and findings to senior experts around Asia.

We are looking forward to seeing this network between graduate students and practitioners continue to grow. As chairs of the session, we are sure the support from ADBI will be highly beneficial for the graduate students as well as for Asian society.

In addition to the variety of HSR planning-related themes being reflected in the graduate students’ research activities, issues related to HSR implementation are now increasingly becoming important. Therefore, following the principles of systems thinking, systematic lessons need to be identified for various technical, human, organizational, and regulatory aspects of the HSR system across the different life stages such as the development, operation and maintenance, and system evolution. ADBI is developing a seminar series that will allow academicians, practitioners, and policy makers from across the globe to exchange ideas and develop practical recommendations for HSR implementation (Bugalia et al. 2021). Graduate students worldwide can benefit from the learning opportunities being created by ADBI and will soon be able to contribute to the program by sharing their findings on the topic.
References

25

Of the People, for the People:
Economic Corridors,
High-Speed Railways,
and Quality of Life in
Post-COVID-19 Asia

Richa Jayal

25.1 Introduction

As the coronavirus disease (COVID-19) pandemic continues to disrupt global economic activity, developing Asia’s gross domestic product (GDP) is now expected to have contracted by 0.7% in 2020. GDP is projected to grow by 6.8% in 2021 (ADB 2020). However, beyond these numbers, what is underway beneath the tip of the iceberg offers strong clues on future prospects of trade and transportation development in the region.

What is underway since January 2020 suggests a widespread, accelerated, almost tectonic global shift in strategic preferences that will undoubtedly trigger opportunities for logistics and transportation expansion in Asia. The ongoing pandemic has already resulted in unprecedented change in global supply-chain priorities. Much of the recent global dialogue has centered on the shift of supply chains from the People’s Republic of China (PRC), the world’s largest manufacturing hub and the country where the COVID-19 virus was first discovered in Wuhan Province (World Health Organization 2020). The slowdown of manufacturing in the PRC due to the COVID-19 outbreak is disrupting world trade in its current form and could result in a $50 billion decline in exports across global value chains (United Nations Conference on Trade and Development 2020), triggering a major rethink along the lines of vertical integration and geographic diversification.
Adding to concerns of COVID-19 spread has been the pressure to decouple the United States (US) economy from that of the PRC. This includes measures by the new US president to disallow federal contracts to be granted to US companies that outsource significantly to the PRC, as well as recent legislation that could remove the PRC’s companies from US exchanges if regulators are not allowed to review financial audits (Congress.gov 2020). We believe this shift in supply-chain priorities is highly likely to boost the pace of Transportation 2.0 (aiming for a safe, sustainable, and resilient network of transportation infrastructure development) and trigger further acceleration in regional connectivity, including more robust land and maritime economic corridors, and greater regional cooperation and integration in the direction of stronger transportation-based cohesiveness in the Association of Southeast Asian Nations (ASEAN) and South Asia.

Before proceeding further, it is important to define what we mean by an “economic corridor.” In this chapter, we will be using the definition offered by the Asian Development Bank (ADB), which states:

Economic corridors connect economic agents along a defined geography. They provide important connections between economic nodes or hubs that are usually centered in urban landscapes. They do not stand alone, as their role in regional economic development can be comprehended only in terms of the network effects that they induce.... Corridor characteristics interact dynamically to create patterns of regional economic development. (ADB 2013: v)

Therefore, the phrase includes logistics that support both manufacturing (products) as well as human (passenger) movement, both interacting and cooperating to create a sustainable ecosystem to support development and prosperity where people and cultures can flourish.

Against this backdrop, the significance of high-speed rail (HSR) systems and the need for policy intervention and innovation for building national networks of high-speed rail in Asia was deliberated on at the ADBI–Chubu University Conference on Transportation Infrastructure Development, Spillover Effects and Quality of Life (12–16 October 2020). The virtual conference was attended by eminent international researchers from academic institutions and government organizations, as well as senior officials from HSR-operating companies. It featured research on spillover impact from transportation infrastructure development on the economy, environment, society, and quality of life of countries, with an emphasis on high-speed rail growth.
This chapter draws on discussions conducted at the session titled Policy and Innovation for Transport 2.0 - Building a National Network of the High-Speed Rail in Asian Countries, held on 15 October 2020. The chapter analyzes how emerging trends in transport infrastructure development and Transportation 2.0 can be expected to create a positive spillover impact on the economy, environment, and society across India and the rest of Asia, with particular focus on expected contribution from high-speed railway networks.

We note that as a leader in HSR development, Japan has set a precedent of how construction and development of HSR networks can usher in an era of development and prosperity (quality of life, or QoL), and in turn, that regional development often gives rise to further HSR corridor development (Hiraishi 2019; Hikasa 2020). The shinkansen (bullet train) is rightfully regarded as an invaluable and indispensable part of Japan’s trajectory in mobility and economic growth.

What is also noteworthy is how countries in Asia are expanding the scope of country-to-country partnerships to include intercity transportation and mobility as a tool for growth. A month before he ended his first term as Japan’s prime minister in 2007, Shinzo Abe made a landmark address to the Indian Parliament in New Delhi. Quoting the Mughal scholar-prince Dara Shikoh, Prime Minister Abe spoke of the “confluence of the two seas”—the Indian and Pacific Oceans—that were undergoing a “dynamic coupling as seas of freedom and of prosperity.” India and Japan, said the prime minister, shared an interest in and responsibility for providing stability and integration to the region (Ministry of Foreign Affairs 2007).

Current efforts underway, including the flagship Japan–India partnership in developing the Mumbai–Ahmedabad High-Speed Rail (MAHSR) Project in India, are expected to bring in such intended synergies to India and the rest of Asia. This chapter notes that this trend of plurilateral partnerships in the sphere of mobility and high-speed transportation as a tool for growth is certain to enhance the already-growing economic and geopolitical significance of Asia in the global economy, especially in the wake of the COVID-19 crisis.

25.2 The Asia Story: Toward the Association of Southeast Asian Nations as a Regionally Integrated Bloc

ASEAN celebrated its 50th anniversary in 2017. The organization has since opened doors to what is now an association that comprises 10 of the 11 countries that make up Southeast Asia. Already considered a loose economic monolith, ASEAN, and particularly nations such as Viet Nam,
has also provided global examples in effective handling and control of the COVID-19 outbreak.

In terms of potential, even excluding the PRC and India, emerging Asia’s contribution to world growth today already exceeds that of the United States and is three times greater than that of the euro area. In a world of stagnating growth, the contrast between western nations and emerging Asia stands out. According to a recent report, Asian economies are expected to grow by at least 7% in the coming years—roughly the pace at which an economy can double in size every decade. The region’s likely “7% club” members in the 2020s include India, Bangladesh, Viet Nam, and the Philippines (Jha 2019).

With a focus on connectivity (physical, institutional, and people-to-people), Japan has been a steady partner of the region for the development of land and maritime economic corridors. An economic corridor is much more complex than a mere railway or highway connecting hubs. It involves the crafting of benchmarks and regulations that comprehensively make it easier to conduct business, access markets, and undertake activities that support trade and development.

While great strides have been made, for ASEAN countries to further develop and deepen integration, it is necessary to concurrently strengthen connectivity within ASEAN member states and between ASEAN and the rest of Asia. The Japan International Cooperation Agency (JICA) has been the foremost proponent for this initiative and has been aligning itself with ASEAN’s various policies for deepening connectivity. It has also been consistently providing support for infrastructure development, investment climate and business environment improvement, and legal systems development (Yamamoto 2020).

The impact of key JICA-supported transportation infrastructure projects in ASEAN so far has been impressive. For example, the opening of the Second Mekong International Bridge of the East–West Economic Corridor has shortened the travel time between Ha Noi and Bangkok from 2 weeks (by sea) to just 3 days by land (JICA 2012). This is a groundbreaking advance and a welcome step forward for the overall region.

Today, in spite of and maybe even in part spurred by the consequences of the crisis induced by COVID-19, Asia is marching on a steady path toward regional integration and enhanced connectivity. Emerging market economies, including India, make up more than a quarter of world GDP at market exchange rates. Sustained economic growth of the Asian economies (other than the PRC) in the post-COVID-19 world is certain to open further doors for the development of infrastructure in the region, which has unfortunately lagged behind its commercial potential.
25.3 India and High-Speed Corridors: An Idea That Meets Its Moment?

25.3.1 Background: Why the Shinkansen? Why Now? Why India?

The Japan–India relationship is recognized as Asia’s fastest-growing bilateral partnership. Even before the collaboration in the area of HSR, we have the example of stellar partnership in the Delhi Metro, one of the most successful examples of Japanese cooperation through the utilization of its official development assistance (ODA) model of assistance.

The Delhi Mass Rapid Transport System Project (Delhi Metro) truly met the need of the hour. New Delhi is one of the world’s largest cities in terms of spread. Traffic congestion is immense, and until 2002 when the first metro trains began operating, the only railways in the populous capital city were long-distance broad-gauge lines linking it to the rest of India. It is a modern miracle that a project the size and scale of the Delhi Metro was completed within the planned timelines and budget. (Phase 1 started in 1996; the project is currently in Phase 4.) The metro in Delhi has also tremendously improved lifestyle and transportation options for residents.

The success of the Delhi Metro additionally provided valuable impetus for an enthusiastic embracing of the idea of a wider footprint for urban rail transit projects across India. Now an indispensable lifeline of Delhi, the Delhi Metro is rightly considered one of the most successful urban transport projects in the world and is an example of a JICA-supported India–Japan partnership (Onishi 2016).

The natural extension of this collaboration in transport infrastructure development has been in the area of intercity transport and HSR. The potential is enormous in terms of both what India needs and the need to balance growth with environmental concerns. HSR systems offer inherent and prominent advantages over similar systems, as is evident from past global trajectories. For the recipient country, HSR systems additionally bring with them a bouquet of new learnings and technology transfer in areas as wide as track laying, signaling, and station management, as well as the opportunity to form a new outlook on punctuality and safety.

The foremost factor that makes HSR significant is the pace of growth in India’s megacities. A nation with a robust, young population of roughly 1.3 billion, India can expect an estimated 275 million people or more to move into its teeming cities over the next 2 decades, a
population roughly equivalent to that of the United States. Such “gateway cities” will continue to provide employment and lifestyle choices to a population searching for growth and opportunity for many years.

However, realizing the limits on burdening a few core megacities as well as the need to allow breathing space in the form of more hubs of employment and industrial activity, the Indian government is on course to develop a series of industrial corridors in an integrated and coordinated manner as part of the National Industrial Corridor Development Programme. This effort is aimed at developing multiple contiguous strings of future-ready industrial cities along corridors that offer “plug and play” infrastructure connectivity. The underlying principle supporting this initiative is that faster transportation options and multiple urban centers along industrial corridors are not just a decongestion tool and a means of gaining competitive advantage, but also a driver of economic growth in its own right.

Against this backdrop, it is essential to note that as a sector responsible for producing 23% of all worldwide carbon dioxide (CO$_2$) emissions, transport is the second largest source of human-made CO$_2$, second only to commercial energy production. This alarming statistic is largely the result of the skew toward road traffic, which alone accounts for 73% of all global transport emissions (Jehanno, Palmer, and James 2011). Compared to this, railways are widely accepted as the most carbon efficient among all mass transportation systems. Comparative data shows a crucial advantage that railway systems enjoy in terms of carbon emissions, with emissions standing at around 19 grams (g) of CO$_2$/passenger/kilometer (km), compared to 51 g of CO$_2$/passenger/km for buses and 109 g of CO$_2$/passenger/km for airlines (Takeshita 2012, 2020). Although average emissions may depend on a variety of factors, such data points overall reaffirm the benefits of railway systems in general and HSR in particular due to speed and coverage advantages.

In emerging economies such as India, intercity transport is most often performed by road or air. As a result, the carbon footprint is much higher than the share of overall passenger transport performance. This creates a challenge for governments to develop an economically and environmentally sustainable ecosystem of intercity transport.

In terms of direction, India under Prime Minister Modi has been committed to addressing environmental concerns and achieving Paris

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1 See data on industrial corridor development by the Department for Promotion of Industry and Internal Trade, Government of India: https://dipp.gov.in/programmes-and-schemes/infrastructure/industrial-corridors.
Agreement commitments. In the last few years, the government has undertaken a series of environmentally conscious policy measures, and the carbon data are already showing reassuring results (emission intensity down 21% vs. 2005 levels; solar capacity up from 2.63 gigawatts in 2014 to 36 gigawatts in 2020; renewable energy capacity grown to fourth largest globally).

In the railways segment, Indian Railways is on track in its mission to achieve its 20-gigawatt renewable energy generation target and to become a net-zero carbon emitter by 2030 through a combination of new technology initiatives, increasing the mix of renewable energy to the grid, and active deployment of solar energy projects (Yadav 2020). Given this trend and the targets outlined in the National Rail Plan, it is only befitting that India is incorporating an environmentally sensitive transportation system such as high-speed railways even as it strives to surpass green commitments (PMIndia 2020).

Another reason high-speed corridors are a credible option for India is evident from the available data on past policy interventions and carbon footprint in intercity transportation. Results from recent research suggest that for achieving and maintaining viability of HSR corridors, governments need to develop and introduce low-carbon transport policies from a longer-term perspective. This, however, needs to be undertaken at the optimum economic growth stage of a country in order to achieve policy objectives.

The viability of a mass transit system depends on both population density and per capita GDP. With a population of around 1.3 billion and a population density of 367/km$^2$ (higher than Japan’s 337/km$^2$), a burgeoning economy such as India finds in systems such as HSR the ideal solution to environmental and transportation issues. The size of the Indian middle class hovered at some 50 million people in 2007, but by 2025 will have expanded dramatically to 583 million—some 41% of the population. This group of households will potentially see its income increase to ₹51.5 trillion ($1.1 billion)—11 times the level of 2007 and 58% of total Indian income (Farrell and Beinhocker 2007).

Additionally, India’s GDP per capita in purchasing power parity (PPP) terms already crossed the $6,000 mark as of 2007. This is relevant and can be considered an inflection point: the work of creating a high-speed corridor spans a decade or more, but countries that are considered heavyweights in HSR development today took the lead in initiating corridor development at similar or even lower GDP levels (Japan at $4,700, PRC at $6,200) (Seetha Ram and Bharule 2019).

Thus, in terms of GDP indicators and data-based criteria, there is little doubt that India meets the requirements for the introduction of HSR systems. The key issue for Indian planners and policymakers going
forward might be the where rather than the why, i.e., correct and suitable corridor selection in a country with tremendously diverse demographics and needs. Selecting optimum connecting hubs would then set the stage in the larger region to offer sizable benefits to stakeholders such as local residents and industry, passengers, and railway operators.

For corridor-level criteria, indicators such as railway passenger volume and corridor distance must be taken into consideration when identifying suitable HSR corridors. A daily passenger volume of approximately 5,000 between terminal stations is considered sufficient to support the economics of the effort and to propel growth along the corridor. Data also suggest that in terms of intermodal preferences, on average passengers are likely to prefer a high-speed train over air travel for journeys where the distance is under 1,000 km, since travelling by high-speed train is time- and price-competitive.

While laying the groundwork for a fully fledged HSR network can take decades, once implemented, such efforts bear rich fruit over many decades. Steady growth in passenger volume can be expected in areas along shinkansen lines as they become more populated in response to the benefits offered by the new transportation ecosystem. For example, passenger volume along the Tokaido shinkansen route, which stood at 85,000/day in 1965 before the bullet train became operational, has since growth at a steady pace to reach the now formidable number of 378,000/day (Takeshita 2019).

As India extends the initiative to create, nurture, and link urban hubs along corridor routes with faster, sustainable, and more environmentally sensitive transportation networks (Indian Railways 2020a; Yadav 2020), it is only natural that it has turned to a partner such as Japan to continue its work on high-speed railways. Appreciating that integration of technology is essential, the Indian government has chosen one country and one technology system as a partner for this ambitious project—Japan and its shinkansen.

As two strong Asian nations held together by shared cultural and democratic values, in 2013 Japan and India embarked on the next step of joint partnership in the sphere of transportation with the signing of a memorandum of understanding for an Indian HSR project. With the commitment to the 508-km bullet train corridor between Mumbai and Ahmedabad consecrated, and financial and technological contours agreed upon, the ambitious MAHSR Project is on course to bring Japan’s shinkansen technology to India and to again change not only the way India commutes and connects, but also how India thinks about safety and mobility.

It is a promising and decisive step forward. There is little doubt that the MAHSR Corridor has the potential to be an inflection point,
to revitalize India’s view of railway transportation, and to trigger new
dynamics for economic growth.

25.3.2 Contours of the Mumbai–Ahmedabad High-Speed Rail Corridor

The MAHSR Corridor will be the first-ever high-speed corridor in
India and will link the two largest cities in the neighboring states of
Maharashtra and Gujarat in western India. Technical and financial
assistance from the Government of Japan through JICA will enable
the creation of 12 shinkansen stations along a stretch of 508.17 km. The
project will be executed and maintained by the National High-Speed
Rail Corporation Limited (NHSRCL), a special purpose vehicle (SPV)
incorporated in 2016 with equity participation by the government of
India and the two stakeholder state governments.

The shinkansen is known to be gentle to the environment and to have
a low carbon footprint compared to air transportation. In keeping with
that philosophy and India’s own environmental guidelines, the Mumbai–
Ahmedabad project has taken exceptional efforts to avoid disturbance to
wildlife sanctuaries and natural ecosystems that exist along its route.
These efforts have resulted in some creative and ambitious technological
workarounds, some of which are sure to become textbook reference
cases of the future.

One definitive example of innovation is the handling an area near the
nodal station of Mumbai, the Thane Creek track, which passes a protected
flamingo sanctuary. Respecting the mangrove home of the pink flamingoes
that migrate to the area (also known as “the forests of Mumbai’s breathing
roots”) between December and May each year, rail tracks for the high-
speed train system there will be taken undersea through a special
single-tube tunnel that will run 40 meters below ground level under the
marshland. Once constructed, this tunnel will become the longest rail
transport tunnel and also the first-ever undersea rail tunnel in India.
NHSRCL completed the survey of the mangroves around the creek using
light distance and ranging (LiDAR)—an aerial survey of the forest using a
100-megapixel camera. This is the first time for the LiDAR technology to
be used in India, as opposed to a traditional manual survey on foot. Aerial
survey allowed the process to be completed in under 3 months.²

One more key element of the MAHSR Project is the transfer of
technology and personnel training in HSR expertise. Japan’s bullet train
is a symbol of Japan’s dedication to constant innovation, precision, and

² See NHSRCL data on the MAHSR project: https://nhsrcl.in/en/home.
a stellar safety record. Going forward, key technological and business culture aspects of the Japanese philosophy on bullet trains are expected to be adopted in India as its workforce gains confidence and expertise in building and maintaining high-speed rail systems.

Additionally, the “Make in India” concept is expected to provide strong motivation for Indian industry to develop and imbibe high-end railway technology and practices, and to provide the required momentum for a leap forward in capability building (Khare 2020). This is expected to occur through joint ventures and knowledge transfer partnerships between the two countries, as well as collaboration between research institutions to create indigenous solutions.

To facilitate the training of personnel who will build and maintain the high-speed train corridor, an HSR training institute will be set up alongside the National Academy of Indian Railways in the western Indian city of Vadodara. This training institute will be the seat of learning and the core training ground for NHSRCL staff, some of whom will be trained in Japan by Japanese experts in shinkansen technology and practices. The High-Speed Rail Training Institute is expected to serve as a backbone for future development efforts as India expands its footprint of high-speed corridors beyond the flagship project.

In its draft Vision 2024 of the National Rail Plan issued in December 2020, Indian Railways has called for infrastructure capacity enhancement and preparatory work for the expansion of HSR to additional corridors across India (Indian Railways 2020b). This vision for expansion suggests strong potential for business opportunities not only for Indian contractors, but also for private sector participants and HSR contenders from across the globe, including Japan.

During his 2017 official visit to India for the groundbreaking ceremony for the bullet train project, Prime Minister Abe expressed a strong desire to travel with Prime Minister Modi on the inaugural trip of the Mumbai–Ahmedabad bullet train. India and Japan remain steadfast allies in a number of spheres, and the inauguration of the first Indian shinkansen is certain to be a milestone that is warmly welcomed by both countries.

25.4 The Japan Precedent: Safety, Spillovers, and Lessons for India and Beyond

25.4.1 History

Global experience suggests that as the number of cities and the population of emerging economies increase, the areas along train lines and corridors meld and we begin to see cities growing and merging, further increasing
their clout as a result of ease of transport and commuting. High-speed rail is a major contributor to this fusion of urban centers (Pagliara, Hayashi, and Seetha Ram 2019).

As an example, Japan’s high-speed system has transformed the greater Tokyo area into a supercity region of close to 100 million people. The shinkansen has emerged as an invaluable part of Japan’s mobility and economy story and has grown to a 22,000-km high-speed network of nine passenger dedicated lines operated by the Japan Railways (JR) Group through six regional companies. Of these, JR East alone oversees five different radial corridors with Tokyo as the terminal station, servicing an astounding 106 million passengers a year (Kawai 2020).

HSR in Japan is respected for its speed (optimal time utilization for passengers), safety (zero fatal accidents since inception), punctuality (less than 30-second average delay per train), and convenience (one train every 4 minutes). In time, these benefits and benchmarks are expected to percolate to Indian operators and passengers as the shinkansen takes off in its new home outside Japan.

25.4.2 Shinkansen and Safety

A zero fatality rate over more than half a century of operation is a formidable achievement by all standards. Japan was able to sustain this impressive record thanks to a combination of factors that provide key insights for emerging economies that hope to incorporate HSR systems into future regional development plans. Undoubtedly, the mix of stringent and continuous efforts in technology improvement, human resource management, operation and maintenance, and safety measures has been the result of a series of iterations and improvements.

At the technology level, the Railway Technical Research Institute has been the nodal organization for research and technological development since 1986. For the shinkansen, the institute’s research has focused on three key areas: (i) safety improvement (such as early disaster warning systems), (ii) green measures (enhanced energy efficiency/noise reduction), and (iii) enhanced customer experience (reducing vehicle vibration, smartcard-based ticketing systems, etc.).

As an example, consistent efforts aimed at addressing one key problem area—noise reduction—have resulted in a series of solution-oriented advances such as lower noise-emitting pantographs, lighter car bodies, advances in streamlining the nose of the shinkansen car, and better rail and wheel grinding practices to produce smoother surfaces and lower friction and noise (Uzuka 2020).

Such advances have been incorporated into bullet train hardware over iterative efforts with active participation from stakeholders such as operators and manufacturers. As India expands its HSR footprint in
the years ahead, it will become an interesting case study as the country widens its thrust from “Make in India” to “Make for India” technological innovations to suit its unique conditions and topography (Khare 2020).

At the operator level, since the start of operations in 1964, JR companies have been on the front line defending the shinkansen’s pristine safety record of zero fatalities. This is the result of a combination of infrastructural and systemic measures and personnel training for human interventions. At the systemic level, the shinkansen has some unique built-in efficiencies, such as dedicated tracks, the absence of level crossings, and automatic train control (ATC) systems that respond to track conditions to assess the distance from the next train. But beyond these systemic measures, it is the effort and resources committed to training staff and the thoroughness of the maintenance and operation regime that have contributed significantly to the safety record of zero fatalities (Kawai 2020).

Iterations and improvements continue, and even as recently as 2019, JR East spun off a new dedicated division—the shinkansen management department—to focus on shinkansen operation and maintenance activities as a separate entity from conventional-line operations. According to Masatoshi Kawai, Senior Executive Officer (JR East), in his presentation at the ADBI–Chubu University Conference on Transportation Infrastructure Development, Spillover Effects and Quality of Life, the operator works on the philosophy that while what is foreseeable can be prevented through non-human interventions such as ATC systems, “our efforts need to be and are equally focused on sensitizing personnel to the importance of making correct and timely human interventions for emergencies that are bound to occur in the course of operation.” The essence of these efforts is effective training of the key human triangle of drivers, conductors, and dispatchers to respond to a range of potential emergencies, from snow and fog to the coupling and uncoupling of train cars.

Apart from the operator’s own training modules, a national-level accreditation system is overseen by the Ministry of Land, Infrastructure and Transport. Here, the shinkansen driver’s license requires trainees to pass an aptitude test, a test to become a learner driver, a written test, and then, finally, a technical-ability test. As more countries in Asia create faster mobility options and high-speed corridors, the improvement curve of operators such as JR East provides a valuable reference point regarding the critical need to nurture human talent and a supportive ecosystem in addition deploying cutting-edge technology.

An encouraging fact for new embracers of HSR technology is that these learnings have in the past been transferred effectively in success
stories such as Taipei, China’s *shinkansen* project. Considered the first true export of the Japanese HSR system, the THSR opened operations in 2007. Here, the Japan Railway Technical Service (JARTS), an association of major railway operators, suppliers, and builders in Japan, front-ended technical assistance efforts through the dispatch of Japanese experts in electrical and mechanical (rolling stock, electrical, signaling, and track) systems. The THSR is based on an as-is model of Japanese electrical and mechanical systems.

A key learning from the THSR project seems to be that the key to knowledge transfer and sustainability often lies in steadily building local capabilities, which makes that task the “most critical factor for determining sustained success” (Kono 2020). Given the long post-construction period when an operator is responsible for maintaining the sophisticated mobility system, JARTS’s efforts in Taipei, China focused on providing effective advisory support through international experts at the initial stages of a project, coupled with a transfer of knowledge and technology to assist local counterparts. Based on this experience and data, it is clear that effective transfer of knowledge needs to work in conjunction with effective percolation of knowledge and capability building in order to achieve true success.

In the MAHSR Project, such assistive interventions will again be essential especially in the early stages and are certain to spur growth in in-house talent at the operator, NHSRCL. As the construction work for the India *shinkansen* project takes off and Indian counterparts mature to a stage where training and certification of experts is handled solely by Indian *shinkansen* experts at the training facility in Vadodara, the project promises to become a seat for learning for future generations of engineers and experts of India-oriented HSR operations.

### 25.4.3 Shinkansen Networks, Quality of Life, and Spillover Effects for Communities

Experience from Japan demonstrates that the impact of HSR on QoL stretches beyond the evident. While an HSR may not in itself be a sufficient tool for socioeconomic growth, benefits accrued from a robust and expansive HSR network are irrefutably numerous, as greater regional reach and integration triggers QoL benefits in terms of greater well-being, ease of transportation, decongestion of cities, and more comfortable and affordable housing options in heretofore underexplored and underpopulated areas along network lines.

Such diversion to outer cities also contributes to alleviating the problem of congestion and pollution in high-density urban areas.
The COVID-19 pandemic has pushed countries and communities to urgently address the twin issues of congestion and commuting. As Yoshitsugu Hayashi pointed out during the ADBI–Chubu University Conference on Transport Infrastructure Development, Spillover Effects and Quality of Life, HSR serves well on both counts—it is a mode of transport that requires comparatively less close contact with fellow passengers in tight spaces while simultaneously offering easy access to work and housing options in uncongested areas outside main cities.

The business model of a typical HSR station also provides a springboard for commercial activity. An HSR station in Japan is typically filled with shops and public services that attract foot traffic. The station is integrated with urban railways and taxi services to facilitate last-mile connectivity and convenience of transfer. This makes the area around an HSR station an ideal hub for commercial spaces and economic activity, forming a growth driver that in turn boosts real estate values, income levels, and revenue sources. These are only some of the salient spillover effects of HSR.

Timely policy interventions to optimize economic activity along HSR corridors have reaped considerable benefits for impacted regions. Data from Japan demonstrate a clear correlation between GDP growth and shinkansen ridership along all routes, making the shinkansen a tool of transformation as well as transportation. An HSR network should be considered a tool that can help achieve a variety of policy objectives, including (i) addressing existing congestion or transport capability issues, (ii) improving mobility options as a means for achieving overall economic growth, and (iii) revitalizing regional economies through better access (Shukuri 2020).

Although questions linger about the commercial viability of capital-intensive systems such as HSR—by some reports the Tokaido shinkansen recovered costs in 7–8 years (Verma and Parakala 2015)—the QoL benefits are indisputable. Even in terms of construction cost, newer entrants that borrow from Japan’s case studies should be able to shorten break-even periods by adopting creative approaches that have succeeded in the past.

For example, the operator in Japan is no longer burdened with the construction cost of new shinkansen lines. This cost is typically shared between the local and central government, and the construction itself is carried out by the Japan Railway Construction, Transport and Technology Agency (Shukuri 2020). This gives the operator the leeway to focus on operation and ownership of rolling stock while exploring additional revenue streams such as the ever-promising “lifestyle business” of retail and commercial services in and around HSR stations.
25.5 The Road Ahead

Capital constraints and land acquisition issues are touted as key reasons why HSR adoption has been slower than expected in some parts of Asia. What may be as pertinent is that Asian countries that have already adopted and invested in HSR systems are reaping tangible benefits in terms of mobility, QoL, and a sharp pace of regional integration, leading them to invest further in HSR systems.

Even amid a once-in-a-century global pandemic, considerable strides are being made in the space. In Japan, JR East has announced plans to conduct autonomous test runs of its E7-series shinkansen bullet trains next fall, with the aim of operating such automated trains in the future (Railway Gazette 2020). This is even as Japan proceeds with the construction of the Chuo shinkansen using maglev technology (Bharule, Kidokoro, and Seta 2019) to connect the three major metropolitan areas (Tokyo, Nagoya, and Osaka). Among later entrants, the PRC alone has built an HSR network of over 30,000 km in nearly 2 decades to connect 80% of the country’s large cities (Xinhuanet 2017); in November 2020, Bombardier’s PRC joint venture announced it has secured a new contract to build 112 additional CR300AF high-speed train cars (Bombardier 2020) for the PRC’s HSR network.

Much of the world is only beginning to emerge slowly from the cycle of COVID-19 outbreaks and lockdowns that paralyzed economic activity for the larger part of 2020. As a positive, the pandemic has triggered a rethink regarding global supply-chain dependencies, the value of living in uncongested communities, and the idea of commuting through safe and sustainable means.

This is a pivotal turning point for Asia as it waits for its moment. As a safe and environment-friendly tool for mobility and regional integration, HSR systems have much to offer and could well become the vehicle to transport Asian countries to their true age of growth and prosperity.
References


Programs to Assist and Develop Capacity in Asian Countries to Build HSR. Presentation at ADBI–Chubu University
Conclusions and Way Forward

KE Seetha Ram, Werner Rothengatter, and Yoshitsugu Hayashi

HSR and Integrated Planning Issues

Partial assessment approaches have been applied in the transport sector since Alfred Marshall developed the partial equilibrium theory in 1890 (Marshall 1890). These allow for relative ease in measuring surpluses by analyzing the shifts in the marginal cost and demand curves only for the transport market. If all other markets are in equilibrium, then this approach provides the total welfare gains induced by investments in transport infrastructure. Over the course of decades of applications, standard evaluation procedures have been developed for quantifying the changes in generalized and external costs effected by an investment project and relating the results to the investment costs. The methodological development has focused on improvements in measurement, the evaluation of internal and external cost components (e.g., the value of time and the value of the CO₂, rate of discount) and filling methodological gaps like the consistent treatment of induced transport activities and modal shifts.

However, the real founder of cost-benefit analysis was not Alfred Marshall, but rather Jules Dupuit (1844), who published his theory of welfare measurement for public works 40 years earlier. As he published in French, his paper was not noticed in the scientific world because of the Anglo-Saxon dominance. As the Dupuit approach of measuring surpluses looks similar if the analysis is reduced to the transport market, the striking difference compared to the Marshallian partial approach was not discovered for a long time. Dupuit did not consider the differentials in transport marginal costs and volumes but rather the changes in costs/prices of all products that are transported in the transport project being analyzed. The change in prices for these products is the essential driver for the welfare impact of transport investments. As a transport project can lower the transportation costs of many products, the Dupuit approach gives a much more complete picture of the scope of impacts. It is, furthermore, not bound to the economic equilibrium paradigm. Dupuit was an engineer and relied on observations rather than on theoretical paradigms.
As Dupuit was a supporter of market liberalization and deregulation, he propagated the private management of transport infrastructure. Insofar, he restricted his analysis to cover the benefits enjoyed by the users of a transport project because these benefits can be capitalized by a private project company. They can be revealed by studying their willingness-to-pay. Dupuit was not interested in indirect impacts stemming from interdependencies, e.g., synergy effects in networks or further economic and societal welfare effects. The latter issues were in the focus of the work of Friedrich List (1838) who was the first economist to describe the impacts of the transportation system—in particular the railway system—on regional and global economic development. Combining the concepts of Dupuit and List and adding social, environmental, and quality of life aspects, we result in today’s integrated approaches for measuring the comprehensive impacts of large transport investments. In particular, the following methodological areas have been developed further in modern integrated assessment:

- network interdependencies leading to the challenge of assessing network configurations instead of single projects;
- wider economic impacts instead of assessing partial surpluses on the transport market;
- strategic environmental impacts, such as greenhouse gas (GHG) emissions, global land take, and deforestation; and
- impacts on equity and quality of life.

Models measuring the impacts on the above areas can be combined for forming integrated assessment methods. Integration assessment methods were first developed in the context of climate modeling to quantify the various impacts of a change in the world temperature. For every impact measurement, a qualified model is applied, and the results of all models are brought together and coordinated on a common data platform. Such holistic approaches can be applied for high-speed rail (HSR) development and lead to the following changes in planning procedures and assessment methodologies:

- definition of the goals and specification by quantitative targets, which allow for performance measurement;
- development of systems configurations that are concordant with the targets and selecting the best configuration; and
- design and selection of projects for HSR (backbone) and secondary network infrastructure.

The ADBI-Chubu University Conference has brought significant progress with respect to integrated planning issues. HSR is not
regarded as isolated facilities, but as forming the backbone of an integrated long distance, regional, and urban public transport system. HSR projects, in this sense, are components of integrated network configurations. Wider economic impacts can be measured by different approaches: by spatial computed general equilibrium models or simplified by elasticity approaches by regional land-use and transport models or by econometric and system dynamics models. Extended dynamic models can include the impacts of HSR on productivity via the positive effects on the knowledge economy. Effective tools have been developed for quantifying energy, environmental, and climate effects within integrated modeling. It is also possible to combine the above elements with fiscal developments that describe the impact of HSR projects on future tax income. This is important for projects that do not break even financially if only direct project-related revenues are considered.

HSR projects, embedded in a network configuration, are planned for improving the quality of life of the people. Every project will bring advantages to particular stakeholders, while other groups do not enjoy direct benefits. Therefore, it is important to balance the overall social impacts by compensatory measures, e.g., by increasing the living conditions in cities or suburbs that do not have direct access to HSR. This could include the strengthening of the administrative and service power of cities according to the concept of polycentric development (“decentral centralization”) such that people find many public, cultural, and educational services in their close environment.

**HSR’s Variety of Impacts and Quality of Life**

In this book, the variety of aspects related to HSR development are presented. They include spillover effects for urban transport modes that are well-connected to HSR and offices and shops in front of HSR stations, the livability of cities, regional capacity development, and the enhancement of democracy by indigenous solutions, etc.

Existing HSR has created impacts on the economy along corridors in all countries and regions. Conventional cost-benefit analysis, which was initiated by the assessment system, COBA, for British motorways in 1972, measures the impacts of saving potential opportunity loss in gross domestic product (GDP) increase if reduced travel time and costs are used for labour input. However, for citizens’ welfare, this analysis only covers part of the input through monetary income and other factors. This may be appropriate if all passengers are businesspeople, but the reality of today is that there are many passengers traveling for other purposes.
A good contrast can be seen between the Japanese *shinkansen* and the Indian HSR, currently under construction. When the Tokaido Shinkansen, the world’s first HSR linking Tokyo and Osaka across approximately 500 kilometers (km), was opened in 1964, the majority of passengers were businesspeople. However, the upcoming Indian HSR, which links Mumbai and Ahmedabad over a similar distance, is expected to be used by a variety of travelers, including tourists, medical patients, and families travelling to meet relatives. Accordingly, the impacts received by citizens will be more varied than those of Japan in 1964 and, thus, the impacts clearly cannot be measured by a GDP increase alone.

For travelers other than businesspeople, the impacts of HSR are diverse and include accessibility to medical services, reductions in GHG emissions and air pollutants compared to alternative modes of air and road transport, enhancement of tourism attractions, new business creation with newly connected cities, additional investments for the improvement of connected urban railway networks, and commercial facility developments in station areas. These are known as the “Wider Economic Impacts” (WEI).

How can we measure the WEI? In the 20th century, people were viewed as labor force resources for the economy, but in the 21st century, the economy should be for the people. The merits of the WEI vary among individuals due to differences in their attributes. Therefore, nowadays, it is essential to look at the impacts from the viewpoint of the quality of life (QOL) of individuals with different attributes, such as age, gender, or income. The impacts of HSR can be very different from one country to another depending on the stages of their own economic development, main industries, and age structure, etc.

The impacts on the regional economy are a surface change in the economic landscape. The real impact can be seen through the change in the internal system of an individual firm, such as in the way that branches in smaller cities might be closed and merged into headquarters due to a travel time reduction to 2 hours from the headquarters’ location. A system dynamics model to trace this individual behavior of firms and a QOL evaluation method, together with a variety of application case studies, will be highlighted in a future ADBI publication.

**HSR Development in Asia**

The vital lesson for policy makers of countries that are planning to implement HSR projects is that the timing and scope of investment in HSR are key factors in a nation’s economic development. Asian policy makers are eager to know the answers to three important questions: (i) When is a country ready to introduce HSR? (ii) What should be the total length of HSR? (iii) How can investment in HSR be justified?
First, our empirical review indicates that when a country has a GDP per capita that is more than $5,000, it is suitable for HSR introduction (Seetha Ram and Bharule 2019). The People’s Republic of China’s (PRC) massive investments to build the world’s largest HSR network within 2 decades merit new policy considerations for other Asian countries (Takagi 2011). HSR has been a strong pillar supporting the steady economic growth of the PRC. India, Viet Nam, Thailand, and other countries are also planning and constructing HSR. Chan (2017) indicates several reasons for the PRC’s success with HSR.

Second, the Republic of Korea has built over 600 km of HSR lines, Japan over 3,000 km, and the PRC more than 27,000 km (Seetha Ram and Bharule 2019). India has started to construct its first HSR line and is preparing another six lines across the country, with a vision to eventually build a 5,000 km network). HSR can be used to solve two different accessibility problems. Firstly, where a point-to-point link is dominant, each train can be a substitute for an air connection between two cities by connecting cities or central business districts over long distances via a direct train connection. Secondly, in countries with a dominant high-speed network, train systems link together many cities and central business districts, creating a new type of region with high intra-regional accessibility sharing a common labor market and common market for household and business services (Pagliara, Hayashi, and Seetha Ram 2020) countries around the world have made significant investments in HSR.

Finally, policy makers are concerned about the economic and social justifications for HSR, particularly, equity and inclusion. Studies on the impacts of transport infrastructure have argued that the effects of transport infrastructure investments at the respective locations are subject to externalities (Hayashi, Seetha Ram, and Bharule 2020). Asian policy makers acknowledge the need for investing nearly 30% in transport infrastructure (Asian Development Bank 2017a, 2017b). Asian countries have also implemented several projects that attract private sector investments, particularly highways and toll roads. Our preliminary estimates show that as high as 26.3% of the total tax revenue would be needed for infrastructure investment in the Asian region as a whole. In South Asia, this is as high as 49.1%. If all the infrastructure projects are financed by tax revenues, a public budget deficit would accumulate.

Academic studies and policy dialogue sessions coordinated by ADBI together with WCTRS have gathered evidence on the significant long-term socioeconomic impacts, known as the spillover effects, at the urban, regional, and national levels. Including such academic evidence
in the decision-making process is, thus, essential for making sound judgment on investments. The studies also point out that developing countries have much to gain from the development of transport modes, such as HSR, that provide high-speed mobility to the masses of their populations. Pagliara et al. (2017) investigated the current situation of non-HSR users in Italy, Spain, and the United Kingdom, as well as the factors preventing them from choosing the service. ADBI will be gathering more evidence from experiences in other countries on HSR and equity issues and identifying solutions that reduce the negative effects of new projects in favor of more inclusive development. Hayashi, Seetha Ram, and Bharule (2020) illustrated the complex impacts of transport infrastructure in a hierarchical pyramid. From bottom to top, they are the direct transport system impact, economic and financial impact, WEI, and QOL impact.
References


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Frontiers in High-Speed Rail Development

High-speed rail (HSR) development has been recognized as an important policy tool for regional development around the world, notably in Asia and Europe. However, the introduction, development, and evolution of HSR have also attracted debate on complex issues, such as project appraisal, the wider economic benefits for regional and national development, the quality of life impacts on society, cohesion and social equity concerns, and the diversity of the challenges faced during execution. While transport corridors have led to substantial benefits in many countries and regions, there have also been cases resulting in HSR patchworks rather than networks.

This book encompasses comprehensive discussions and insights into the prevalent frontiers in HSR development, drawing on global cases and past experiences. Its objectives are to analyze and enhance the current state of understanding of HSR for policy making and expand its frontiers for future projects. Frontiers in High-Speed Rail Development is organized in six parts and offers readers stimulating ideas and new perspectives that will advance their knowledge of HSR development and planning.

Part I: Impacts of COVID-19 on Transport and Logistics
Part II: Wider Economic Impacts and Quality of Life Implications of Transport Infrastructure
Part III: Impacts of High-Speed Rail on Other Modes of Intercity Travel
Part IV: Transport–Urban Development Interactions
Part V: Research and Innovation for High-Speed Rail Development in Developing Nations
Part VI: High-Speed Rail for the People

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