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EVOLUTION OF HIGH-SPEED RAIL AND ITS DEVELOPMENT EFFECTS: STYLIZED FACTS AND REVIEW OF RELATIONSHIPS

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Abstract

The potential effects of high-speed rail (HSR) reach into many overlapping fields of interest. This paper summarizes the evolution of HSR and elaborates on the development effects of the HSR transport infrastructure. HSR can simultaneously become a core component on desired urban developments, while also having undesirable outcomes. Positive impacts will be achieved only if interactions with other factors and contexts are maintained. This paper stratifies and expands the understanding of the development effects of HSR at three levels – regional, urban, and station area – based on the economic and temporal nature of all infrastructure projects.

There is ample evidence that at the regional level, the implementation of an HSR service disrupts the existing network of cities along the proposed corridor. The HSR network changes the accessibility of a locality. Better accessibility will change the mobility patterns and will eventually affect the development in the impacted region, reshaping the entire urban-regional system. The HSR is expected to play a catalyzing role in driving the spatial and urban transformation process. This paper emphasizes the importance of establishing a synergy between HSR and urban development. A synergy between HSR and other elements, like urban transit facilities, paratransit, station area development, node, and sub-center development, can usher in spatial and economic development, but an institutional arrangement across all the elements is of paramount importance. Such a synergy would enhance livability and provide improved quality of life opportunities in cities and regions served by HSR.

Last, an HSR corridor is beneficial both to the settlements along the corridor and to the railway operator. An HSR corridor is also beneficial to the cities along the railways, and the station areas provide an important opportunity to harness revenue through non-railway businesses. However, achieving the full development effects of an HSR project may take decades. Careful pre-planning of the project and coordination amongst the stakeholders are necessary to accomplish a set of phased goals to realize the envisioned development of an HSR corridor.

Keywords: high-speed rail, regional development, urban development, station area development

JEL Classification: O18, R11, R12, R52, R58

Contents

1. DEFINING HIGH-SPEED RAILWAY AND ITS STATUS THROUGHOUT THE WORLD

Since the origin of railways in Great Britain in the early 19th century, 'high-speed' has been a time-relative concept. The 56 km Liverpool-Manchester Railway was the world's first passenger railway developed for intercity transport. The 50km/h speed record achieved by the steam-powered 'Rocket' locomotive in 1830 represented a truly high speed for its time. Soon, with the change in technology, passenger rail travel would see tremendous upgrades in speed. The German diesel trains achieved 215km/h in 1939; French electric-powered TGV holds the current record on steel rails at 574km/h (set in 2007). More recently, the magnetic levitation Chuo Shinkansen of Japan achieved 603 km/h on a test track in Central Japan.

In rail transport, trains that use specialized rolling stock and operate at more than 250 km/h on new dedicated lines and 200 km/h or 220 km/h on upgraded lines are accepted as HSR, as per the International Union of Railways (UIC 2008), although there is no single standard definition of HSR. In order to provide a non-speed related definition, Campos and de Rus (2009) reviewed the technical and economic characteristics of 166 HSR lines in 20 countries. Examining various lines – based on the infrastructure, development costs, operation costs, and forecasted demand – the authors distinguish four HSR network types, namely, the exclusive exploitation type, mixed speed type, conventional mixed type, and thoroughly mixed type. The description makes it clear that HSR is a combination of various infrastructural elements, which together form a single, integrated system and should be observed as a complete system. Figure 1 compares the planned and currently operational HSR corridors across the world (Bharule 2019a).

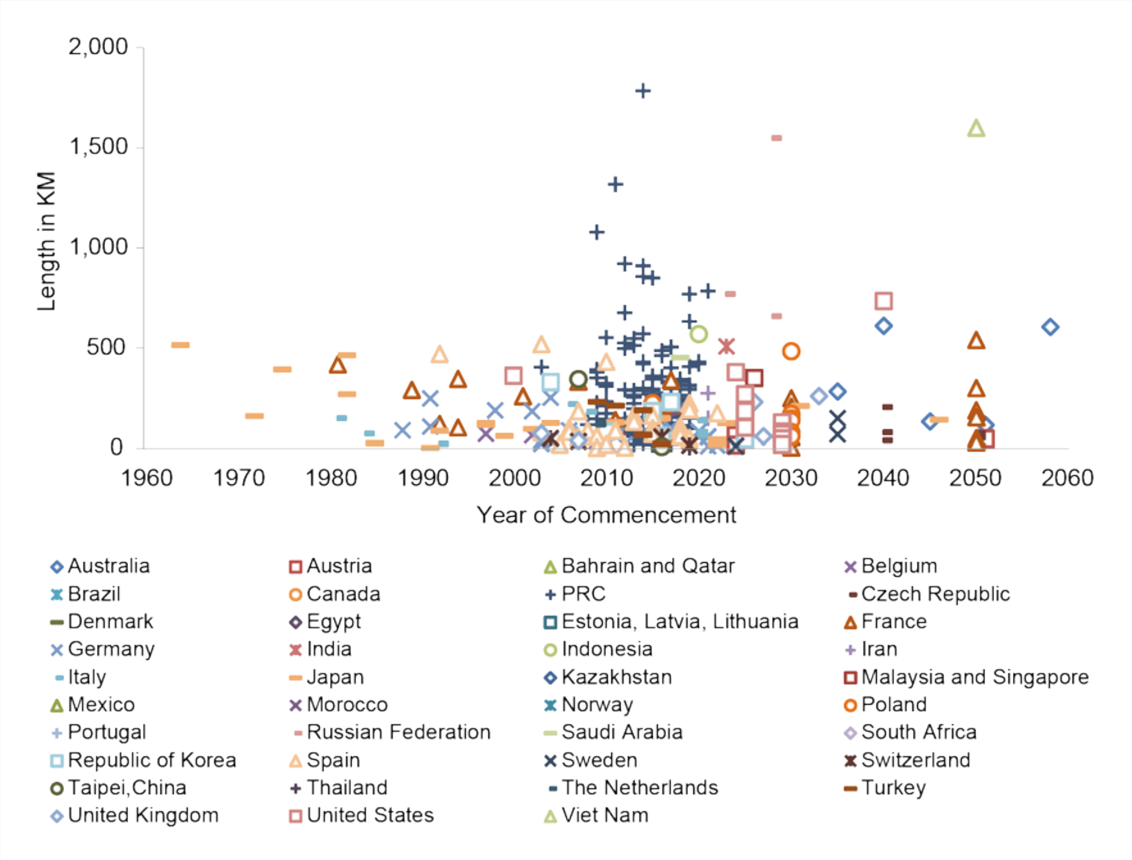
1.1 Japan

Japan is the pioneer in introducing the HSR to the world. The first HSR link in the Japanese Rail network came into commercial service in 1964, connecting Tokyo to Osaka. Known as the Shinkansen (新幹線), meaning 'new trunk line,' the 515.4 km Tokaido line corridor was built in a linear geographic setting that was apt for rail travel, with a primary goal of expanding the capacity on an overcrowded route. Takatsu (2007) points out that the design of the Tokaido line alignment attempted to use existing railway stations through many cities along the corridor served by new stations. The author highlights that after the first speed upgrade from 210 km/hr to 270 km/hr in 1992, the travel time was reduced to 3 hours and 10 minutes, making Tokyo–Osaka day trips feasible.

1.2 Republic of Korea

The Republic of Korea's Seoul–Busan axis is the primary passenger and freight traffic corridor. The National Rail operator introduced the Korail Express (KTX) HSR service in 2004. The KTX service has shrunk the inter-city travel time to fewer than three hours. This has not only changed commuting habits and lifestyles, but it has also had a significant social, economic, and cultural impact (Terabe et al. n.d.). Since the introduction of KTX, the number of rail passengers has increased, alongside a significant decrease in the number passengers opting for private cars, express buses, and aircraft to travel along the same route. The national government aims to expand the KTX network and reduce the road usage to the extent that it is possible to reach any part of the country within 1 hour and 30 minutes (The Chosun Ilbo 2010).

Figure 1: Comparison of Global High-Speed Rail Corridor Length



Source: Adapted from Bharule (2019a).

1.3 Taipei,China

Plans for Taipei,China's first HSR corridor came to light in 1989. The plan aimed to tackle the growing issues in managing the congestion between Taipei,China's two largest cities. The THSRC, HSR Corporation operates 345 km of HSR between Taipei,China in the north, to Kaohsiung in the south. Valued at $13 billion at the time of implementation, the project was one of the world's largest privately funded railway construction projects. Under the Station Zone Development Agreement, the government granted the rail corporation a 50-year concession to develop the land surrounding the stations for commercial, residential, and recreational purposes (Terabe et al. 2013). Although the project started without much delay, the ridership count was lower than expected. The government revived the debt-ridden company, introducing new operations and management structure. The Government of Taipei,China is a major stakeholder in the THSRC, but the company operations are privately managed (Chen 2018). The operator expects an increase in ridership after the opening of more stations on the line in the near future.

1.4 People's Republic of China

The People's Republic of China (PRC) leads the world in terms of HSR line length. The Mid-to-Long Term Railway Network Plan, laid out for Horizon 2020 and adopted by the government in 2004, was updated in 2008. Under this plan, the Beijing–Tianjin HSR was first of a new generation of HSR, opened in August 2008 with a maximum speed of 350 km/hour. High density corridors, like Beijing–Shanghai and Beijing–Guangzhou, have a design speed of 350 km/hr, one of the highest in the world, while several other corridors with more modest passenger volumes have a maximum design speed of 250 km/hour. Generally, both of these types of HSR projects in the PRC are passenger-dedicated lines (PDL) and green-field projects (UIC 2008). At the end of December 2013, most of the metropolitan regions in the PRC were either connected, or in the process of being connected, to lines with a maximum speed of 200 km/hour or higher (Ollivier, Sondhi, and Zhou 2014).

The PRC's HSR network is expected to span 30,000 km by 2020. This expansion will help in connecting 80% of PRC cities by creating eight corridors, each from north to south and east to west. This network configuration is envisioned to revitalize many economically challenged cities in west and central PRC, because of the hub effect created by the HSR system, especially at junctions (Li et al. 2016). With increasing passenger flow and accessibility, cities on HSR lines are becoming strategically important targets for industries, such as hotels, catering, logistics, and real estate. While regional economic differences are not rare in a global economy, the PRC's regional differences are by far the most disparate of any in the world (Amos, Bullock, and Sondhi [2010]; Ollivier et al. [2014]).

1.5 Europe

The first HSR lines in Europe were built around the 1980s. By connecting important cities, they improved the travel time on intra-national corridors. Private operators operate almost all lines in the European Union (EU), and they receive EU funding. The EU Council Directive of 1996 specifically aimed to achieve interoperability of High-Speed Trains.[1] This cross-border infrastructure promotion was the part of larger Trans-European Transport Networks (TEN-T), which are a part of wider Trans-European Networks (TENs) envisioned by the EU in 1990. The wider system of TENs includes transportation, telecommunication, and a proposed energy network spread across the EU.

1.6 France

France was the first European country to start HSR services in 1981. The TGV service between Paris and Lyon has a duration of 2 hours and covers for 450 km, as part of a strategy to decongest the overly congested conventional routes. A dedicated HSR line was adopted, and the terminals were integrated with the existing stations. While converging all the lines toward Paris, the French government strategically developed more profitable lines first. In recent years, the observed regional development in terms of social returns was higher than expected.[2] Such an initiative has encouraged the government to contribute to the construction costs and further expand the network.[3]

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1 EU Law. (2008). Council Directive 96/48/EC of 23 July 1996 on the interoperability of the trans-European high-speed rail system. Retrieved 27 April 2019, from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Al24095.

2 APF/The Local. (2018, September 12). France to get five new high speed train lines after government gives green light – The Local. The Local. Retrieved from https://www.thelocal.fr/20180912/french-government-gives-green-light-to-five-new-high-speed-tgv-lines.

3 O'Sullivan, F. (2018). France Expands TGV High-Speed Rail to Move Beyond Paris – CityLab. Retrieved 27 October 2018, from https://www.citylab.com/transportation/2018/09/france-tgv-expansion/569992/.

1.6.1 Spain

The first Spanish AVE line opened between Madrid and Seville in 1992. As in the case of Japan, the incompatible Spanish rail gauge made it necessary to overlay a new standard gauge line (Givoni 2006). The first line was progressively extended and connected to Barcelona. As a part of an EU Commission to develop an extended Trans-European Network (TEN), the Spanish network was connected to the French railway network in 2012.[4] In 2010, Spain developed the largest HSR network in Europe. With the population concentration around the coast and Madrid in the center of the country, Spain developed a radial railway network. Currently, with over 3,200 km of HSR lines, Spain's network is second to the PRC HSR network.

1.6.2 Germany

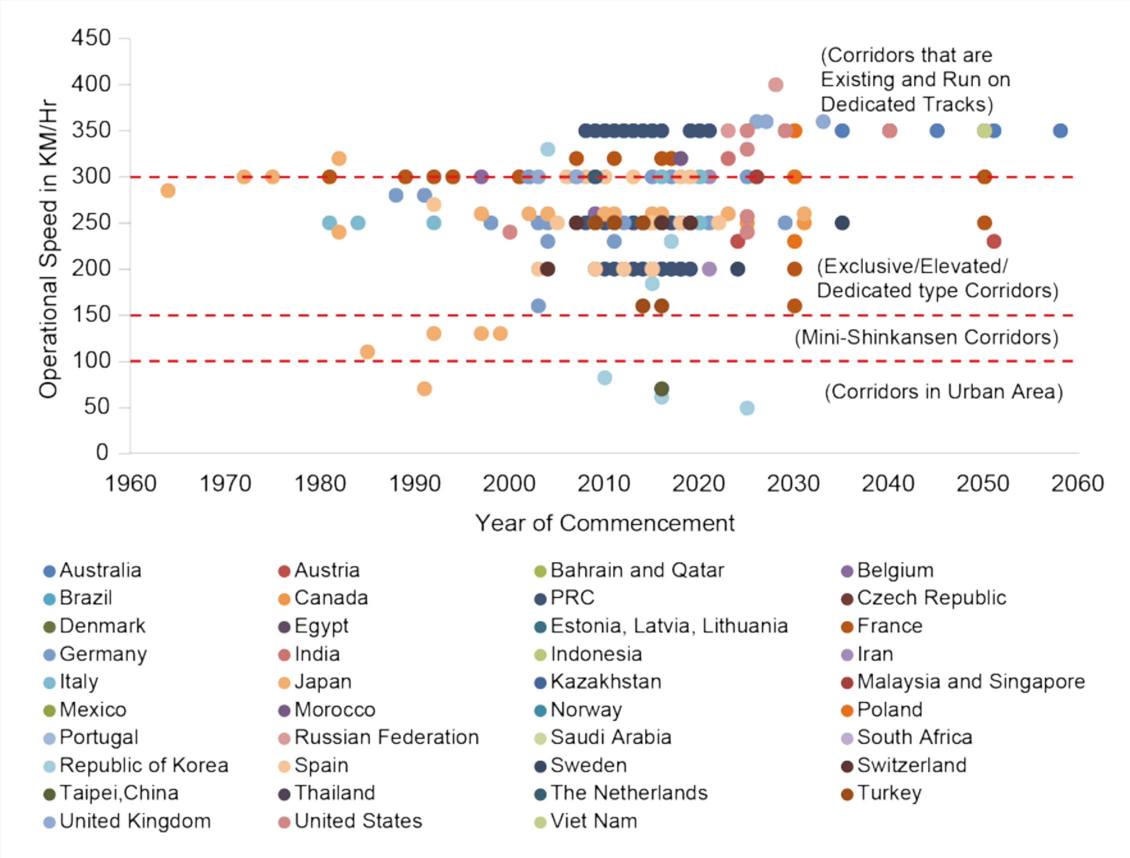
Deutsche Bahn, the German railway company, started its first railway service, InterCity Express (ICE), in 1991. The ICE network is designed to connect many major cities and hubs within Germany and in the neighboring countries of France, the Netherlands, Switzerland, Denmark, Belgium, and Austria (Sands 1993). German ICE services are used for short to medium distances between the cities, and lines operate at speeds of 200 km/hr and 250 km/hr (UIC 2008).

1.6.3 Italy

Italy partially began its first dedicated HSR in 1978, while a 254 km 'direttissima' line connecting Rome and Florence was under construction. The line was completed in 1992. With the introduction of *direttissima* lines, the travel time between the main Italian cities has been progressively reduced (Desmaris 2016). Infrastructure in Italy follows the country's geography, and the HSR lines are oriented in a north-south perspective, with the greatest density in the north. Italian HSR is an exception in Europe, as the distance between the cities is shorter compared to other countries, and Italian HSR lines operate at different speed levels. A comparison of the operational speed of all HSR lines across the world is shown in Figure 2 (Bharule 2019a).

[4] Railway Gazette. (2011). Perpignan – Figueres link inaugurated – Railway Gazette. Retrieved 27 April 2018, from https://www.railwaygazette.com/news/infrastructure/single-view/view/perpignan-figueres-link-inaugurated.html.

Figure 2: Operational Speed Vs Year of Commencement



Source: Adapted from Bharule (2019a).

2. COUNTRIES CURRENTLY DEVELOPING HSR INFRASTRUCTURE

2.1 India

In early 2010, the Ministry of Railways of the government of India announced – in its 'Vision 2020' – seven HSR lines connecting several cities in distinct parts of the country. A 508 km HSR line connecting Mumbai and Ahmedabad along western India will be the first in development. In 2015, India and Japan entered into a 'Memorandum of Cooperation on High-Speed Railways.' Under the agreement, the Mumbai Ahmedabad High-Speed Rail will adopt Japanese Shinkansen Technology. Adopting a dedicated track configuration, the line is envisioned to decongest India's busiest passenger railway corridor. The project is estimated to be operational by late December 2023 and to cost $16 billion funded by Official Development Aid (ODA) from the Japan International Cooperation Agency.

2.2 Indonesia

The Java HSR project is planned to connect the densely populated region between the national capital Jakarta and the second-largest city, Surabaya, which are located 730 km apart on the Indonesian island of Java. As a part of the PRC's Belt Road Initiative, a 150 km initial phase of the rail link is envisioned to be operational by early 2021. After several rounds of proposals and bidding since 2008, the project was finally awarded to the PRC in 2015, and it is being developed at an estimated cost of $5.5 billion for the first phase connecting Jakarta to Kertajati-International Airport, the second-largest airport in Indonesia, near Bandung city.

2.3 Thailand

The Government of Thailand approved five HSR lines in late 2010. Although the status of all lines varies, all the planned 1500 km network converges in Bangkok, the capital city of Thailand. The network will be developed in several stages and it is envisioned to be complete by 2036, with the earliest operation beginning in 2021. The complete network inclusive of airport links is estimated to cost $30 billion. The Thai HSR network is developed as ODA projects, with two lines awarded each to Japan and the PRC, while the fifth line is still in the proposal stage. In addition to the network, a 220 km corridor of airport link HSR is under development as a part of the Thai Eastern Economic Corridor (EEC) Project. Under the EEC project, the airport link is proposed to connect three international airports between Bangkok and Pattaya. Developed under a Sino-Thai public–private partnership (PPP) consortium, the project is due to open in 2024.

3. HSR AND ITS EFFECTS

Since the early 1900 Japan has been the pioneer in railway operations and integrated land development (De Souza, Ochi, and Hosono [2018]). A consistent incremental improvement in the integrated land development practices has resulted in economic development of the cities served by the Shinkansen corridors, suggesting an inter-dependence of implementation and the planning process. Over time, services and industries agglomerated along the first Shinkansen corridor, established nodes with connecting transit facilities in cities like Tokyo, Nagoya, and Osaka, which have emerged as prominent hubs (RIDA and OECF 1995).

The Republic of Korea has followed the Japanese integrated model of development, but has required additional efforts in integrating regional public transport to the KTX corridors and stations to enhance revenue. With the fast mobility of KTX, a new form of the national economy was born. International conferences could now be held at places other than Seoul. The added accessibility attracted almost 10,000 people to connected cities from the Seoul capital area (KOTI 2015). This population shift was unprecedented in the country's history. The integration of public transit with KTX is underway around hub stations (Lee 2014).

The case of THSRC, an HSR corporation in Taipei,China, is unique. After becoming almost bankrupt, the company has resurrected itself in the past ten years by making meticulous efforts to streamline the operations and sustainability of HSR. Reorganizing the company's operations management; improving stakeholder relationships; and establishing station-to-city-center bus services, which increased ridership, resulted in steady revenue growth (Chen 2018).

This countrywide discourse makes it clear that it takes more than a decade to establish a thriving HSR corridor, and that the methods to achieve success can be different.

3.1 Temporal Effects of HSR

HSR systems are built to reinforce accessibility and strengthen inter-regional, as well as intra-regional, relations. HSR corridors are set between pairs of cities, which ushers in a paradigm shift for inter-regional mobility, boosting the national economy. Empirical data analysis of HSR's impact in Japan and other countries shows the direct impacts of salient features of HSR, like savings in travel time, safety, comfort, punctuality, and frequency of trains, which are significant in terms of increased business activity and productivity. With the increased accessibility to better markets, it is possible for businesses located in one region to explore national and international opportunities, which would previously have been accessible only to businesses located in capital cities.

3.2 Immediate Effects

HSR contributes significantly to saving in travel time, comfort, and safety. For 400–700 km distances, HSR is the preferred mode of travel over automobiles and planes. Since the inauguration of the first Shinkansen line, the intercity travel time has reduced by over 50% in Japan. Technological innovations have helped in upgrading top-speed and train car safety, assuring increased frequency and improving the ride quality (KOTI 2015). HSR competes with roadways and airlines, not just because of the change in share, but also the total travel time, including access and egress, with the added comfort and travel safety.

3.3 Medium-Term Effects

A city is a complex geographic setting with inter-linked functions. Urban life in a city is extremely intertwined, and interdependencies of networks of activities are endless. An HSR line is one such link connecting and creating important hubs in the cities through which it travels. Yoshino and Abidhadjaev (2016) analyze the effects of linking cities with an HSR in the case of Kyushu Shinkansen in Japan. The Shinkansen line construction started in 1991. It was partly operational until 2004, and in 2011, it became fully operational. During construction, the land price and the property tax revenue increased in municipalities around HSR stations. However, the trend around each station varied after the opening of the line.

4. HIGH-SPEED RAIL AND DEVELOPMENT

4.1 HSR and Regional Spillover of Development

Evidence through academic work emphasizes inter-city and inter-region HSR investments, they can create regional imbalances. When HSR investments are made where the city or region pairs have different levels of development, such investments may work in favor of primate regions and cities at the expense of weaker surrounding regions.[5]

[5] A primate city distribution is a rank-size distribution that has one very large city with many much smaller cities and towns, and no intermediate-sized urban centers.

Along a proposed corridor, cities that will have access to HSR through a station may accrue benefits, although the distribution of impacts and gains requires rigorous study. Cities of regional importance might benefit at the sacrifice of neighboring hinterlands, thereby yielding certain impacts, although various research has argued that countries with dominant cities tend to accumulate net benefits.

Under the umbrella term of 'New Economic Geography' (NEG), Krugman (1991) explains the prolonged existence of regional disparities. Krugman emphasizes the advantages for higher productivity gains developed due to the agglomeration of economic activity in major cities, which attracts organizations and labor. NEG is a theoretical framework for understanding the economic processes that produce regional inequalities (Tomaney 2012a). The theory explains the choice of location of individual businesses as an outcome of a trade-off between increasing returns to scale and optimum transportation costs (Krugman 1999).

NEG establishes itself as an important principle, although it fails to explain the preference of an organization to relocate in urban areas, where costs of establishment are significantly higher compared to peripheral hinterlands. A city is the resultant product of localization or agglomeration economies. The concentration of organizations and firms in specialized clusters is understood as 'localization,' whereas the presence of organizations and firms in cities and urban areas with a diversified economy is referred to as 'agglomeration'. Fujita and Krugman (2003) conclude that the combination of the benefits of agglomeration and localization in the form of scale economies, labor pool, and knowledge spillover collectively explains the 'pull effect' of urban locations on firms.

Further detailing the transport cost and regional economic relationship, Lafourcade and Thisse (2011) point out that core regions are more likely to benefit through reduced transport costs, although these benefits will involve disservice to poorer regions. Agglomeration economies generate positive externalities, which are mutually reinforcing. Therefore, city regions and their surroundings are likely to create a more competitive business environment, resulting in higher overall productivity. As a result, when firms and businesses located in the core of the region are competing with those located in the periphery of the region, the former has an advantage over the latter.

Nevertheless, a prevailing assumption states that the impact of transport cost reductions on the regional economies follows a bell curve (Tomaney 2012a). Tracking the timeline of transport infrastructure, Rodrigue, Comtois, and Slack (2016) clarify that the concentration of certain economic activities in the immediate agglomerations may in fact be a result of lowered transportation costs. Lower transportation costs tend to expedite redistribution of economic activity, especially toward the periphery. This is particularly true for manufacturing activities. However, this would imply that transportation costs become almost negligible, which might not be the case. In such cases, the centrally located peripheral region supports the connected region.

Examining the trends in regional inequalities in the EU, Puga (2002) focuses on regional disparities. He notes that connectivity augmentation between regions of different levels of development not only allows the less developed region to have access to better markets located in the more developed regions, but it also makes it easier for firms in developed regions to supply more impoverished areas. This added advantage may directly harm the industrialization prospects of areas with lower development levels, and the result may directly affect the environment as well as the quality of life of individuals (Hayashi et al. 2015; Rothengatter et al. 2015).

Highlighting the importance of NEG models, Puga stresses that they not only point out the potential ambiguity of reductions in transport costs on less developed regions. The models also clarify that the overall effects depend not just on the characteristics of the transportation infrastructure projects, but also on specific aspects of the economic environment where the project is implemented – for instance, among two regions to be connected by new transport infrastructure and if the difference in wages and inter-regional migration are low, and the regions differ widely in terms of the attractiveness to business services.

The investment in the new transport infrastructure can do very little to reduce the regional inequalities. Puga (2002) argues that the potential impact of HSR is primarily focused on businesses and the location of headquarters. Puga suggests that HSR services give an added advantage for business service providers to serve remote locations and access the headquarters at the same time, which leads to a further concentration of businesses in a few large cities. A resultant effect is higher tariffs in cities, making them less attractive for manufacturing firms to relocate. The rise in tariff accelerates the transformation in the economic geography from sectorally specialized regions to functionally specialized region (Bharule 2019a).

On the emergence of the trend described above, Duranton and Puga (2001) draw evidence from France. After the construction of the TGV between Paris and Lyon, the TGV investment led to the relocation of business headquarters from Lyon to Paris. This movement contrasted with the government's claims of new commercial development along Part-Dieu station in Lyon, an indicator of the positive effects of HSR. Although there was no mention of net impacts on growth and employment, this points to a negative net impact for the city of Lyon.

Differentiating the types of ail investments, Puga (2002) concludes that inter-regional investment facilitates trade between regions, and intra-regional investment facilitates trade within regions. Puga concludes that improvements in the inter-region infrastructure may causes more harm than good – especially to peripheral regions – whereas intra-regional improvements appear to have no negative impacts. Similarly, hub-and-spoke type HSR network systems appear to produce different effects on their surroundings. In a multiple spoke network, where several of the spokes or rail corridors are connected to a single hub or city core, this tends to promote agglomeration in the hub. Businesses and firms located at the hub will face lower transport costs to any end of the spoke than firms going from one spoke to another. Moreover, hub locations would tend to trigger inequalities among spoke regions (Duranton and Puga 2000, 2005, 2014, 2015; Fujita, Krugman, and Mori 1999; Fujita and Mori 1996, 2005; Puga 1999).

Highlighting the ambiguity in the results of the impact assessment of HSR projects, de Rus (2009) concludes that impact assessment using NEG models to ascertain the potential impact of lower transport costs on less developed regions remains undetermined. Furthermore, the overall effect on the region would also depend on the economic environment and the characteristics of the transport projects. In this regard, the TEN-T has resulted in developing better accessibility in most of the economic centers across the EU. However, the ‘time-space convergence’ due to the new infrastructure may widen the relative accessibility gap between the urban core and the periphery. The emphasis on HSR links is likely to favor the central and terminal nodes of the HSR system network and is not likely to promote the development of new activity centers in minor nodes or intermediate locations (de Rus 2008). The accessibility gap widens with each added HSR service, thus augmenting inequality in regions and reinforcing the core regions as transport hubs (Puga 2002).

On the contrary, Rodrìguez-Pose and Fratesi (2002) argue that the effects on regional convergence were barely noticeable, in spite of investments in new roads, freeways, expressways, and high-speed rail proposed under the TEN-T project masterplan. Significant returns were visible only in the case of education and human capital. They consider several potential reasons for this, but they conclude that the primary reason for the disappointing performance and low returns is the weak relationships between infrastructure investments and regional convergence.

Highlighting the bi-directional nature of transport and telecommunication links, they emphasize the formulation of a strategy with a strong understanding of the regional characteristics, which must act as a root of all the infrastructure development in the region. They further explain that providing various activities around the investment corridor may resolve a vital block in development while reducing the gap in infrastructural demand with the rest of Europe (Rodríguez-Pose and Fratesi [2004]; Tomaney [2012]). However, such a policy may expose the weaker regions to competition from stronger and more technologically advanced businesses located in the core cities, causing more harm than benefit.

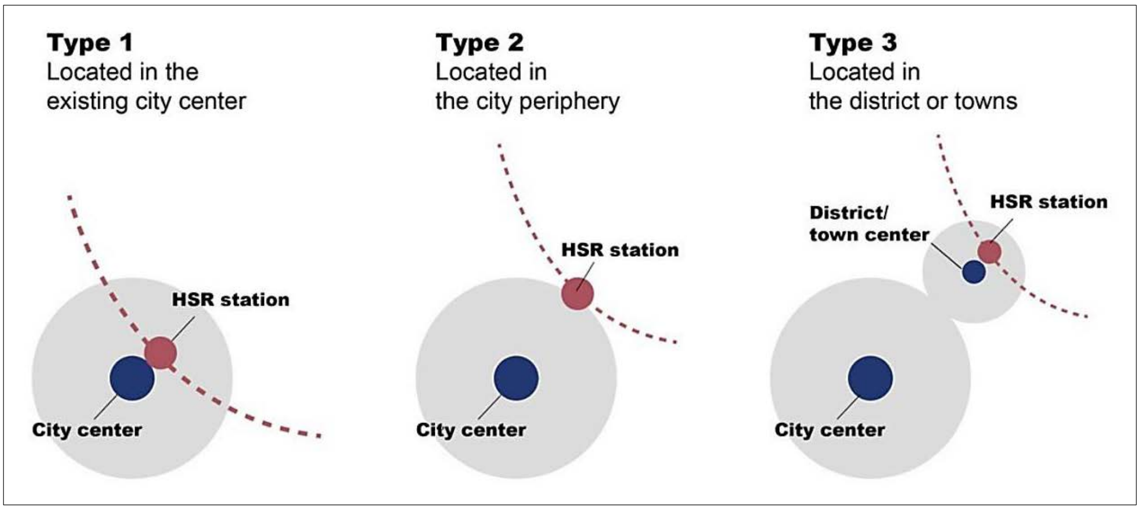
5. HSR AND URBAN DEVELOPMENT

Empirical evidence through academic work emphasizes that HSR investments become a catalyst for urban restructuring. Extensive research focuses on one concern: 'Location of the HSR station with respect to the City Center.' The HSR-urban interaction can result in a boon for urban development. Studying the HSR station location typologies in Europe (see Figure 3), Hall (2009) identified three types of urban impacts of HSR depending on the location of the station:

- The first type is when the station is located beside or within the traditional Central Business District (CBD). This improves or reinforces the CBD's attraction as a place for commercial investment.
- The second type of station is usually located on the edges of cities, adjacent to, but separate from, the major urban centers. This helps in developing complementary sub-centers within the urban area.
- The third type of station uses the station as a driver for a new commercial 'edge city' on the periphery of the urban area.

The latter two types may help in promoting the transformation of a mono-centric city to a poly-centric urban region. Priemus (2008) clarifies that having an HSR station away from the city center helps in the development of more nodes and urban centers by connecting the urban patterns and infrastructure network together. Discussing the development of the European high-speed rail network, Vickerman, Spiekermann, and Wegener (1999) demonstrate accessibility improvement for hub cities in the EU, whereas peripheral cities have gained some improved accessibility, but still less than hub cities. Nodal cities gain the most from improvements to the high-speed network, while places between the nodes or on the edge of the network do not make significant gains.

Figure 3: Types of HSR Station Location with Respect to CBD and Urban Fabric



Source: Hall (2009).

The HSR-urban interaction should be observed at an urban-regional level. The advent of HSR plays two roles in influencing the urban economy: a catalyzing role and a facilitating role. The HSR network plays a catalyzing role by drawing new activities to the urban region, and a facilitating role by impacting the cities in terms of accessibility to enhance the local economy (van den Berg and Pol 1998). However, the major challenges that loom in the landscape of development adjacent to HSR stations include managing the competition and dynamics between the old and new station areas, nodes, and centers and to blend the new development with the existing urban fabric (Yin, Bertolini, and Duan 2015).

5.1 Characteristics of HSR Station Area Development Projects

HSR station areas have been described in various texts using several characteristics and indicators. Terrin, Marie, and Leheis (2011) highlighted the characteristics of HSR development projects in the European cities of Barcelona, Lille, Lyon, Marseille, Rotterdam, and Turin. They argue that HSR stations may be on their way to becoming a new architectural typology: a new kind of mobility infrastructure that is a hybrid of an airport hub and a service-oriented shopping space, while still being a multi-cultural public space at the same time. The highlighted characteristics described are primarily based on two models: transport infrastructure-led economic development, and a network model connecting local and global hubs while producing mobility-induced services (Terrin 2016).

Reviewing the urban development impacts induced by HSR, Sands (1993) presents empirical evidence from Shinkansen in Japan, the TGV in France, and the ICE in Germany. He focused on the change in travel time and urban economic impacts, such as demographic changes, as well as station area development and redevelopment. At the local level, his analysis categorized the station in two types: first, HSR that was introduced into existing conventional rail stations and, second, new stations exclusively built for HSR. At a regional level, he compared stations by looking at stations where only express HST stopped in comparison with those served by slow HSTs, which stopped at all the stations.

Berg and Pol (1998) propose two groups of cities in the European context: international service cities and cities in transition. They pointed out that international service cities such as London, Paris, Barcelona, Amsterdam, and Lyon have a competitive edge in the international service and knowledge economy, and, because of their international facilities, attractiveness, and accessibility, they compete to be global players. The cities in transition, such as Lille, Liverpool, Marseilles, Rotterdam, and Turin are often old port or industrial cities seeking to transform and boost their economy by attracting new economic activities and inhabitants through investments. Both groups of cities see the HSR station as an opportunity to attract more business activity and commercial and real estate land development in and around the station area (Pol 1998). However, not all the station area developments observed were similar. For instance, Peters and Novy (2012, 2013) analyzed cases in Europe and identified four distinct categories of train station area development:

- *Station Renaissance Projects:* These were focused on the redevelopment of station facilities, such as the restoration and expansion of historic stations. Some stations also enhance the shopping and entertainment facilities within the station premises.
- *Transport Development Projects:* The primary goal of these projects is to enhance the transportation infrastructure and improve the transfers between different modes available at the station.
- *Strategic Mega-Projects:* They involve significant and large-scale development in the vicinity of a railway station, and they require the active involvement of stakeholders in both public and private investment.
- *Urban Development Projects:* The redevelopment of the railway station and its surroundings must be conducted under as single, integrated master plan. Complementarity in-land use while master planning of the station surroundings is carried out helps in balancing the pressures on infrastructure.

Comparing the case of the proposed California HSR with Japanese Shinkansen, Murakami and Cervero (2010) examined the locational characteristics of job and labor markets around the planned HSR stations. They applied cluster analysis to build a typology of 26 proposed stations in California and 17 exiting stations in Japan. The purpose of categorization was to assess how different factors would influence the impact of HSR on urban development. On the basis of variables based on city characteristics, the authors categorized 26 proposed stations in the following five categories:

- Global and regional business centers,
- Edge cities,
- Aerotropolis,
- Leisure cities, and
- Small intermediate cities.

Hall (2003) stresses that the edge city stations have a locational advantage of maximum potential for future development, especially when the HSR services directly connect to airports. Kasarda (2011) proposed the concept of aerotropolis, a city based on aviation-linked businesses with outlying HSR corridors extending across the clusters of these business and associated residential developments to a 30–40 km radius from an international airport. Empirical findings suggest that new HSR projects are more likely to lead to benefits in knowledge- and service-based industries along the corridor, but they tend to agglomerate in large, globally connected cities (Blanquart and Koning 2017;

Chen and Hall 2012; Chen, Loukaitou-Sideris, de Ureña, and Vickerman 2019; Hall 2014). Growth may also shift from small intermediate cities to edge cities because of enhanced accessibility.

Learning from cases in Spanish cities, Bellet (2009) finds that cities adopt inter-related strategies on the advent of an HSR:

- Strategy: An HSR station is placed in the city periphery, and simultaneous removal occurs of the conventional line tracks from the city center of Ciudad Real. This strategy provided the city with an opportunity to strengthen the core by consequently redeveloping the city center. The new HSR station at the periphery is an opportunity to create a secondary center in the city.
- Strategy: Using land in a central location to build the HSR station, relocating the existing railway activities in the periphery of Zaragoza city. There is relocation of railway yards, freight facilities, and workshops. This provides a significant amount of land in the core city area, making it possible to be redeveloped for commercial establishments.
- Strategy: Integrating new HSR services within the existing conventional rail station by expanding the station building and simultaneously redeveloping the area around the station in Lleida. The city was able to accommodate more commercial activity in the vicinity of the station.

Loukaitou-Sideris et al. (2011) discuss six variables that intervene and influence the type of urban design strategy and station area development:

- *Geographic context:* Large metro center, small metro center, suburban employment center, suburban dormitory and outer-urban dormitory, rural, airport-related
- *Ridership:* Origin, destination
- *Station location:* Central or peripheral
- *Network type:* Shared with a conventional line or dedicated tracks
- *Guideway track:* Elevated, surface tunnel, type of parking
- *Type of parking:* Structure or surface; concentrated or distributed

Loukaitou-Sideris and Colton (2017) argue that the geographic context, ridership count, and station location directly influence the mix of land use as well as the type and scale of development in the station area. The type of rail network will drive the type of development on the adjacent land, whether it is shared with the conventional rail or dedicated tracks. The arrangement of the guideway tracks also defines the morphology of the surroundings: For instance, stations located underground or elevated stations provide more land for development adjacent to the station in comparison to stations located on the surface. This aspect, along with the type of parking, would together define the level of integration of the station into its surroundings.

5.2 Factors That Trigger Station Area Development

Europe in the past two decades had observed intensification of station area development and redevelopment projects. Bertolini and Spit (1998) identify several innovations and changes that were responsible for redevelopment projects near HSR railway stations across Europe. Changes such as technological innovations, new institutional frameworks, and transformation in the spatial dynamics of the region have been driving innovative public policies, adding to the quality of life.

Cutting-edge engineering and technological innovations, particularly the development of HSR, helped in minimizing the distances and improving accessibility of the cities served by HSR. This enhanced accessibility worked as a boon for many multi-branch firms. This demand generated by the relocation of firms triggered new developments around stations. One of the most reviewed case studies is that of Lille, a critical junction between London, Paris, and Brussels on the Channel-Tunnel link. The proposal of a station at this junction triggered significant development in the station surroundings, known as 'Euralille.'

Privatization of railway operating companies is one of the common institutional changes found across rail operators in Europe. Privatization helps companies capture the locational advantage of a railway station to its maximum potential, attracting investments to develop land above and around the station. Not only the railway operators, but also the city municipal corporations, were seen updating their policies in order to improve the city's competitive image, taking advantage of the HSR investment. This resulted in some large-scale station-city redevelopment plans. In the case of the Netherlands, such redevelopment plans are part of national policies: The country's HSR stations are part of sizeable nation-wide, government-funded urban development projects, referred to as the 'New Key Projects' (Bruinsma et al. 2008).

In addition to the aim to gain economic advantages, policies for urban development are often provoked by a desire for sustainable, inclusive, and compact urban forms. These are desirable since they can easily be served by city-level transportation, promote walkability, reduce environmental impacts, and enhance quality of life. Development of dense urban nodes around the HSR stations has been promoted to achieve a certain desired urban form, as some of the central European cities are currently shrinking. These developments are enabled by the public, as well as private, sectors who are willing to invest, as well as the availability of large parcels of developable land near many station areas. However, a significant driver has been the brownfield sites – left empty in the wake of de-industrialization and the shift to a service economy – resulting in the structural transformation of the whole region.

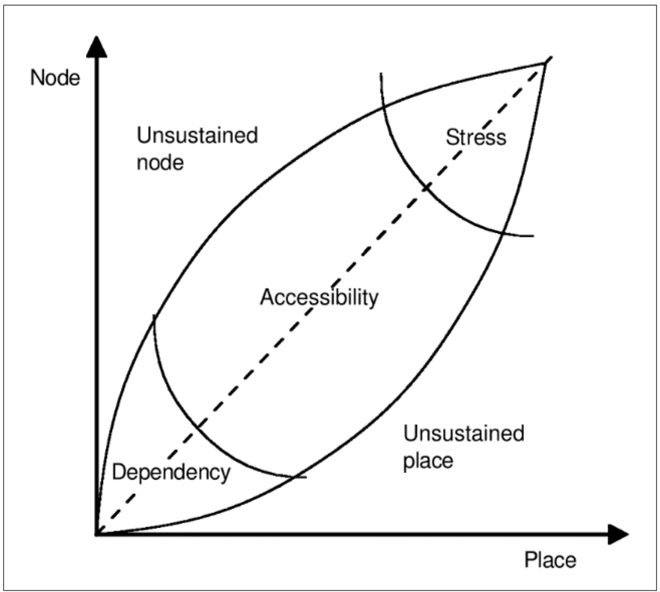
Seeking to understand and measure the forces behind the intensification of station area development in the Netherlands, Bertolini (1998) elucidates the node-place dynamics of the station area. He uses examples of different station areas around Dutch railway stations to form a model in which different station areas vary in their value as nodes and as places. In the Node-Place model (shown in Figure 4), the value of a station as a node is a function of the accessibility of the HSR station. However, value as a place is a function of the intensity and diversity of activities in the station area.

Nevertheless, the model clarifies the tremendous need for urban design considerations to be given to each station type – node or place, or both. The binary nature of station areas having to become nodes, catering to both transport and non-transport networks, and as places hosting diverse uses, generates a series of challenges. Bertolini and Spit (1998) identified five challenges:

- *Spatial challenges* arise because of the compressed nature of most of the station sites. These challenges may paralyze the fluidity required for passengers' intermodal transfers, as well as other users, including railway staff. The cumbersome nature of railway infrastructure often creates a barrier effect dissecting the station from the area around it. However, unlike airports, railway stations may be integrated into dense urban contexts, forming nodes.

- *Temporal challenges* arise as urban redevelopment plans and investments in transport infrastructure do not align on time horizons. Moreover, with the generally decade-long time frame of station area development, the projects generate uncertainty. Such uncertainty is exceptionally puzzling for public authorities as well as private developers, delaying subsequent investments in the surroundings. Unexpected fluctuations in the real estate markets can indirectly affect planning.
- *Functional challenges* arise in setting up multifunctional environs, as HSR railway stations act as both transit nodes and places for passengers and non-travelers to move and or assemble. The complexity thus created by the mélange of activities within a relatively tight area is challenging to address.
- *Financial challenges* become a burden in the case of addressing technical difficulties and including incompatible design requirements. Hence, the public sector often relies on private sector instruments, like the use of higher floor-area ratios (FARs) or floor-space index (FSI) and the transfer of development rights (TDR) for intensifying the land use. Revenue from the tax is essential; this creates more demand for commercial land use than other land-uses in the proximity of the station.
- *Management challenges* give rise to 'not in my backyard' issues and arguments. Due to the presence of public, private, and public–private investments and properties in and around the station, many stakeholders are involved in and are responsible for maintenance. Hence, the need for stakeholder coordination is of paramount importance for operation and future planning of the station, as well as the station area.

Figure 4: Node-Place Model by Luca Bertolini (1998)



5.3 The Good Station Area Plan

The earlier section elaborated on the fact that development within an HSR station and surrounding areas is crucial and challenging in inter-disciplinary ways, too. What contributes to proper HSR station area planning?

As the previous sections have highlighted, HSR station areas should be both transportation nodes and connector places. A third dimension regarding the sophisticated setting of a good station area consists of planning and policy factors. Planning and policy factors result in an envisioned blend of facilities around the station. Compatible planning and urban development policies can achieve good intermodal connections, better door-to-door services, and compact urban forms, by the concentration of business, cultural, and entertainment activities.

Japan, after the introduction of the first HSR, has had the most extensive history of station-adjacent developments (駅前開発). Learning from the station area development cases in Japan, Morichi (2013) suggests a decision-making process for station area development. He suggests a four-step guideline for achieving positive impacts of high-speed rail on urban development in the form of station area development projects:

- Developing a strategy for future urban structures based on the potential of the impact on the region and formulating a master plan of the station area;
- Select the target zone to be developed and decide on the types of incentives and available or required regulation mechanisms;
- Establish an institution for the development to be responsible for implementing the zoning and land-use changes as per the target zone requirements; and
- Implement the project as per by the master plan.

The above points demand an uncluttered understanding amongst the stakeholders. Moreover, the timing of the land development around the station overrides all other decisions made during the project. Timing is critical for driving the relationship between the demand for land and its price as soon as an HSR project is announced. Land prices are expected to be lower soon after the completion of the HSR project, even though they might be higher without the HSR project. This means that the cost of land development can be less expensive compared to delayed development in the station area.

Schutz (1998) (quoted and translated in Pol 2003) describes the development areas that might benefit from the advent of an HSR. He distinguished the areas around an HSR station into three development zones: primary, secondary, and tertiary development zones (see Table 1).

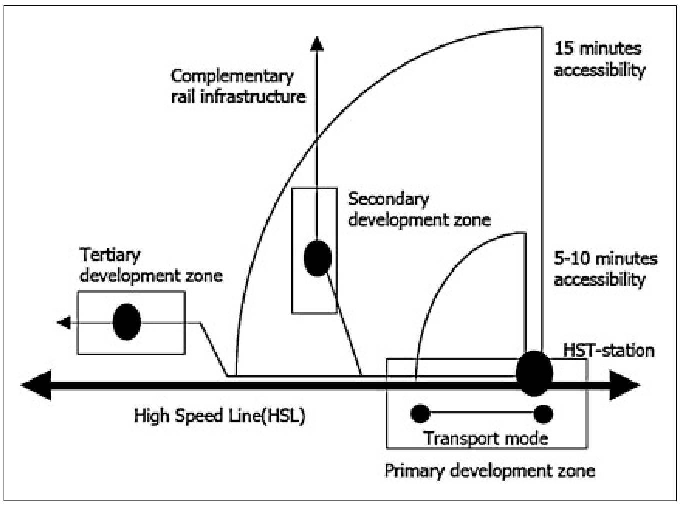
Table 1: Development Zones around an HSR Station

	Primary Development Zone	Secondary Development Zone	Tertiary Development Zone
Accessibility to and from the HSR station	Direct 5–10 min on foot or by seamless transport	Indirect <15 min, by complementary transport modes (including travel and transfer time)	Indirect >15 min, by complementary transport modes (including travel and transfer time)
Location potential	Location for high-grade (inter)national functions	Secondary location for high-grade functions. Specialized functions related to specific location (cluster)	Variety of functions depending on specific location factors
Building density	Very high	High	Depends on specific situation
Development dynamic	Very high	High	Modest

Source: Schutz (1998).

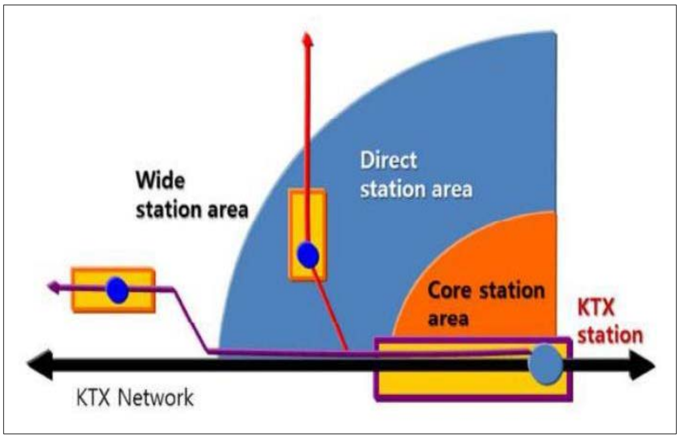
Schutz affirms that the primary development zone, among all other zones, would receive and reflect the greatest effects of the advent of an HSR station. Because of the proximity to the HSR, the area profits directly from its improved status as a location. Therefore, in the primary development zone, high-grade office and residential functions can be established, and within the same zone, land and real estate prices are expected to change the most. As a result, to reap maximum benefits, high building density becomes an important aspect in the development of this area. Secondary development zones may also establish high-grade functions, although the benefits in real estate will be less compared to those of the primary development zone. The tertiary development zones may add to the benefits of the primary development zone by the introduction of complementary transport modes that would serve other areas in the urban region. The tertiary zone, however, is not likely to show any direct development effects that can be associated with the arrival of HSR services.

Figure 5: Three Development Zones around an HSR Station



Source: Schutz (1998), adapted from Pol (2002).

Figure 6: Hub and Spoke Model of Station Area Development



Source: Oh (2013).

According to Oh (2013), the KTX stations are emerging as the core of the regional development in the Republic of Korea. Station area development plans were prepared for KTX stations. A hub-spoke model was adopted to increase station accessibility from the surrounding areas (refer to Figures 5 and 6). The plans embedded intermodal transport center complexes (ITCCs), which both combine intermodal transfer and integrate business and commercial activities within the station area, although, the station development projects have had some difficulties that resulted in inadequate returns from investment. First, there was a delay in the construction of the feeder transport system. Second, there was a delay in development due to lack of capability of the project-executing agencies. Third, there were no rules or guidelines for the station area development (Sunduck et al. 2005). The integrated coordination of all the stakeholders is overly complicated and is very difficult to be adjusted, if not established beforehand.

In a survey of HSR experts, Loukaitou-Sideris and colleagues (2011) summarize the essential preconditions found for station area development. The experts highlighted some critical pre-conditions for the policymakers and other stakeholders to develop the HSR station areas. These include central station location, integration of the station with its surroundings, connectivity to the station, level of service, and strong political will and vision of the stakeholders.

6. SUMMARY

HSR has been in operation for over 50 years in many countries. Within Asia itself, during the past two decades several corridors have been developed in the PRC and countries like India, Viet Nam, and Thailand, and others are also planning and constructing HSRs. The studies reviewed in the paper have argued that the effects of transport infrastructure investments on the location are subject to externalities. In spite of such growth in the HSR networks, the doubts of the potentials of the HSR infrastructure have not been fully dispelled. While the potential effects of HSR can be long-ranging and multitudinous. Such challenges include building alternative resources that are required to elicit benefits from the spillovers of mega-infrastructure projects.

This paper outlines the global experience of HSR and concludes that HSR brings in considerable socio-economic benefits that cannot be captured through econometric modelling alone. Capturing the impacts of HSR infrastructure requires analysis involving a scaler as well as a temporal lens. Impacts of infrastructure on quality of life vary with the scale of development and time required to achieve the expected impacts. This paper shows that HSR may become a core infrastructure for desired urban developments and – at the same time – may also lead to undesirable outcomes.

In terms of scale, first – at the regional level – the HSR network changes the accessibility of a locality. Better accessibility will change the mobility patterns and will eventually affect the development in the impact region, reshaping the entire urban-regional system. Countries developing an HSR network need to rigorously plan the path to elicit maximum benefits while investing in HSR infrastructure. This is particularly important in the case of countries with an elaborate city system. Countries like India, Thailand, and Indonesia need to understand their metropolis formation processes. Understanding the current system of cities may aid in planning HSR routes to redistribute the urban functions from one region to another, in order to attain a balanced regional development.

Second, at the urban scale, the HSR is expected to play a catalyzing role to drive the spatial and urban transformation processes. The paper emphasizes the importance of establishing a cooperation between HSR and urban and local development. A synergy between HSR and other elements, like urban transit-paratransit facilities, station area development, and sub-center development, would radically increase the spillover effects (Bharule 2019a). Increased accessibility to services and the convenience of travelling thereby enhance the overall quality of life in the city. This has been a common experience among all HSR-operating countries. Achieving such cooperation demands innovation in institutional arrangements across all the relevant elements to deliver enhanced livability in an urban space.

Third, this paper also draws attention to the importance of station area development planning and its relationship with HSR stations. The discussion elucidates the multiple characteristics and overlapping factors associated with station area development, while noting that these complexities collectively lead to the formation of a station area. Development in the station surroundings usually takes more than a decade, and a robust strategy and long-term vision are therefore necessary from the outset of the project (Seetharam and Bharule 2019). A vision for long-term integrated development demands for a policy framework that gives equal importance to all the members, stakeholders, and actors. However, varying governmental setups and frameworks of infrastructure adoption present several challenges in setting up an egalitarian policy framework, especially in emerging economies, where these policy challenges are sensitive to local context.

Last, an HSR corridor is beneficial both to the cities and towns along the corridor and the railway operator. To the cities and towns, HSR serves as a form of urban amenity that is crucial to accelerating their economic growth and improving the quality of life. For the railways, station areas provide an important opportunity to harness revenue through non-railway businesses (Bharule 2019b). Realizing the full development effects of an HSR project may take decades. Therefore, careful planning and coordination among the stakeholders is a necessity to accomplish a set of phased goals. Although evidence suggests that the introduction of HSR services is largely associated with the service sector, the spillover of the economic activities and transport infrastructure generates implications for local as well as regional spatial development strategies, enhancing the quality of life at all levels.

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