ADB

# Technical Assistance Consultant's Report

Project Number: 42518-024
September 2018

# Connecting the Railways of the Greater Mekong Subregion

(Financed by the People's Republic of China Regional Cooperation and Poverty Reduction Fund)



Asian Development Bank

Project Number: 42518-024
Regional—Policy and Advisory Technical Assistance (R-PATA)
September 11, 2018

# Final Report on GMS Missing Railway Links

TA-9123 REG

## Prepared by the TA team

# Connecting the Railways of the Greater Mekong Subregion

(Financed by the People's Republic of China Regional Cooperation and Poverty Reduction Fund)

## List of Abbreviations

| Abbreviation | Explanation |
|---|---|
| ADB | Asian Development Bank |
| BCR | Benefit Cost Ratio |
| CAREC | Central Asian Regional Economic Cooperation |
| EDI | Electronic Data Interchange |
| EIRR | Economic Internal Rate of Return |
| ERTMS | European Railway Traffic Management System |
| ETRC | European Train Control System |
| FIRR | Financial Internal Rate of Return |
| FNPV | Financial Net Present Value |
| GDP | Gross Domestic Product |
| GHG | Greenhouse Gas |
| GMS | Greater Mekong Subregion |
| GRMA | Greater Mekong Railway Association |
| HS | harmonized system |
| HSR | High Speed Rail |
| IWT | Inland Waterways Transport |
| Kph | Kilometers per hour |
| LAO PDR | Lao PDR People's Democratic Republic |
| MR | Myanmar Railways |
| MRTM | Mekong (Sub-) Regional Transport Model |
| NPV | Net Present Value |
| NRA | National Railway Administration, PRC |
| O&M | operations and maintenance |
| ORP | (Railway) Operational Readiness Plan |
| Pa | Per annum |
| Pcu | passenger car unit |
| PRC | People's Republic of China |
| PRC Fund | People's Republic of China Regional Cooperation and Poverty Reduction Fund |
| SRT | State Railways of Thailand |
| TA | Technical Assistance |
| TAZ | Traffic Analysis Zones |
| TSI | Technical Specifications for Interoperability |
| UIC | International Union of Railways |
| USD or $ | United States dollars |
| VNRA | Viet Nam Railway Administration |
| WG | Working Group |

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## EXECUTIVE SUMMARY

The Greater Mekong Subregion (GMS) Economic Cooperation Program Strategic Framework, 2012 – 2022 stresses the importance of connecting all GMS countries by rail as well as promoting the development of a seamless GMS rail network[1]. With ADB support, the Greater Mekong Railway Association (GMRA) was established.

This ADB Technical Assistance (TA 9123-REG) is a direct response to the GMS member governments' request for ADB assistance to review the 9 priority rail links (known as the missing rail links that would cross the national borders), that were agreed by the GMRA in 2015, and to provide advice on their feasibility, and opportunities for investment. These 9 links are illustrated in the figure on the previous page. Projects 1 to 3 and projects 7 to 9, form part of the defined GMS economic corridors while projects 4 to 6 form part of what are considered to be the GMS transport corridors[2].

Since the commencement of the TA in November 2016, there have been a total of 6 consultation meetings held by the ADB TA team with each of the GMS' railway bodies at their home offices. There have also been three meetings of the working group[3] that reports to the GRMA with the ADB TA team that were held in Bangkok, Thailand.

A draft final report of the TA was issued on March 6, 2018 and the findings presented in Vientiane, Lao PDR, at the GRMA Board of Directors General Meeting held on March 22, 2018. Findings were also presented at a meeting of the Working Group meeting on March 21, 2018. Comments were subsequently received from GRMA member countries and these comments are taken into account in the updated Draft Final Report dated August 1, 2018. This updated report included new technical work on demand model calibration, updated project costings, revised economic and financial evaluations because of the changes in costs, and new work on environmental and social screening. Comments on this report were received on September 5, 2018 and were taken into account in this updated final version of the report.

### A. Objectives of the TA

The TA had four main objectives that were refined during the Inception Phase of the TA:

(i) Prepare updated studies for the 9 rail links;
(ii) Develop criteria to assess and further prioritize the rail links;
(iii) Identify potential financing modalities for the priority links; and
(iv) Identify actions needed to bring the priority rail links to transaction stage.

The resultant objectives were met by conducting a pre-feasibility level technical, economic and financial assessment of each of the 9 rail links.

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[1] Cambodia, Lao PDR, Myanmar, Thailand, Viet Nam and the provinces of Yunan and Guangzhi, People's Republic of China.
, make up the GMS. They are defined as 'localities' for the purposes of describing travel in this report.
[2]The GMS economic corridors are planned to link the subregion to major markets and are an expansion of key transport corridors; nodal points within the economic corridors will serve as centers for enterprise development.
[3] Consisting of the representatives of each railway body.

## B. Development Trends

### 1. Current Transport

The major transport network in the GMS currently consists of 37,000 kilometers of primary road, 17,000 kilometers of railways and 10,000 kilometers of waterways, each of which is used for both the movement of people and freight. Coastal shipping and airline services also exist. There are also extensive domestic, intra-regional and international airline services.

In 2015, it was estimated there were about 593,000 inter-locality person trips made daily[4]. Today, the dominant mode is bus that has almost a 50% market share of inter-locality person trips, followed by private vehicle with 28%, air with 13% and rail with 8% (mainly between Yunan and Guangzhi, PRC). Inland waterways and coastal shipping play a very minor role for inter-locality person movement. Rail is constrained at present by the missing cross-border rail connections and generally poor rail infrastructure in much of the GMS, with the exception of rail systems in the two provinces in the People's Republic of China (PRC) that are part of the GMS.

It is estimated there were 273,000 inter-locality freight tonne movements made per day in 2015. Trucks were estimated to carry 99.02% of total inter-locality freight while rail represented 0.94%. Inland waterways and coastal shipping represented the balance.

### 2. Current Development

In 2015, the GMS population was estimated at 341 million. Available data shows that the average population growth rate across all the localities was approximately 1% per annum from 1998 – 2014 with Lao PDR growing at about double the average rate. GDP growth across the seven localities over the same period has averaged 8.6% per annum. GDP per capita has grown at 7.7% per annum. Rates of population, GDP and GDP/capita growth have varied significantly by locality as shown in Section II.

### 3. Future Development

Key drivers of future passenger and freight travel demand are economic growth and population and demographic changes, with improved transport acting to facilitate the realization of an increasing demand for travel. The GMS' population is expected to grow to 438 million by 2050 growing by 28% from 2015. The distribution of the population by locality at 2050 is expected to remain similar to that in 2015.

By 2050, Yunan and Guangzhi are expected to account for 54% of total GDP in the GMS, almost a doubling from 2015. The other GMS localities are also projected to grow rapidly and together would represent the balance of 46% of the total subregional GDP at 2050. Average GDP per capita in the localities is projected to grow by 370% from 2015 to 2050.

## C. Review of the Missing Links and Potential Network Development

### 1. Technical and Cost Review

The available capital cost estimates for constructing the missing rail link projects were reviewed to check their reasonableness. Projects No. 4 on the PRC side, and all of Project No. 5, were

[4] Inter-locality trips are also by definition trips that travel across borders (i.e. cross-border trips) of the defined localities.

confirmed to be under construction at the beginning of the TA. Domestic rail lines connecting to the other missing rail link projects are generally old and in need of rehabilitation and upgrading to facilitate efficient railway operation. The potential costs of such additional work were included in the capital cost estimate for each missing link project.

The resultant capital cost estimates for each rail link are shown in Table S1. The estimates are broad and not based on detailed surveys or designs and instead are based on estimates sourced from feasibility studies (if available), checked against what were considered to be applicable per kilometer costs for the type of construction and types of facilities likely to be required. Actual costs following detailed design could be significantly higher.

Future cross-border railway operations are envisaged to make use of modern higher capacity and speed passenger and freight trains more along the lines of those used presently in the PRC. Investment in railway infrastructure and rolling stock must be complemented by 'soft' investment targeted at helping GMS railways to improve operating performance and asset management and to improve the capacity of governments to regulate railway operations. In this regard, the GRMA should consider developing a Railway Operational Readiness Plan that would set out key performance indicators and the activities critical to their achievement.

A critical aspect needing immediate attention is for the GRMA and the GMS member countries to decide (collectively or bi-laterally) whether entire trains will cross borders or whether they will be broken down, and re-constituted with different locomotives, at borders. Each option would require different train operations, border activities and regulatory institutions.

**Table S1: Summary of Capital Costs USD millions (indicative 2017 Prices)**

| Countries | Missing Links | Project | Capital Cost ($m) |
|---|---|---|---|
| CAM | Poipet - Border Bridge/Aranyaprathet | 1 | 632 |
| THA | Aranyaprathet - Klong Luk Bridge (Border Bridge with CAM) | | |
| CAM | Bat Doeung - Snoul (Loc Ninh) | 2[5] | 5,431 |
| VIE | Loc Ninh (Snoul) - Ho Chi Minh City | | |
| MYA | Dawei - (Banpunamron) | 3 | 5,500 |
| THA | Banpunamron – Kanchanaburi (to Laem Chabang) | | |
| MYA | Lashio - Muse (Ruili) | 4 | 1,941 |
| PRC | Ruili (Muse) - Baoshan | | |
| PRC | Mohan (Boten) - Yuxi | 5 | 5,968 (Lao PDR side) |
| LAO PDR | Vientiane - Luangprabang - Boten (Mohan) | | |
| LAO PDR | Vientiane - Thakhek - Mu Gia | 6 | 6,125 |
| VIE | Mu Gia - Vung Ang | | |

[5] A meeting of transport ministers of Viet Nam and Cambodia in February 2018, decided to change the alignment of link 2 to connect Phnom Penh and Ho Chi Minh City via Barvet in Cambodia rather than Snoul reducing the total length by about 140 km. The new alignment runs through sensitive environmental areas and will parallel the alignment of a proposed expressway. Functionally, link 2 as formulated originally and as investigated in this TA, and the new alignment would be expected to have a similar demand but a lower cost. The possibility of the lower cost was covered by the sensitivity testing in the economic and financial evaluations carried out in this TA. The environmental and social issues associated with the new alignment would need to be satisfactorily addressed.

| Countries | Missing Links | Project | Capital Cost ($m) |
|---|---|---|---|
| THA | Mukdahan - Savannakhet | 7 | 11,106 |
| LAO PDR | Thakhek - Savannakhet - Pakse - Vangtau (Chongmek) | | |
| THA | Ubonratchathani - Chongmek (Vangtau) | | |
| LAO PDR | Savannakhet - Lao Bao | | |
| VIE | Lao Bao - Dong Ha | | |
| LAO PDR | Pakse - Dong Kralor (Voun Kam) | 8 | 2,000 |
| CAM | Voun Kam (Dong Kralor) - Snoul | | |
| VIE | Lao Cai - Hekou | 9 | 654 |
| PRC | Hekou - Lao Cai | | |
| | | **Total (USD)** | **39,357 million** |

Source: TA team;
Note: Appendix A provides information on the associated rail upgrades included in the cost estimates.

### 2. Environmental and Social Issues

A high-level environmental and social screening of the rail missing link projects was undertaken based on available project reports and other information from ADB's mapping of environmental vulnerabilities in the GMS and associated economic and transport corridors. Specific comments on each of the rail missing links are provided in Table E.1 in Appendix E. Overall, the issues identified are all considered to be amenable to mitigation through careful project planning and management of implementation. A summary of the significant impacts is provided below.

1. **Biodiversity impacts.** Construction of the following links may have an impact on GMS biodiversity conservation initiatives.
   - No. 3. Dawei (MYA) - Ban Phu Nam Ron (THA)
   - No. 6. Vientiane - Thakhek (LAO) - Mu Gia - Vung An (VIE)
   - No 7. Thakhet-Pakse (Lao) – Savannakhet - Lao Bao - Dong Ha (LAO/VIE)
   - No 8. Pakse-Don Kralor (LAO) - Voun Kam-Snuol (CAM)

2. **Energy efficiency.** Studies undertaken by the International Energy Agency (IEA) and the International Union of Railways (UIC)[6] have shown the railway transportation is significantly more energy efficient when transporting large volumes of passengers or freight. Electrification of the railway links and associated lines should be considered where power supply is reliable.

3. **Re-settlement.** All of the developments, (including the rehabiliation of existing associated lines) will involve some degree of re-settlement. For safety and operational reasons, the right of way for new tracks should be (where practical) at least 50 meters either side of the track.

4. **Indigenous People.** Generally, construction of the missing links does not have a direct impact on a specific group of indigenous people – although there are indigenous people in each the project areas. The exception is link No. 4 between Lashio and Muse in

[6] The IEA estimates global averages for carbon intensity of passenger rail to be 30 - 60 gCO2eq/passenger-km (compared with 200 - 270 gCO2eq/passenger-km for air transport), and carbon intensity of freight rail to be 15 - 40 gCO2eq/tonne-km (compared with 190 - 300 gCO2eq/tonne-km for long distance trucking).

Myanmar, which would be constructed in Shan State where the Shan State Army (SSA) is actively opposing the Union of Myanmar's military forces. As well, extension of the Lashio-Mandalay railway line to Kyauk Phyu has been mooted since 2010. This would involve construction of the railway line through Rakine State, which is the home of the Rohingya people, and currently a conflict area.

### 3. Future Network Development

During the August 2017 working group meeting of GMS railway representatives, a consensus was reached on how the GMS railway network could be developed by 2025 (or soon after) taking into account ongoing and committed projects, projects that are of modest cost or with adequate demand and no identified special difficulties. Therefore, it was considered that projects 1, 2, 4, 5, 6 and 9 could be realized by 2025 assuming their viability would be supported by subsequent economic, financial, environmental and social assessments, noting that part of project 4 and all of project 5 are currently under construction. Projects 3, 7 and 8 were assumed to be able to be developed by 2050 (or after) subject to demonstrating adequate feasibility and political support.

## D. Future Railway Technology Needs

Major changes have occurred in railway operations and technology in the last 10 years. Many more changes can be expected through to 2050 and beyond. This section describes the main directions in railway operations and technology that should be included in a modernization program and the Railway Operational Readiness Plan. GMS railways will need investment in:

- Modern control systems and communications;
- New infrastructure – particularly electrification; and
- New locomotives and rolling stock.

Future train operations should be controlled by systems similar to the European Railway Traffic Management System. New intelligent systems will collect a massive amount of operational data ('big data'). By 2025 most passenger trains should be Diesel Multiple Units, or Electric Multiple Units if tracks are electrified

New railway lines in the PRC to its borders with Myanmar (Project 4), Lao PDR (Project 5), and Viet Nam (Project 9), have, or are being, electrified. Project 5 from the PRC/Lao PDR border to Vientiane will also be electrified. Decisions to electrify all or parts of the rest of the GMS network would alter both the scope and timing of investments. The higher capital cost of constructing electrified lines would be offset by lower operating costs, reduced energy use and greenhouse gas emissions, and cleaner air. A study on the cost and benefits of railway electrification in the GMS should be undertaken before too much investment is made in conventional railway tracks. At the same time, the potential for other new technologies should be considered including high speed trains on dedicated track and the new, emerging alternative technology known as Hyperloop, which could be up to three times as fast as high speed rail.

Freight trains will likely be longer and heavier. Tracks should be designed to accommodate as a minimum 25 tonne axle loads. Longer sidings (passing loops) of at least 1,000 meters will need to be constructed. The interoperability of railway systems is crucial to the development of a smooth and efficient GMS rail network and is a key factor in attracting investors. New railway technology and technical standards would need to be adopted by the GRMA.

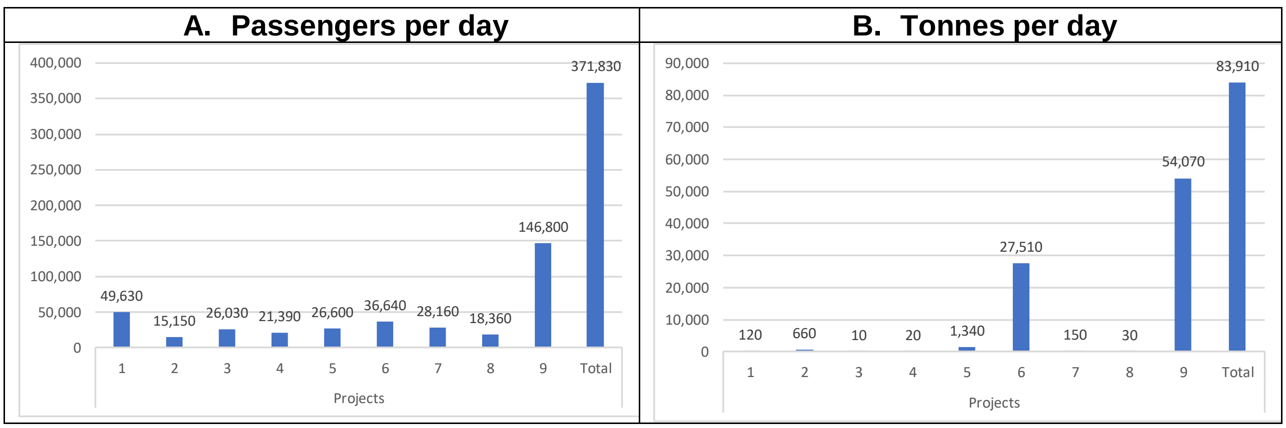
## E. Transport Demand Projections

A computerized, multi-modal transport demand model was developed within the TA to produce projections of future passenger and freight demand in the GMS. This model, the Mekong (Sub-) Regional Transport Model (MRTM), can produce projections of passenger and 5 categories of freight demand on a multi-modal basis[7]. A wide variety of projections for passengers and freight were made for 2025 and 2050.

### 1. Demand Projections for Individual Projects at 2050

Figure S.1A illustrates the projections of daily passenger demand at 2050 for each project individually[8]. At 2050, Projects 1 and 9 are projected to have the highest patronage demand at 147,000 and 50,000 passengers per day respectively. The demand for projects 2 to 8 is projected to vary from 15,000 to 37,000 passengers per day. Also by 2050, as shown in Figure S1B, Projects 9 and 6 are projected to have the highest freight demand at 54,000 and 28,000 tonnes per day respectively. The other projects are projected to have much lower freight demand. However, these projections of freight demand do not account for the possible future development of new mineral or other resource developments that could dramatically increase freight movements benefiting projects 4, 5 and 6 particularly.

**Figure S1: Projected Demand for the Missing Rail Links at 2050**




Source: TA team; demand shown is total passenger or freight trips per day i.e. the incremental inter-locality and other non inter-locality trips induced by each individual project compared to the base case at 2050.

[7] At present, the demand projections are provisional as more calibration of MRTM is required. Updated projections will be made as part of a proposed short extension of this TA described in Section H of this Executive Summary.

[8] However, the demand for projects 1 and 2 assume both are developed and mutually support each other.

### 2. Demand Projection for Integrated Rail Network Development at 2050

The effect of the development of comprehensive railway development in the GMS (i.e. with all missing link projects and high speed passenger rail connecting Hanoi to HCMC in Viet Nam) was examined. Passenger and freight demand projections were made for both the base case and the comprehensive railway improvement scenario at 2050. The projections indicated that the comprehensive railway network would increase rail demand in 2050 as follows:

- Rail passenger demand, as measured by person-kilometers, from 494 million in the base case to 602 million, an increase of 22%.
- Rail freight demand, as measured by rail tonne-kilometers, from 65 million in the base case to 97 million, an increase of 50%.

Significant congestion relief would be experienced on the road network.

## F. Prioritization of the Missing Rail Links

The main means of prioritization of the missing rail link projects was a strategic economic evaluation undertaken to the level of detail relevant for a pre-feasibility study. A strategic financial evaluation was also undertaken. The capital costs and estimated recurrent costs of each railway links together with the projections of demand were key inputs to both evaluations. Other criteria relating to potential social and environmental risks will be investigated at a later stage.

Using the demand projections for each missing link project, the economic evaluation quantified the whole-of-life costs and benefits of each project. It was found that projects 9 and 1 appear to have a strong economic justification for an opening year of 2025 due to their high demand and moderate capital costs. The other projects had a weaker economic justification at 2025, but for an opening year after 2040 most projects began to show economic rates of return in the range 3% to 5%, indicating emerging economic potential.

All projects were not considered to be financially viable, taking into account demand and other risks, if they were required to recover their initial investment via passenger and freight revenues (and savings in road maintenance cost).

Based mainly on the economic analysis, the priority project groupings are:

- ‘A’ being the highest priority – projects 9 and 1;
- ‘B’ being the second priority – projects 6 and 2; and
- ‘C’ representing the third or lowest priority – projects 3, 4 and 7 + 8.

  (Project 5 is currently under construction as is Project 4, on the PRC side, at present)

This three level grouping of priorities does not yet fully account for country attitudes although the March 2018 workshop and GRMA Board meeting provided relevant country perspectives.

## G. Analysis of Procurement Modalities

All of the missing link projects are highly vulnerable to a variety of risks including:

- Construction technical risk/ cost overrun and delay due to unexpected changes in project scope, construction difficulties;
- Land acquisition delay;
- Environmental and social safeguards not implemented adequately;
- Train capital costs – risk of poor value for money;
- Demand risk – long ramp-up[9] and a lower level of demand than anticipated;
- O&M cost higher than anticipated or revenues lower due to competition, higher operating costs than anticipated; and
- Risk of poor integration of different lines and slow progress with cross-border facilitation.

Consequently, a strong government role in financing infrastructure development, management of environmental and social safeguards, rail network management and regulation of rail operations would be important. However, there is good scope for involvement of the private sector or commercialized government corporations to supply trains, operate and maintain them and maintain rail track.

## H. Next Steps

Future work is desirable to: (i) establish the preferred organization structure of the GMRA; (ii) develop an operational readiness plan for GMRA; (iii) update the GMS railway strategy; and (iv) update the GMS transport demand model.

[9] This is the period during which potential demand (i.e. passengers and freight shipping companies) adjust to the provision of new services, their prices and quality. Experience shows this ramp-up period can take from 1 to 3 years, and sometimes longer.

# I. INTRODUCTION

## A. BACKGROUND

1. The Greater Mekong Subregion Economic Cooperation Program Strategic Framework, 2012–2022 stresses the importance of: (i) ensuring that all countries in the Greater Mekong Subregion (GMS) are connected to a GMS rail network by 2020, and (ii) promoting the development of a seamless rail network in the GMS as part of a regional cooperation strategy to facilitate cross-border infrastructure development.[10]

2. The Asian Development Bank (ADB) previously provided technical assistance (TA) to assess the requirements for regional rail connectivity and prepared the *Connecting Greater Mekong Subregion Railways: A Strategic Framework,* which was endorsed at the GMS ministerial meeting held in Ha Noi in August 2010.[11] These agreements laid the groundwork for regional rail development, along with the establishment of the Greater Mekong Railway Association (GMRA), whose membership includes all of the GMS countries. Refer to Box 1 for more information on the GRMA.

3. To create a regional rail network, it was considered necessary to develop new rail links to connect between the individual national railway systems. The GMS countries have therefore agreed upon nine priority rail links (i.e. the 'missing links') that when completed would enhance railway connectivity in the GMS.[12] The GMRA board endorsed the selection of the nine rail links for further study in 2015.[13]

4. This TA (TA 9123 – REG) is a direct response to the GMS member governments' request for ADB assistance to review the rail links and provide advice on their feasibility and investment opportunities. The status of these nine links and their proposed physical features are described in this report in Section III.

**Box 1: The Greater Mekong Railway Association**

The Greater Mekong Railway Association (GMRA) was initiated following the GMS Ministers' endorsement of the *Strategic Framework for Connecting the Subregion's Railways*. As agreed upon at the GMS Ministerial Meeting in Ha Noi in August 2010, the main purpose of the GMRA is to ensure that all GMS countries are connected to a rail system by 2020. The GMRA seeks to increase railway connectivity by promoting efficient, safe, and environmentally sustainable rail transport of goods and people with and beyond the subregion.

ADB is providing technical assistance that will define the scope and purpose of the GMRA, develop its long-term objectives and initial operation plan and to help formulate the organization's financial plan for the next 5 years. Three Working Groups (WGs) have been created to assist in the future sustainability of the organization: (i) Network Connectivity; (ii) Network Integration and Interoperability; and (iii) Partnerships and GMRA Operations.

[10] ADB. 2011. *Greater Mekong Subregion Economic Cooperation Program Strategic Framework, 2012–2022.* Manila. http://www.adb.org/sites/default/files/institutional-document/33422/files/gms-ec-framework-2012-2022.pdf

[11] ADB. 2010. *Technical Assistance Completion Report: Greater Mekong Subregion: Railway Strategy Study*. Manila (TA 7255 – REG); and ADB. 2010. *Connecting Greater Mekong Subregion Railways: A Strategic Framework.* Manila.

[12] The Lao People's Democratic Republic–Myanmar rail connection was deemed low priority as the expected demand between these two countries is limited and falls below the required demand levels for rail connections in the short to medium term.

[13] The GMRA agreed on the 9 rail links at the first general meeting of the GMRA on March 12, 2015 in Kunming, People's Republic of China.

5. The TA formally commenced with the meeting of the Working Group on Network Connectivity during November 8–9, 2016, in Bangkok. The Inception Phase of the TA took place from November 2016 to February 2017. Following the initial meeting of the Working Group in November 2016, country visits and consultations, as well as additional working groups meetings were held as follows:

**Consultation Meetings**

- Beijing, PRC (January 10 – 11, 2017) and Hanoi, Viet Nam (January 13, 2017); and
- Nay Pyi Taw, Myanmar (January 31, 2017); Bangkok, Thailand (February 1, 2017); Phnom Penh, Cambodia (February 2, 2017); and Vientiane, Lao PDR (February 6, 2017).

**Working Group Meetings**

- August 16 – 17, 2017, ADB Thailand Resident Office; and
- December 12, 2017, ADB Thailand Resident Office.

**GRMA Board of Directors General Meeting**

- March 22, Vientiane Lao PDR (and at working group meeting on March 21 also held in Vientiane).

The list of attendees at the meetings is shown in Appendix E.

6. The TA, and therefore the work described in this Final Report, was carried out in support of the Working Group on Network Connectivity also consisting of representatives of the individual national railway organizations.

## B. OBJECTIVES

7. The TA had four main objectives:[14]

(i) Prepare updated studies for the 9 rail links;
(ii) Develop criteria to assess and further prioritize the rail links;
(iii) Identify potential financing modalities for the priority links; and
(iv) Identify actions needed to bring the priority rail links to transaction stage.

8. The resultant objectives were met by conducting a pre-feasibility level technical, economic and financial assessment of each of the 9 rail links through:

- Objective (i) on the updated studies – determining investment costs and operations and maintenance (O&M) costs of each rail link, identifying a feasible sequence of network development, and assessing the passenger and freight demand through development of a computerized transport demand model;
- Objective (ii) on prioritization criteria – analyzing the economic and financial viability of each rail link or combination of links;

[14] The original objective (iv) set out in the TA Paper was described as “identify impacts of alternate scenarios for regional rail development”. During the Inception Phase of the TA it was considered that this objective would be best addressed as part of objective (ii), since it is only by considering network impacts that the most viable links can be adequately determined. The new fourth objective was then added that reflected the intention of the GRMA to have a sound understanding on what needs to be done to bring the priority links to fruition.

- Objective (iii) on financing modalities – identifying potential modalities and assessing how they address potential risks; and
- Objective (iv) on identifying actions to bring the priority links to transaction stage – identifying steps to confirm feasibility and implementation readiness.

9. The TA was therefore intended to add to the existing studies on alternate scenarios reflecting the network impacts of regional rail development as opposed to stand-alone rail links. The policy advice provided by the TA was intended to support the development of regional rail connectivity, in addition, and parallel, to the growth of national rail networks, to form a complete rail network in the region.

## C. ADB TEAM AND COORDINATION ARRANGEMENTS

10. The work done under this TA was performed by the ADB team and was supported by the following consultants:

- Philip Sayeg, International Railway Specialist and Team Leader, whose role was to assist coordination, undertake transport planning, and assess economic and financial feasibility, and prepare reports;
- Leonard Johnstone and Boonchuay Tongkam, Senior Modeling and Modeling Specialists respectively, who prepared a working transport model and future passenger and freight demand projections;
- Paul Power, Railway Specialist, who reviewed strategies to complete priority rail links, as well as to identify requirements for regional rail system development; and
- Pamela Nacpil, Senior Regional Project Coordination Specialist, who facilitated meetings and prepared meeting summaries and assisted to coordinate the TA's activities.

11. The individual railway organizations provided information and expert knowledge, key advice and peer review throughout the duration of the TA. The ADB team and the railway organizations met several times during the TA as indicated in paragraph 5 and were in regular contact using electronic means of communication.

12. A draft final report of the TA was issued on March 6, 2018 and the findings presented in Vientiane, Lao PDR, at the GRMA Board of Directors General Meeting held on March 22, 2018. Findings were also presented at a meeting of the Working Group meeting on March 21, 2018. Comments were subsequently received from GRMA member countries and these comments are taken into account in the updated Draft Final Report dated August 1, 2018. This updated report included new technical work on demand model calibration, updated project costings, revised economic and financial evaluations because of the changes in costs, and new work on environmental and social screening. Comments on this report were received on September 5, 2018 and were taken into account in this updated final version of the report.

## D. DEFINITIONS

13. All references to GDP and relevant parameters used for development of the demand model are based on constant 2010 US dollars. Otherwise, all costs and prices are expressed in mid 2017 constant prices.

# II. DEVELOPMENT TRENDS AND FUTURE DEVELOPMENT DRIVERS

## A. GMS CONNECTIVITY

### 1. Transport Network

14. The GMS as addressed in this TA includes the five countries of Cambodia, People's Republic of China (i.e. the southern provinces of Yunnan and Guangxi), Lao PDR, Myanmar, and Thailand. These individual administrative and geographic entities are also referred to as localities throughout this report.

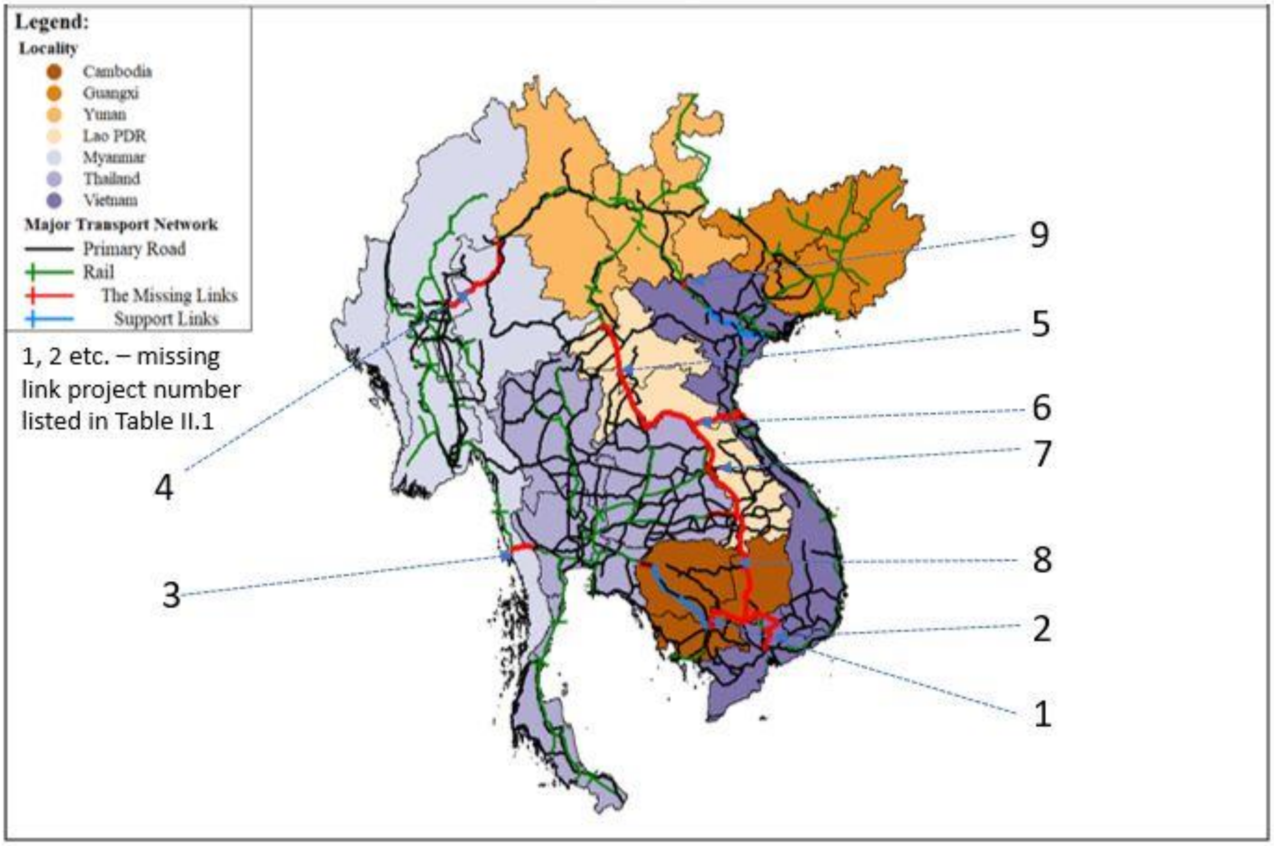
15. The extent of the current major transport network in the GMS is shown in Figure II.1. Currently, it consists of 37,000 kilometers of primary road, 17,000 kilometers of railways and 10,000 kilometers of waterways, each of which is used for both the movement of people and freight. Coastal shipping and airline services also exist. Waterways, coastal shipping and airline services are not shown in Figure II.1 to aid clarity.[15] These statistics were extracted from the multi-modal Mekong (Sub-) Regional Transport Model (MRTM) that was developed in this TA, that is described in Section V.

16. The MRTM's base case network includes details of all committed, planned and proposed transport projects that can improve inter-locality person and freight movements to 2050. Other scheduled improvements of the various domestic railway networks that are planned by individual countries and are independent of the missing links were also included in the future base case network. For example, the railway line from Chachoengsao, Thailand to the Cambodian border is assumed to be double tracked by 2025 as planned by the State Railways of Thailand's (SRT).

17. The rail corridors and the associated nine 'missing link' rail projects as agreed by the members of the GMRA (Table II.1) are illustrated in the figure on the page before the Executive Summary of this report. They are also indicated on Figure II.1 with necessary domestic railway upgrading as shown in blue in this figure. These domestic rail improvements are mainly needed to support Projects 2 and 9 that would not be well integrated into the whole railway network if developed as proposed.

[15] As shown in Section V, the MRTM permits the projection of freight and passenger demand in response to development of new rail links, other changes in the transport system and changes in regional development patterns. The MRTM is a major achievement but was not envisaged within the original design of the RETA. Currently, MRTM has been developed as a platform and framework to be developed further in future. Further details of the MRTM and the demand projections are presented in Section V.

**Figure II.1: The GMS Road and Rail Network**




Source: TA team and MRTM

**Table II.1: The Transport Corridors and 9 Missing Railway Links**

| Project Number | Country Links | Corridor | Missing links |
|---|---|---|---|
| 1 | Cambodia - Thailand | Kunming, Ha Noi, HCMC, Phnom Penh, Bangkok | CAM: Poipet - Border Bridge/Aranyaprathet |
| | | | THA: Aranyaprathet - Klong Luk Bridge (Border Bridge with CAM) |
| 2[16] | Cambodia – Viet Nam | Kunming, Ha Noi, HCMC, Phnom Penh, Bangkok | CAM: Bat Doeung - Snoul (Loc Ninh) |
| | | | VIE: Loc Ninh (Snoul) - Ho Chi Minh City |
| 3 | Myanmar – Thailand | Kunming, Mandalay, Mawlyaning, Yangon, Bangkok | MYA: Dawei - (Banpunamron) |
| | | | THA: Banpunamron - Kanchanaburi |
| 4 | Myanmar – China | Kunming, Mandalay, Mawlyaning, Yangon, Bangkok | MYA: Lashio - Muse (Ruili) |
| | | | CHI: Ruili (Muse) – Baoshan |
| 5 | Lao PDR – China | Kunming, Vientiane | LAO: Vientiane - Luangprabang - Boten (Mohan) |
| | | | CHI: Mohan (Boten) – Yuxi |

[16] A meeting of transport ministers of Viet Nam and Cambodia in February 2018, decided to change the alignment of link 2 to connect Phnom Penh and Ho Chi Minh City via Barvet in Cambodia rather than Snoul reducing the total length by about 140 km. The new alignment runs through sensitive environmental areas and will parallel the alignment of a proposed expressway. Functionally, link 2 as formulated originally and as investigated in this TA, and the new alignment would be expected to have a similar demand, but the link 2 investigated here would have a higher costThe possibility of the lower cost was covered by the sensitivity testing in the economic and financial evaluations carried out in this TA. The environmental and social issues associated with the new alignment would need to be satisfactorily addressed.

| Project Number | Country Links | Corridor | Missing links |
|---|---|---|---|
| 6 | Lao PDR – Viet Nam | Kunming, Ha Noi, Vung Ang, Thakek, Vientiane | LAO: Vientiane - Thakhek - Mu Gia |
| | | | VIE: Mu Gia - Vung Ang |
| 7 | Thailand - Lao PDR – Viet Nam | GMS East-West Corridor | THA: Mukdahan - Savannakhet |
| | | | LAO: Thakhek - Savannakhet - Pakse - Vangtau (Chongmek) |
| | | | THA: Ubonratchathani - Chongmek (Vangtau) |
| | | | LAO: Savannakhet - Lao Bao |
| | | | VIE: Lao Bao - Dong Ha |
| 8 | Lao PDR - Cambodia | Vientiane - Pakse - Phnom Penh | LAO: Pakse - Dong Kralor (Voun Kam) |
| | | | CAM: Voun Kam (Dong Kralor) - Snoul |
| 9 | Viet Nam – China | Kunming, Ha Noi, HCMC, Phnom Penh, Bangkok | VIE: Lao Cai – Hekou |
| | | | CHI: Hekou - Lao Cai |

Source: ADB project file

### 2. Current Travel and Land-Based Travel Times

18. In 2015, it is estimated that there were 593,000 inter-locality person trips made daily as shown in Table II.2[17]. There are high volumes of passenger trips generated by all localities but the two major generators are Thailand and Viet Nam closely followed by Yunnan, Guangxi and Cambodia. Today, the dominant mode is bus that was estimated to have almost a 50% market share of inter-locality person trips, followed by private vehicle with 28%, air with 13%, rail with 8%[18] and inland waterways 1.7%. Coastal shipping has a very minor role in passenger transport. Rail is constrained at present by the missing cross-border rail connections and generally poor rail infrastructure in much of the GMS.

**Table II.2: Daily Person Travel – Inter-locality in 2015[19]**

| Locality | Locality | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total |
| 1-Cambodia | - | 100 | 100 | 1,500 | 100 | 39,100 | 35,000 | 75,900 |
| 2-Guangxi, PRC | 100 | - | 67,900 | 300 | 100 | 400 | 30,000 | 98,800 |
| 3-Yunnan, PRC | 100 | 68,000 | - | 1,600 | 8,000 | 1,700 | 11,000 | 90,400 |
| 4-Lao PDR | 1,600 | 300 | 1,500 | - | 500 | 32,200 | 13,000 | 49,100 |
| 5-Myanmar | 100 | 100 | 8,100 | 600 | - | 23,900 | - | 32,800 |
| 6-Thailand | 39,100 | 400 | 1,600 | 32,100 | 23,600 | - | 29,000 | 125,800 |
| 7-Viet Nam | 35,000 | 30,400 | 11,800 | 13,300 | 100 | 29,700 | - | 120,300 |
| **Total** | 76,000 | 99,300 | 91,000 | 49,400 | 32,400 | 127,000 | 118,000 | 593,100 |

Source: TA team and MRTM

19. MRTM estimates that in 2015 there were 273,000 inter-locality freight tonne movements per day with more than 41% generated by Thailand with another 25% generated by Viet Nam, as shown in Table II.3. Trucks were estimated to carry 99.02% of total inter-locality freight while rail represented 0.94%. Inland waterways and coastal shipping represented the balance.

[17] Inter-locality trips are also by definition trips that travel across borders (i.e. cross-border trips). The factor of 365 is assumed for converting daily person and freight trips to an annual basis.
[18] The majority of inter-locality trips by rail are between the two PRC provinces.
[19] This table does not include the movement to external locations i.e. those area located outside the area defined as the GMS for the purposes of this TA.

**Table II.3: Daily Tonnes – Inter-locality Movements in 2015**

| Locality | Locality | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total |
| 1-Cambodia | - | 5,700 | 5,200 | 100 | 800 | 400 | 3,300 | 15,500 |
| 2-Guangxi, PRC | 300 | - | 7,800 | 200 | 1,400 | 500 | 5,800 | 16,000 |
| 3-Yunnan, PRC | 200 | 10,900 | - | 400 | 1,900 | 400 | 6,900 | 20,700 |
| 4-Lao PDR | 100 | 200 | 2,800 | - | 100 | 300 | 1,400 | 4,900 |
| 5-Myanmar | 1,300 | 3,400 | 5,400 | 200 | - | 2,200 | 22,100 | 34,600 |
| 6-Thailand | 21,300 | 1,000 | 900 | 8,000 | 15,000 | - | 66,200 | 112,400 |
| 7-Viet Nam | 5,200 | 6,600 | 10,800 | 1,100 | 3,300 | 41,900 | - | 68,900 |
| **Total** | 28,400 | 27,800 | 32,900 | 10,000 | 22,500 | 45,700 | 105,700 | 273,000 |

Source: TA team and MRTM

20. Currently, car, bus and truck are estimated to have average travel speeds of 56 kph, 54 kph and 50 kph respectively. These average speeds include normal stops but exclude times for border crossings and associated immigration and customs procedures. The estimated travel times for representative corridors are shown in Table II.4.

**Table II.4: Current Travel Times (hours) by Road**

| Corridor | Distance (km) | Travel Time (hours) by Mode | | |
|---|---|---|---|---|
| | | Car | Bus | Truck |
| Kunming, Ha Noi, HCMC, Phnom Penh, Bangkok | 3,546 | 52.2 | 54.6 | 57.0 |
| Kunming, Mandalay, Mawlyaning, Yangon, Bangkok | 2,256 | 38.3 | 40.1 | 41.8 |
| Kunming, Vientiane | 1,470 | 24.6 | 25.7 | 26.8 |
| Kunming, Ha Noi, Vung Ang, Thakek, Vientiane | 1,929 | 30.2 | 31.6 | 33.0 |
| GMS East-West Corridor | 1,125 | 20.7 | 21.6 | 22.5 |
| Vientiane - Pakse - Phnom Penh | 1,270 | 22.3 | 23.4 | 24.4 |

Source: TA team and MRTM

## B. CURRENT DEVELOPMENT PATTERNS

21. The current development patterns within the GMS have been influenced by past economic and demographic change in combination with the development of transport and other infrastructure. The subregion’s population was estimated to be 341 million at 2015. The average population growth rate across all the localities was approximately 1% per annum from 1998 to 2014 with Lao PDR growing at about double the average rate as shown in Table II.5.

22. Figure II.2 indicates the current distribution of the population by locality in 2015. Viet Nam had the highest population encompassing 28% of the total GMS population in 2015. Together, the two PRC provinces also accounted for 28% of the total GMS population. Thailand and Myanmar both accounted for about 19% of the total GMS population. Cambodia and Lao PDR together represented the balance of 6% of the total population. The relative population

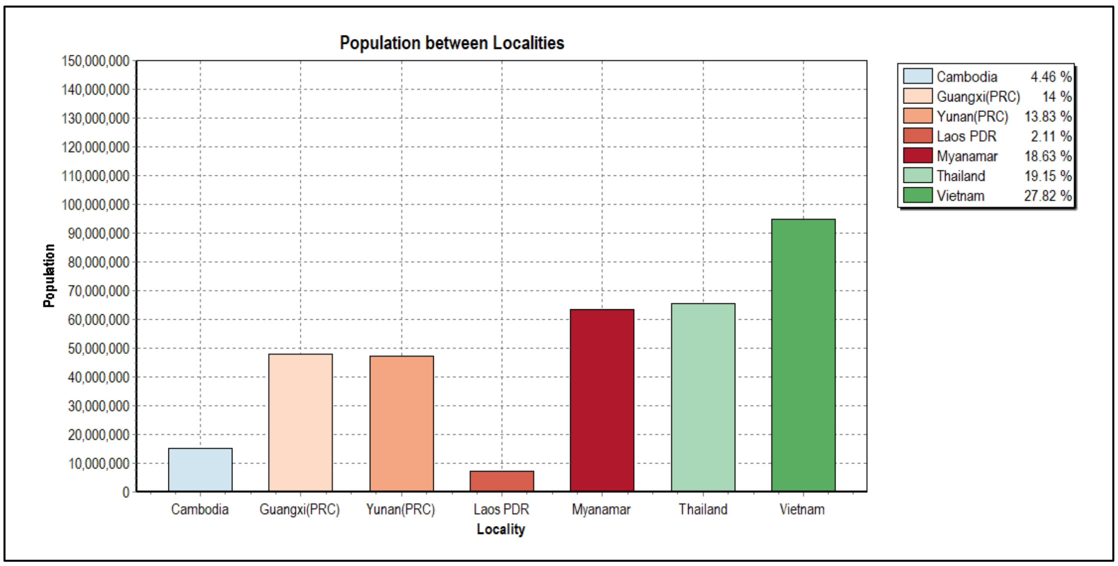
distribution for these localities at 2050 is projected to remain similar to the present day as described below.

**Table II.5: GMS Key Statistics**

| Locality | Growth per annum 1998 – 2014 | | |
|---|---|---|---|
| | GDP | Population | GDP per Capita |
| Cambodia | 10.1% | 1.4% | 8.5% |
| Guangxi, PRC | 12.4% | 0.1% | 12.3% |
| Yunnan, PRC | 11.3% | 0.9% | 10.4% |
| Lao PDR | 9.7% | 2.1% | 7.5% |
| Myanmar | 13.4% | 0.8% | 12.4% |
| Thailand | 6.3% | 0.7% | 5.6% |
| Viet Nam | 8.6% | 1.1% | 7.3% |
| **Total** | **8.6%** | **0.8%** | **7.7%** |

Source: Greater Mekong Subregion Statistics on Growth, Infrastructure, and Trade Second Edition, August 2016

**Figure II.2: Existing GMS Population Distribution by Locality in 2015**




Source: GMS Statistics on Growth, Infrastructure, and Trade Second Edition, August 2016.

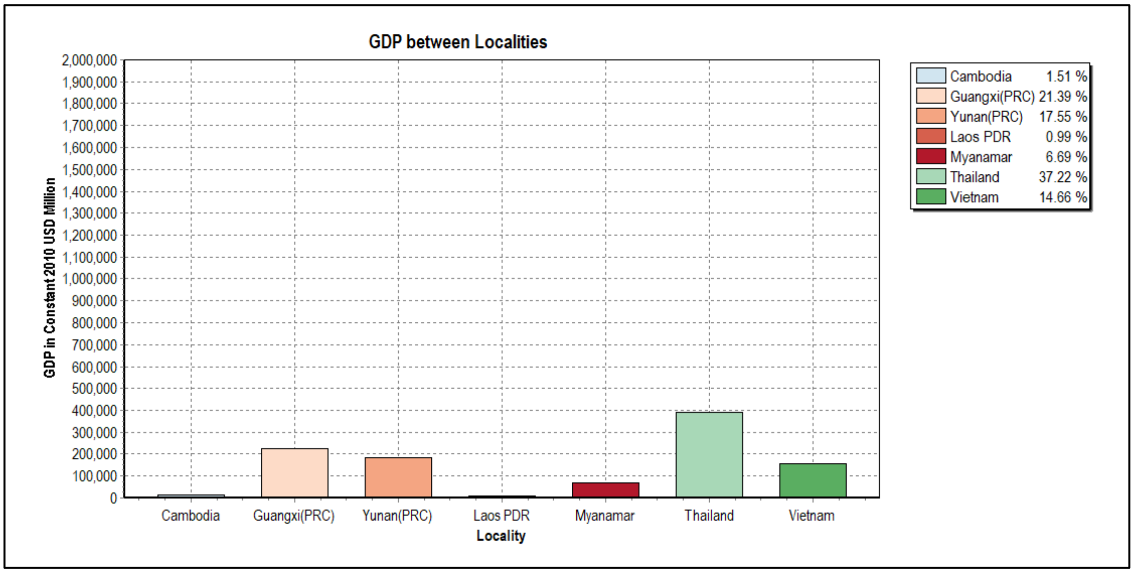
23. Economic growth in the seven localities from 1998 – 2014 has averaged 8.6% per annum as shown in Table II.5. Rates of growth among the localities have varied significantly. Guangxi and Yunnan and Cambodia and Myanmar have experienced GDP growth rates in excess of 10% per annum over 1998 – 2014[20]. Myanmar's higher GDP growth rate of 13.4% per annum is also a direct result of its lower starting base.

24. Taken together, the two Chinese provinces represented 39% of the GMS GDP in 2015 slightly higher than for Thailand that accounted for 37% of total GDP as shown in Figure II.3 The relative economic significance of the two Chinese provinces is projected to increase in future relative to Thailand. This is because Thailand's economic growth has moderated as it graduated to a middle-income country in 2011. Viet Nam represented 15% of the GMS GDP and the other three localities the balance of 9% at 2015. GDP per capita has grown most strongly in

[20] The Gross Domestic Product (GDP) is estimated in constant US Dollars in the base year of 2010 at market prices.

Myanmar, Guangxi and Yunnan while the lowest growth in GDP per capita was reported in Thailand.

**Figure II.3: Existing GMS GDP Distribution by Locality in 2015**




Source: World Bank, World Development Indicators, 2017

25. At present, significant inter-locality passenger and freight movements in the GMS are limited. However, with planned improvements in rail and other transport infrastructure, and further trade facilitation, the demand for inter-locality movements can be expected to increase greatly, as illustrated in the following sections.

## C. FUTURE DEVELOPMENT DRIVERS

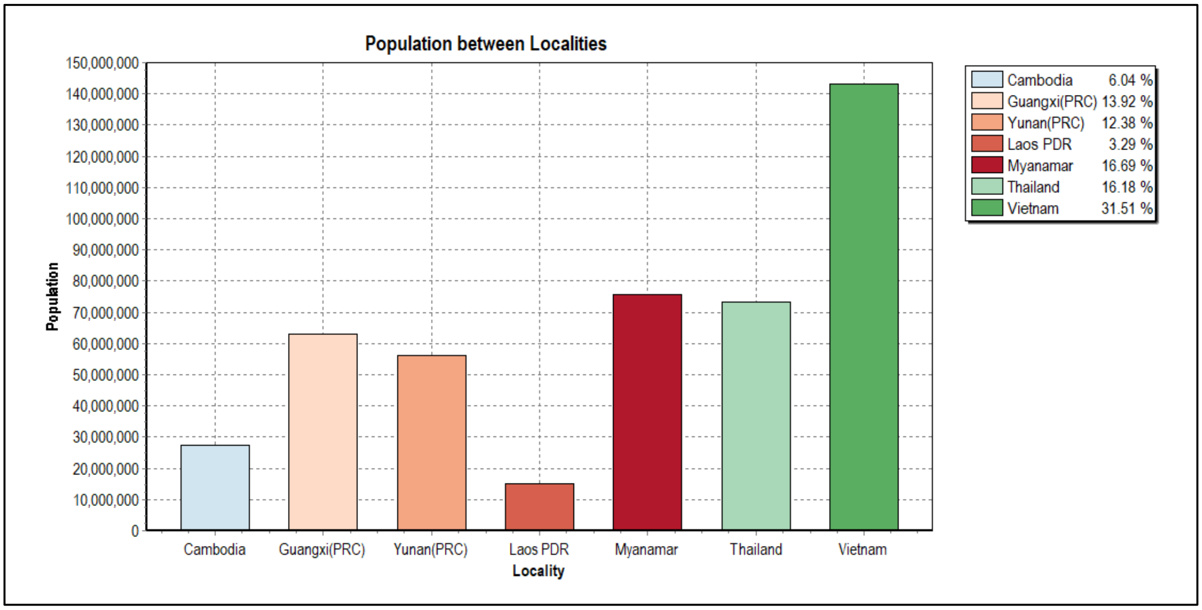
26. Key drivers of passenger and freight travel demand are economic growth and population and demographic changes, with improved transport acting to facilitate the realization of an increasing demand for travel. The subregion is projected to grow to 438 million by 2050. The dominance of the two Chinese localities is projected to continue into the future. As shown above, together they currently represent 28% of the GMS population and 39% of the GMS GDP. Through to 2050, it is projected they will continue to account for about 28% of the GMS population as shown in Figure II.4.[21] Their share of the total GMS GDP is projected to almost double to 54%, as shown in Figure II.5. The other GMS localities are also projected to grow rapidly and represent 46% of subregional GDP at 2050. The projections of future sub-regional GDP by locality are based on the growth rates shown in Table II.6.

27. Considerable growth in average GDP per capita in the localities is projected in future as shown in Table II.7 – at 5.3% p.a. from 2015 – 2025 and 4.2% p.a. from 2025 – 2050. Myanmar is projected to have the highest growth in per capita GDP in the later time horizon of 2015 – 2050 while the other economies are expected to exhibit more subdued growth due to their increasing maturity over the same time period. Thailand's GDP per capita growth is projected to average around 3% p.a. to 2050.

[21] The future economic and population projections are based on trend data except for Thailand, Myanmar and Vietnam. In these three localities, the economic and population projections were derived from the national transport databases.

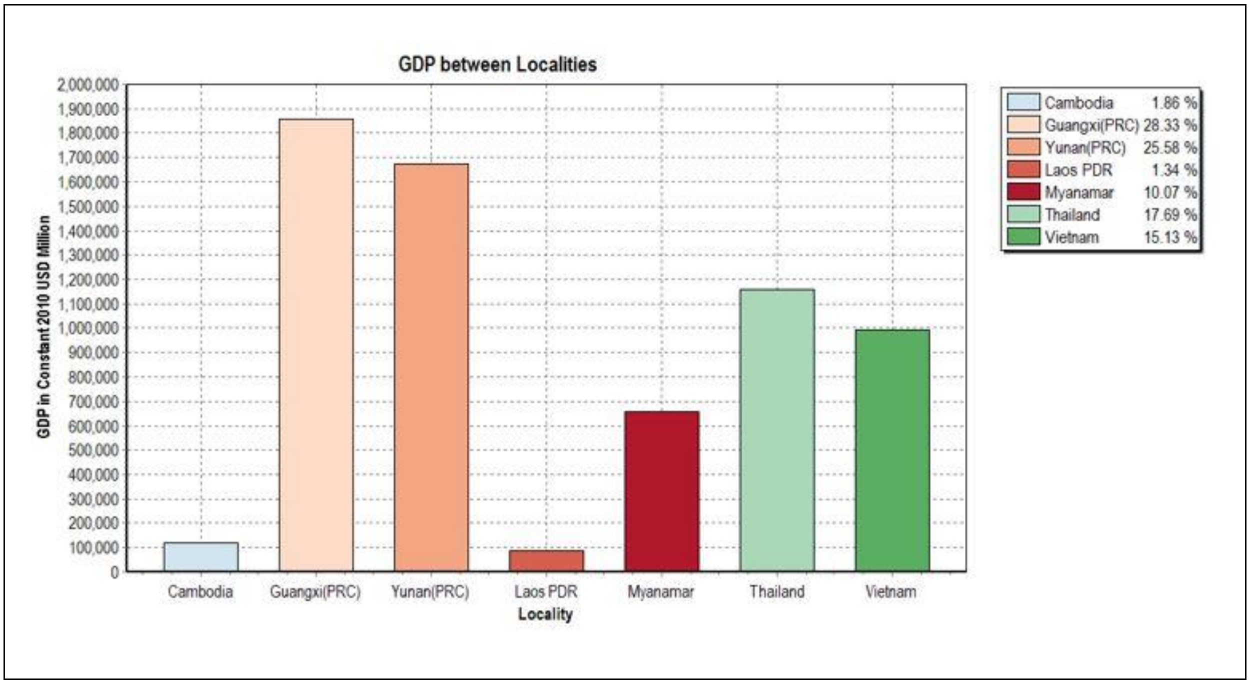
28. The projections of population, GDP and GDP per capita by locality to 2050 were key inputs to the MRTM to support the preparation of the passenger and freight demand projections for 2025 and 2050 that are provided in Section V.

**Figure II.4: GMS Population Distribution by Locality in 2050**




Source: TA team and MRTM

**Figure II.5: GMS GDP Distribution by Locality in 2050**




Source: TA team and MRTM

**Table II.6: Annual GDP Growth Rate 2015-2050**

| Locality | 2015-2025 | 2025-2050 |
|---|---|---|
| Cambodia | 7.2% | 5.5% |
| Guangxi, PRC | 7.7% | 5.6% |
| Yunnan, PRC | 8.4% | 5.7% |
| Lao PDR | 7.9% | 5.7% |
| Myanmar | 8.4% | 5.9% |
| Thailand | 3.3% | 3.1% |
| Viet Nam | 6.1% | 5.2% |
| **Total** | **6.2%** | **5.0%** |

Source: TA team and MRTM

**Table II.7: Annual GDP Growth Rate per Capita 2015-2050**

| Locality | 2015-2025 | 2025-2050 |
|---|---|---|
| Cambodia | 5.4% | 3.7% |
| Guangxi, PRC | 6.8% | 4.8% |
| Yunnan, PRC | 7.9% | 5.2% |
| Lao PDR | 5.7% | 3.5% |
| Myanmar | 5.7% | 5.5% |
| Thailand | 3.5% | 2.7% |
| Viet Nam | 4.5% | 4.0% |
| **Total** | **5.3%** | **4.2%** |

Source: TA team and MRTM

# III. REVIEW OF THE MISSING LINKS AND POTENTIAL NETWORK DEVELOPMENT

## A. CAPITAL COST

29. Table II.1 lists the 9 missing railway links in the GMS. The available capital cost estimates for constructing these links were reviewed to check their reasonableness. The links connect to various national railway systems that are generally old and need to be modernized. The exceptions are the railway lines in Yunnan and Guangxi, PRC that are quite modern. Consequently, all the missing link projects excluding Projects No. 4 on the PRC side, and all of Project No. 5[22], that are under construction also need associated capital investment for upgrading and/or rehabilitating sections of the adjoining domestic railway lines to facilitate their efficient operation. The capital cost review used the assumptions set out in Table III.1.

**Table III.1: Assumptions for Capital Cost Review**

The parameters and assumptions used for estimating the capital costs and maintenance requirements were:

| | |
|---|---|
| Track construction | Standard gauge[23], single track, 20-ton axle load, design speed 120 km per hr passenger, 80 km per hr freight and Automatic Block Signaling: USD 5 million per km |
| Stations | 1 in every 10 km, USD 0.5 million each |
| Bridges | USD 7.5 million per km |
| EDI systems | USD 1.0 million, each side of border |
| Major bridges / tunnels | Estimates, sourced from available studies/reports |
| Track rehabilitation/upgrading | USD 1.5 million per kilometer |
| Border infrastructure | USD 1.0 million, each side of border. USD 2.5 million where a gauge change is required |
| Project 2: CAM (Bat Doeung-Snoul) | 2 Bridges across Mekong: USD 300 million |
| Project 4: MYA (Lashio-Muse) | Bridges and tunnels: USD 200 million |
| Project 5: LAO (Vientiane-Luang Prabang-Boten) | Extensive tunneling: USD 3.5 billion |

Note that these are broad estimates and are not based on detailed site/quantity surveys. Land acquisition costs are not included.

Source: TA team

30. Table III.2 summarizes the available capital cost information after the TA's technical review. Where relevant, the cost of associated domestic upgrading has been included. Further details are shown in Appendix A.[24]

## B. TRACK GAUGE

31. Track gauge differences will need to be resolved at the links between China and Myanmar and between China and Viet Nam. Engineering solutions, such as dual gauge (3rd rail), variable bogies (wheelsets) and various transshipment facilities have developed to the

[22] At the beginning of the TA, it was confirmed that the Lao PDR side of Project No. 5 was under construction.
[23] Or meter (1000 mm) gauge track on standard gauge platform.
[24] Costs for projects 3 and 7 & 8 (these two need to be developed together) were based on existing studies with the resultant capital costs shown in this Section. These projects are unlikely to be feasible before 2050. Consequently, a capital cost review was not undertaken in this TA.

point where gauge change is no longer a significant issue at railway border crossings. The 'barriers' to efficient cross border railway transportation are institutional rather than physical[25]. Without specific interventions, but moderately efficient operations at borders, transshipment times of 5 hours for freight and 3 hours for passengers are expected. Instead, times should be reduced to 1 hour for freight and to 30 minutes for passenger transit by 2025.

**Table III.2: Summary of Capital Costs USD millions (indicative 2017 Prices)**

| Countries | Missing Links | Project | Capital Cost ($m) |
|---|---|---|---|
| CAM | Poipet - Border Bridge/Aranyaprathet | 1 | 632 |
| THA | Aranyaprathet - Klong Luk Bridge (Border Bridge with CAM) | | |
| CAM | Bat Doeung - Snoul (Loc Ninh) | 2 | 5,431 |
| VIE | Loc Ninh (Snoul) - Ho Chi Minh City | | |
| MYA | Dawei - (Banpunamron) | 3 | 5,500 |
| THA | Banpunamron – Kanchanaburi (to Laem Chabang) | | |
| MYA | Lashio - Muse (Ruili) | 4 | 1,941 |
| PRC | Ruili (Muse) - Baoshan | | |
| PRC | Mohan (Boten) - Yuxi | 5 | 5,968 (Lao PDR side) |
| LAO PDR | Vientiane - Luangprabang - Boten (Mohan) | | |
| LAO PDR | Vientiane - Thakhek - Mu Gia | 6 | 6,125 |
| VIE | Mu Gia - Vung Ang | | |
| THA | Mukdahan - Savannakhet | 7 | 11,106 |
| LAO PDR | Thakhek - Savannakhet - Pakse - Vangtau (Chongmek) | | |
| THA | Ubonratchathani - Chongmek (Vangtau) | | |
| LAO PDR | Savannakhet - Lao Bao | | |
| VIE | Lao Bao - Dong Ha | | |
| LAO PDR | Pakse - Dong Kralor (Voun Kam) | 8 | 2,000 |
| CAM | Voun Kam (Dong Kralor) - Snoul | | |
| VIE | Lao Cai - Hekou | 9 | 654 |
| PRC | Hekou - Lao Cai | | |
| | | **Total (USD)** | **39,357 million** |

Notes:

Project 5 in Lao PDR and PRC under construction.
Project 4 in Myanmar under discussion; cost estimate is for single track Muse-Mandalay only; China side under construction.
Project 3 costs from 2015 Feasibility Study "The Feasibility Study of Rail Link Project Between Laem Chabang Port - Dawei Deep Sea Port" by TEAM consultants et. Al 2015, commissioned by SRT.
Project 8 costs from project database.
Project 9 assumes some upgrading between Lao Cai and Hanoi.
Land acquisition costs not included

Source: TA team based on capital cost review in June 2018

[25] A "Framework Agreement for Cross Border Railway Transport Connectivity in the GMS" is being developed in TA-8748 REG and will address institutional issues affecting cross border railway transportation.

## C. ROLLINGSTOCK

32. Most of the locomotives and rolling stock in the GMS (excluding those in China) are over 30 years old and should be replaced. This would increase the total investment required to implement operations on the project lines. For the purposes of the economic and financial evaluations, the capital costs of rollingstock were adopted as shown below[26]:

Cost per locomotive: $3 million
Cost per freight wagon: $80,000
Cost per coach: $700,000

## D. GMS TRAIN OPERATIONS

33. As 2025 approaches, GMS train operations and asset management will need to improve so that performance becomes more consistent throughout the subregion. There is a wide gap between railway performance in China and that of other GMS railways as indicated in Table III.3 below. Future cross-border railway operations are envisaged to make use of modern higher capacity and speed passenger and freight trains more along the lines of those used in China.

34. Investment in railway infrastructure and rolling stock must be complemented by 'soft' investment targeted at helping GMS railways to improve operating performance and asset management. Such investment would also assist to improve the capacity of governments to regulate and manage railway operations. The GMS will need to agree on targets for the key railway performance indicators (KPI) that can be realistically achieved.

**Table III.3: Productivity of China Railways and GMS Railways (circa 2015)**

| Net tonne-km per: | China | Myanmar | Thailand | Viet Nam |
|---|---|---|---|---|
| • Locomotive | 114.9 | 16.13 | 34.76 | 26.48 |
| • Wagon | 4.9 | 0.32 | 0.49 | 0.88 |
| • Full time employee | 9.8 | 0.20 | 2.04 | 0.19 |
| Average train payload (tonnes) | 2,000 | 400-800 | | |

Source: Rail statistics from Thailand, Cambodia and Viet Nam railway bodies and China Railway Yearbook

35. In this regard, the GRMA's member railway bodies should give consideration to developing a Railway Operational Readiness Plan (ORP) that would set out agreed time-based Key Performance Indicators and supporting activities that are critical to their achievement. The scope of an ORP would cover such aspects as:

- Train operations;
- Cross border railway operations;
- Cross border non-rail operations;
- Asset status (inventory and condition);
- Technical Specifications for Interoperability (TSI);
- Automation of data exchange/interchange;
- Railway safety and operating regulation; and
- Linkage to capital investment programs.

[26] These costs are conservative and could be as much as 20-40% higher.

36. A critical aspect needing immediate attention is for the GRMA's railway bodies to decide (collectively or bi-laterally) whether entire trains will cross borders or whether they will be broken down, and re-constituted with different locomotives, at borders. Each option will require different train operations, border activities and regulatory institutions. In addition, TSI related to locomotives is more complicated than TSI for wagons and coaches. If the objective is to minimize the time spent at borders crossings for passengers and freight then cross border trains is the better, but more complex, option. Because of its complexity, it may not be possible to introduce cross-border trains in the GMS by 2025. In the meantime, the time spent crossing borders will need to be monitored. It is important that the GRMA obtain good information on border crossing times. The Central Asia Regional Economic Cooperation (CAREC) Program has developed a good model that could be adapted for monitoring improvements in GMS cross-border operations.[27]

## E. OPERATING COST PARAMETERS

37. Freight and passenger trains in China run at higher average speeds and freight trains are longer and heavier (more wagons per train). In contrast, trains in the other GMS countries are slower and freight trains carry lower payloads. Trains in all other GMS countries are costlier to operate than in China. For the purposes of the economic and financial evaluation described in Section VI the operation and maintenance costs of current future passenger and freight train operations were estimated (refer Appendix B). These estimates of recurrent costs are expressed in financial terms, but for the economic evaluation were converted to an estimate of economic costs. Due to the strategic nature of the subsequent economic and financial evaluation, they include initial capital costs of rollingstock and their mid-life refurbishment and maintenance costs.

## F. FUTURE NETWORK DEVELOPMENT

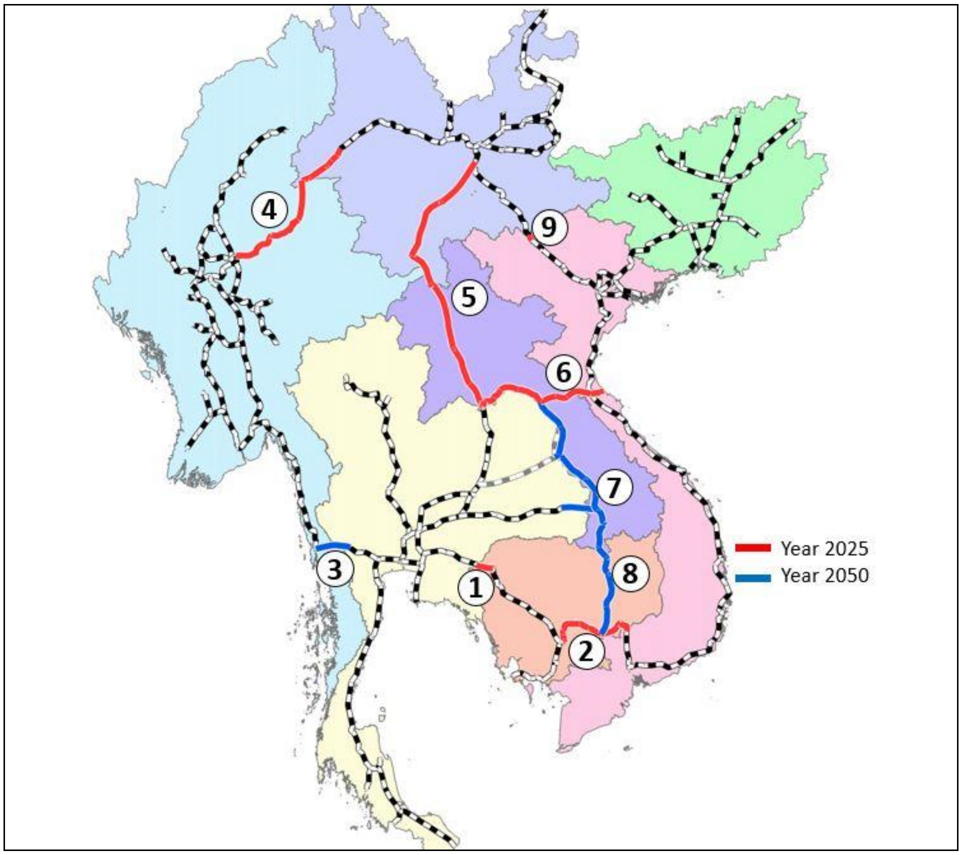
38. During the August 2017 meeting of GMS railway representatives, a consensus was reached on what the GMS railway network could be like at 2025 (or soon after) taking into account ongoing/committed projects, projects that are of modest cost and/or adequate demand with no identified special difficulties. It was considered that six missing link projects could be realized by 2025 assuming their viability would be supported by subsequent economic, financial and environmental and social assessments. They are projects: 1, 2, 4, 5, 6 and 9. Projects 3, 7 and 8 that were not identified for 2025 (or soon after), were assumed to be able to be developed by 2050[28].

39. Consequently, the potential staging of the network that could be realized by 2025 and 2050 is illustrated in Figure III.1. This network was used as an input to the future transport demand assessment described in Section V.

[27] See ADB 2014. *Central Asian Regional Economic Cooperation Performance Measurement and Monitoring: A Forward Looking Perspective.*

[28] The east-west part of Project 7, connecting between Savannakhet/ Lao Bao, Lao PDR and Dong Ha, Vietnam, a military sea port, has been proposed to form a part of the GMS East-West economic corridor as shown in Figure III.2. However, it in fact duplicates the east-west connection between Vientiane, Lao PDR and Vung Ang port, in Viet Nam, a more major sea port than Dong Ha, that is located 195 km to the north of Vung Ang. The Viet Nam railway representative and other railway representatives present at the workshop in August 2017 were supportive of project 6 in the period to 2050, but not of the east-west part of project 7, that is therefore not shown in Figure III.1.

**Figure III.1: Potential Sequence of Missing Rail Link Development**




Source: August 2017 workshop

40. Also relevant are whether these railway links form part of the current vision for the GMS economic corridors that are shown in Figure III.2. Table III.4 describes whether the railway links are part of an economic corridor and if not, they would have been assumed to be part of a transport corridor. An economic corridor is assumed to have the potential for more freight and passenger demand. The latest definition of economic corridors shown in Figure III.2 indicates that all projects lie in economic corridors.

**Table III.4: Mapping of Railway Links to Economic Corridors**

| Corridor | Economic Corridor |
|---|---|
| 1 | Yes |
| 2 | Yes |
| 3 | Yes |
| 4 | Yes |
| 5 | Yes |
| 6 | Yes |
| 7 | Yes |
| 8 | Yes |
| 9 | Yes |

Source: TA team

**Figure III.2: Overlay of the GMS Economic Corridors on the GMS Corridor Network**


Source: ADB 2018, *Review of Configuration of The Greater Mekong Subregion Economic Corridors.*

# IV. FUTURE RAILWAY TECHNOLOGY NEEDS

## A. KEY TECHNOLOGIES AND STANDARDS

41. As indicated in the previous section, railway operations in the GMS need to be improved and modernized if an efficient regional railway network is to be realized. Major changes have occurred in railway operations and technology in the last 10 years. Many more developments in railway technologies can be expected in future and it would be wise for the GRMA to anticipate, and plan for them. This section describes the main directions in railway operations and technology that should be included in a modernization program or in the Railway Operational Readiness Plan (ORP). Investments to be made in the GMS requires, to a large extent, catching-up with China and other countries. Table IV.1 below summarizes the main trends in developments in railway operations and technology that the GMS railways will eventually need to adopt.

**Table IV.1: Trends in Railway Technology Development**

| Component | Progressive Development of Standards by 2025 | Benefits |
|---|---|---|
| Command, Control Communications | Predictive & operational train control (ERTMS/ETCS, PTC) | Increased network capacity and safety |
| | High-bandwidth telecoms, high capacity voice & data communications (GSM-R) | Lower capital costs for signaling |
| | In-cab signaling (track/cab communications replacing line signals) | Less manual intervention |
| | Automated train operation | Remote safety management |
| | Intelligent and automated traffic management systems | Safety improvements and energy/fuel savings |
| | Automated data collection and data sharing | Freight and passenger train management, automated MIS |
| Infrastructure | Electrification (25Kv) | Low carbon operations<br>Energy savings |
| | Automated condition assessment – lasers / circuitry | Predictive maintenance lowers whole-life maintenance costs |
| | Resilient construction materials | Longer track life. Heavier freight trains |
| | "Slab" track replaces ballasted track | Lower construction costs and construction time |
| Locomotives and Rolling Stock | Multi-fuel (hydrogen, Liquid Petroleum Gas) energy efficient engines | Low carbon operations, energy maximization |
| | Automated condition assessment – wheel/track interface | Predictive maintenance lowers whole-life maintenance costs |
| | Multiple units for passenger trains (DMU/EMU) | Lower operating cost |
| | Energy recoverable braking systems (recuperative) | Operating efficiencies<br>Energy savings |
| | Automatic coupling systems | |
| | Variable bogies | Faster than changing bogies |
| | Lighter construction materials for wagons | Energy maximization |
| | “Smart” rolling stock – automated reporting and performance monitoring | Operating efficiencies |

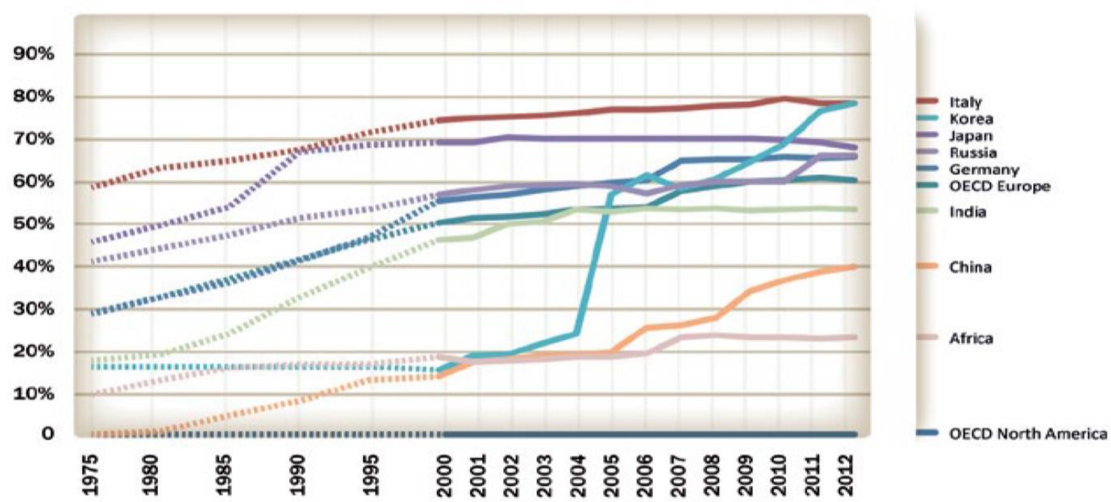
Source: TA team

## B. KEY THEMES

### 1. Electrification

42. Electrification is a major trend in railway development worldwide as shown in Figure IV.1 and is a cornerstone of the International Union of Railways' (UIC) 'zero carbon' initiative.[29] The higher capital cost of constructing electrified lines is offset by lower traction (locomotive) operating costs, less energy use and cleaner air. New railway lines in China to its borders with Myanmar (Project 4), Lao PDR (Project 5), and Viet Nam (Project 9), have or are being electrified. Project 5 from the China/Lao PDR border to Vientiane will also be electrified. However, there are no other plans for electrification of national and regional railway routes elsewhere in the GMS.[30] Decisions to electrify all or parts of the rest of the GMS network would alter both the scope and timing of investments. A study on the cost and benefits of railway electrification in the GMS should be undertaken before too much investment is made in conventional railway tracks.

**Figure IV.1: Railway Electrification Trend in Europe, India, China, Africa & North America**




Source: Elaboration by IEA based on UIC (2014a)

### 2. Digitalization

43. Numerous reports in railway journals and magazines signal the arrival of the 'digital railway'. The focus of digitalization was initially on automating the collection and sharing of operating data. The focus has extended into automating the control of train operations, to the communication of real time information on operations and asset condition, and on improving a passenger's travel experience through applications such as automated ticketing and Wi-Fi. Unfortunately, most of these developments are not present nor are they applied in national railways in the GMS, except for China. However, many of the new systems are built into urban

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[29] UIC 2014 and 2015. *Railway Handbook, 2015* and *Zero Carbon Railways*, Final Report. The latter states "Diesel trains are characterized by higher energy use, which can imply energy-related expenditures that are nearly twice as high as those of electric alternatives. Consequently, the electrification of both existing and new lines should be prioritized".

[30] Excluding high speed railway lines, urban light railways and metros.

rail systems and metro operations in Thailand, and those being constructed in Viet Nam, and could be adapted to other train operations.

44. In particular, today's locomotives and rolling stock carry a series of on-board computer systems that are an integral part of the equipment and which increases their cost. However, there are additional benefits in terms of safer and more energy efficient operations and savings due to predictive maintenance, that offset the higher initial capital costs.

### 3. New types of railway operations

45. Train operations would be controlled by systems similar to the European Railway Traffic Management System (ERTMS). This system features two main components: (i) the European Train Control System (ETCS);[31] and (ii) GSM-R[32] radio communications. Railway signal and traffic control systems will incorporate fail-safe principles.

46. New intelligent systems will collect a massive amount operational data ('big data'). New systems will be introduced for processing, analyzing and sharing this information. By 2025 most passenger trains will be Diesel Multiple Units (DMUs) (Figure IV.2) or Electric Multiple Units (EMUs) if tracks are electrified (Figure IV.3). Each unit of a 6 – 10 unit DMU/EMU is self-powered. This "consist"[33] would replace the traditional consist of one or two locomotives pulling coaches. EMUs are more expensive to purchase ($10 – $12 million each) but are cheaper to operate and maintain and offer smoother traction and a more comfortable journey.

**Figure IV.2: Example of a Modern Diesel Multiple Unit (DMU)**


Source: Flirt DMU Stadler Ansaldo-Breda

[31] Similar systems in North America are referred to as Positive Train Control (PTC).
[32] Global System for Mobile Communications – Railway or GSM-Railway is an international wireless communications standard for railway communication and applications.
[33] Railway language for the composition of a train.

**Figure IV.3: Example of a Modern Electric Multiple Unit (EMU)**

Source: Auckland Trains, New Zealand

47. Freight trains will likely be longer and heavier. Tracks will need to be designed to accommodate as a minimum 25 tonne axle loads. Longer sidings (passing loops) of at least 1,000 meters in length will need to be constructed.

## C. TECHNICAL SPECIFICATIONS FOR INTEROPERABILITY (TSIS)

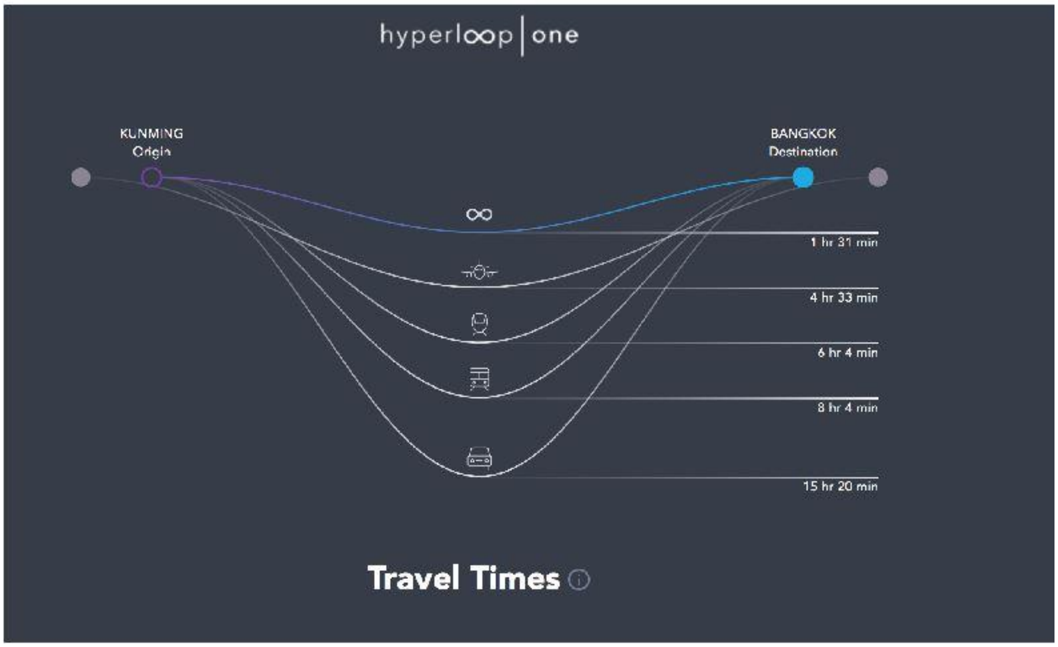
48. Interoperability of railway systems is crucial to the development of a smooth and efficient GMS rail network and is a key factor in attracting investors. The new railway technology and emerging technical standards will need to be part of discussions on technical standards for interoperability. The agreed TSI would need to be flexible to accommodate changes that are expected to occur in future.

## D. NEW TECHNOLOGIES

49. Railway transportation in 2050, especially for passengers, will be very different from the railway in 2025. Train speeds will be higher. High speed rail (HSR) on dedicated track is currently the preferred option for transporting passengers between major population centers because operating speeds are significantly higher than conventional rail passenger transport. HSR is very expensive to build–over $20 – $40 million per kilometer and trainsets are also expensive. The 'Hyperloop' concept has recently emerged as an option to HSR. Proponents claim 40% lower capital costs and operating costs than HSR. Hyperloop technology is not yet proven and costs at this point are only indicative. However, feasibility studies are underway in several countries. Hyperloop's potential should not be ignored as can be seen in the following graphic showing estimated travel times between Bangkok and Kunming by hyperloop, air, high speed rail, conventional rail and car[34].

[34] Abu Dhabi, Czech, France, Sweden, Norway and USA.

**Figure IV.4: Possible Potential of Hyperloop: Kunming to Bangkok**




Source: Hyperloop One

# V. TRANSPORT DEMAND PROJECTIONS

50. To determine the potential demand for new rail and other infrastructure in the GMS that covers 2.6 million square kilometers a valuable tool is a computerized transport model. As referred to in Section II, the multi-modal Mekong (Sub-) Regional Transport Model (MRTM) was developed whose features are summarized in Box V.1.[35]

**Box V.1: Features of the MRTM**

The geographical extent of MRTM includes the entire GMS i.e. includes the nations of Cambodia, PRC (southern provinces of Yunnan and Guangxi), Lao PDR, Myanmar, and Thailand. It includes 254 traffic zones of which 216 are internal to the GMS with the remaining zones outside the GMS i.e. they are defined as external zones. Within the MRTM framework, 25 sectors representing groups of zones have been defined for the development of summary tables and ease of data visualization.

The base year of 2015 has been adopted as well as future projection years of 2025 and 2050. The MRTM's master transport network includes all known transport projects at present, both existing and proposed, that are incorporated into a master network with the potential opening year of any new project provided as a network parameter. At the same time the economic and population datasets are prepared for each year mentioned that enables the preparation of the demand projections.

The key passenger transport modes represented within the MRTM are passenger car, bus, rail, air and inland waterways. Additionally, the model has the capability to include higher speed rail (i.e. higher speed than conventional passenger trains in the GMS) as well as standard rail. For example, higher speed rail is considered linking Hanoi to Bangkok via Ho Chi Minh City and Phnom Penh. For the analysis of freight movements, the key modes represented within the MRTM are road, rail, inland waterways transport (IWT) and coastal shipping. Freight movement is divided into 5 commodity classifications. The MRTM can therefore produce projections of passenger and 5 categories of freight demand by the modes indicated for 2015, 2025 and 2050.

Source: TA Team

## A. FUTURE TRANSPORT NETWORKS

51. The transport model includes a linkage between supply and demand as illustrated in Figure V.1. That is, where travel is made less difficult, due to having improved transport, demand tends to increase in response to the enhanced accessibility and connectivity. Within the MRTM, the linkage between supply and demand is via the travel cost or travel impedance between each traffic zone that consists of perceived travel time, trip quality and 'out-of-pocket' cost components such as fares and tariffs. The model consists of three components: (i) the transport database; (ii) the model structure or set of numerical equations; and (iii) the software platform.

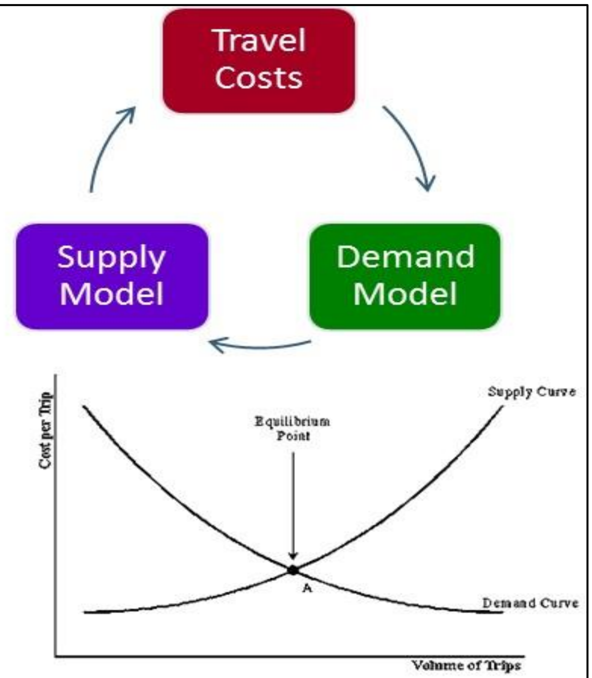
52. The transport database is usually developed after undertaking comprehensive surveys. In this case, due to resource limitations, the transport database was collated from several existing data sources. Likewise, the model structure for the MRTM was based on the 2006 GMS model[36] and available national models for Thailand, Myanmar and Viet Nam. The intention was

[35] The software platform for model development is CUBE, proprietary software of the Citilabs Corporation of the United States. ADB have not yet purchased a license to use CUBE so the modeling software cannot be provided to ADB at present. However, databases and data files will be provided to ADB and would be able to be used by others who use CUBE.

[36] ADB 2006. *TA No. 6195-REG: GMS Transport Sector Strategy Study.*

to ensure flexibility in future by enabling the MRTM to incorporate new data from future surveys and transport studies.

**Figure V.1: The Demand and Supply Formulation**




Source: *Transport Models: TAG Unit 3.1.2*. Department for Transport, June 2005

53. To provide data on the features of the transport network, there were different national and regional network models available. The scope of the master network is illustrated in Figure V.2. The network includes road, rail, air, inland waterways and coastal shipping. All major road links are shown on the map. Details of smaller roads and airline services are not shown in the diagram to ensure clarity.

54. The master network included projects proposed in national transport plans where such plans were available to the TA Team. The inclusion of these national plans and projects was important to allow a representation of all trips in the GMS, that is, not only inter-locality movements (that are also cross-border), but also all trips made within each locality. Two key versions of the network were developed from the master network: (i) a base case network without the 9 missing rail link projects at 2015, 2025 and 2050; and (ii) an improved network was also developed that included the 9 rail missing link projects and associated domestic upgrades for the same years.

**Figure V.2: The Master Network**


Source: TA Team and MRTM; Note: airline services not shown for sake of clarity.

## B. MODEL DEVELOPMENT OVERVIEW

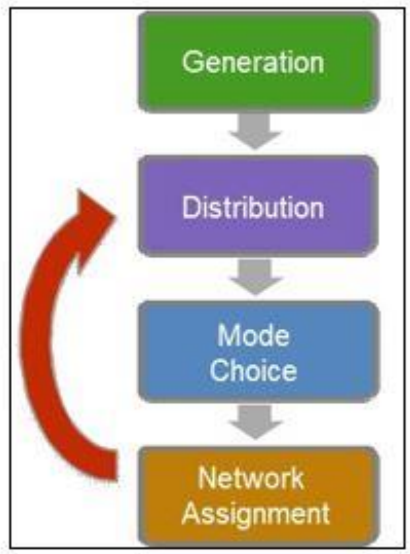
55. The structure of the MRTM follows the traditional four step model[37] for both person and freight movements as depicted in Figure V.3. There were two phases for development of the MRTM and one for preparation of the demand projections:

- Phase 1: Data collation for zones and networks;
- Phase 2: Model development; and
- Phase 3: Demand projections with and without the 9 missing rail links.

### 1. Data Collation

56. The traffic zoning system (TAZ or traffic analysis zones) provides the boundary conditions of the demand-side of the model. These zone boundaries correspond to administrative boundaries with the amalgamation of smaller administrative areas into a single traffic zone. The zoning system adopted for MRTM is the same as that for the 2006 GMS Transport Sector Strategy Study[38]. Within the two provinces of China there are 30 zones. In Myanmar, there are 40 zones while Thailand has a total of 56 zones. There are 17 zones and 24 zones in Lao PDR and Cambodia respectively. Finally, Viet Nam has 49 zones. Thus, the model has a total of 216 internal zones. The total number of zones is 254 including 38 external zones of which 30 of the externals are seaports. The decision was made not to significantly modify the number of zones to ensure compatibility with the 2006 study. The zoning system detail is depicted in Figure V.4 with each locality color coded for ease of identification.

**Figure V.3: The Model Structure**




57. For the purpose of internal reporting within MRTM, a combination of zones has been agglomerated into a 25 sectoral system for ease of data visualization. Each locality is divided into three sectors except for the larger geographical regions of Myanmar and Thailand each of which is allocated 5 sectors for the purpose of summary reports.

58. The master network was then developed that included all future known projects as well as the nine projects relevant to this analysis using the projects data from the other transport models. Relevant regional model data were accessible to the modeling team including that from the 2006 ADB GMS Transport Sector project[39]. Access was obtained to all the relevant digital files associated with the model developed for the 2006 TA, thus providing the foundation for the MRTM. Since that time of original development, newer national models have become available. Key model datasets used as a resource for MRTM are listed in Table V.1.

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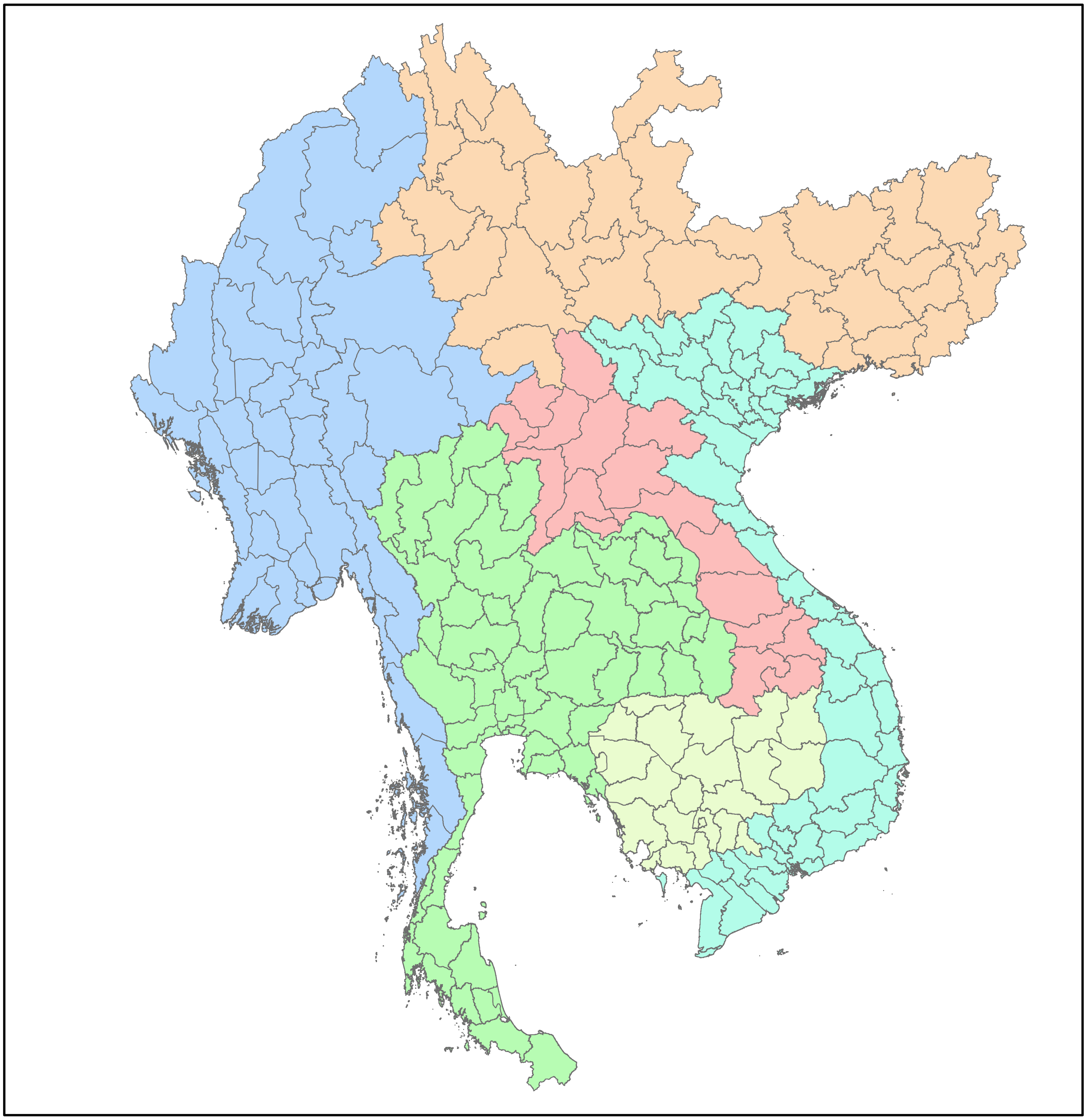
[37] That is, trip generation, trip distribution, modal choice and trip assignment.
[38] This zoning system is compatible with the zoning systems of the existing national transport databases structure.
[39] ADB 2006. o*p. cit.*

**Figure V.4: The Zoning System of MRTM**



Source: TA Team and MRTM

**Table V.1: MRTM's Data Sources**

| Locality | Data Source |
|---|---|
| Cambodia | • Preparation Material for a Private Toll Road Study<br>• KOICA National Transport Plan, 2013 |
| Lao PDR | • The Comprehensive Study on Logistics System in Lao PDR, 2011 |
| Myanmar | • The Survey Program for the National Development Plan in the Republic of the Union of Myanmar, 2014 |
| Thailand | • Transport Data and Model Integrated with Multimodal and Logistics (TDL2), 2014<br>• Thailand Customs Data |
| PR China | • China Customs Data |
| Viet Nam | • The Comprehensive Study on the Sustainable Development of Transport System in Viet Nam (VITRANSS2), 2010 |
| Viet Nam/Lao PDR | • Interim Report of the Feasibility Study for the Railway Link from Vientiane in the Lao PDR to Vung Ang in Viet Nam, 2017 |
| Regional | • T.A. No. 6195-REG: GMS Transport Sector Strategy Study, 2006<br>• Greater Mekong Subregion Statistics on Growth, Infrastructure, and Trade Second Edition<br>• Initial Assessments of Road Transport Infrastructure and Transport and Logistic Services for Trade Facilitation in the GMS Countries, 2012<br>• ADB Collation of current passenger movements and recent trends, modes used and use of international gateways prepared as part of the GMS tourism work (http://www.mekongtourism.org/about/tourism-performance/) including the individual country reports. |

Source: TA team

59. In addition to these datasets, data from individual feasibility studies were incorporated into the framework of MRTM. A notable exception was that there were no sources of modeling data available for the two Chinese localities for this edition of MRTM other than the 2006 TA, and recent Chinese Customs data.

### 2. Model development

60. The demand-side of the model development required the development of person and freight movement demand. The demand projections were themselves a function of population, GDP and GDP per capita in each traffic zone for 2015, 2025 and 2050. These socio-economic data were presented in Section II by locality and were distributed to each traffic zone for the purposes of modeling.[40]

61. Access was also obtained to the Thailand and Chinese custom databases that provided valuable information on the major cross-border freight movements in the GMS. These datasets became available during model development and were used to verify the model[41]. In the case of such commodity data, all such data is specified by harmonized system (HS) coding[42].

62. The HS codes also form the backbone of the Myanmar and Thailand national freight models and was originally developed in detail for fifteen categories. For MRTM, five broad categories of freight were analyzed for the freight analysis as shown in Table V.2. This table also includes the first two digits of the HS codes which broadly detail the specified commodity.

[40] The distribution of such data where national transport model databases were not available was undertaken following the pattern of the earlier 2006 GMS Transport Sector Strategy Study.

[41] The term 'verification' should not be confused with 'calibration' that signifies more exhaustive matching of projections of existing demand to traffic counts and other data on movements. There was insufficient data on passenger and freight movements across inter-locality borders and other screenlines to permit a full model calibration. Hence, the term 'verification' has been used here to mean a partial calibration.

[42] The Harmonized Commodity Description and Coding System generally referred to as "Harmonized System" or simply "HS" is a multipurpose international product nomenclature developed by the World Customs Organization (WCO). It is a six- digit coding system.

The five freight categories adopted in these two national models provide the foundations of the mathematical analysis for the movement of freight within the GMS[43].

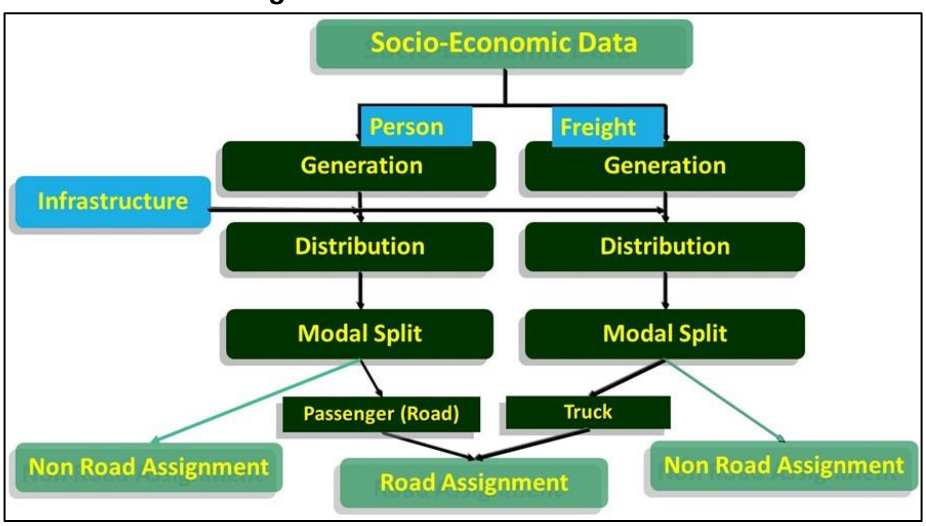
**Table V.2: The Five Freight Groupings for MRTM**

| MRTM | | HS Codes | | Adopted Groups | |
|---|---|---|---|---|---|
| **Category** | **Description** | **HS - Start** | **HS-End** | **Category** | **Description** |
| 1 | Agricultural | 1 | 5 | 1 | Animal & Animal Products |
| 1 | Agricultural | 6 | 15 | 2 | Agricultural Products |
| 2 | Processed Food | 16 | 24 | 3 | Foodstuffs |
| 3 | Chemical/Mineral | 25 | 27 | 4 | Mineral Products |
| 3 | Chemical/Mineral | 28 | 38 | 5 | Chemicals & Allied Industries (Fuel) |
| 3 | Chemical/Mineral | 39 | 40 | 6 | Plastics / Rubbers |
| 4 | Wood/Skins | 41 | 43 | 7 | Raw Hides, Skins, Leather, & Furs |
| 4 | Wood/ Skins | 44 | 49 | 8 | Wood & Wood Products |
| 3 | Chemical/Mineral | 50 | 63 | 9 | Textiles |
| 4 | Wood/Skins | 64 | 67 | 10 | Footwear / Headgear |
| 5 | Miscellaneous | 68 | 71 | 11 | Stone / Glass |
| 5 | Miscellaneous | 72 | 83 | 12 | Metals |
| 5 | Miscellaneous | 84 | 85 | 13 | Machinery / Electrical |
| 5 | Miscellaneous | 86 | 89 | 14 | Transportation |
| 5 | Miscellaneous | 90 | 97 | 15 | Miscellaneous |

Source: TA team and MRTM

63. Model development then followed two paths with the infrastructure supply and socio-economic demand being inputs to develop person and freight models as depicted in Figure V.5. The following sections discuss trip generation, distribution, mode split and assignment for person trips and freight movement.

**Figure V.5: Model Flowchart**

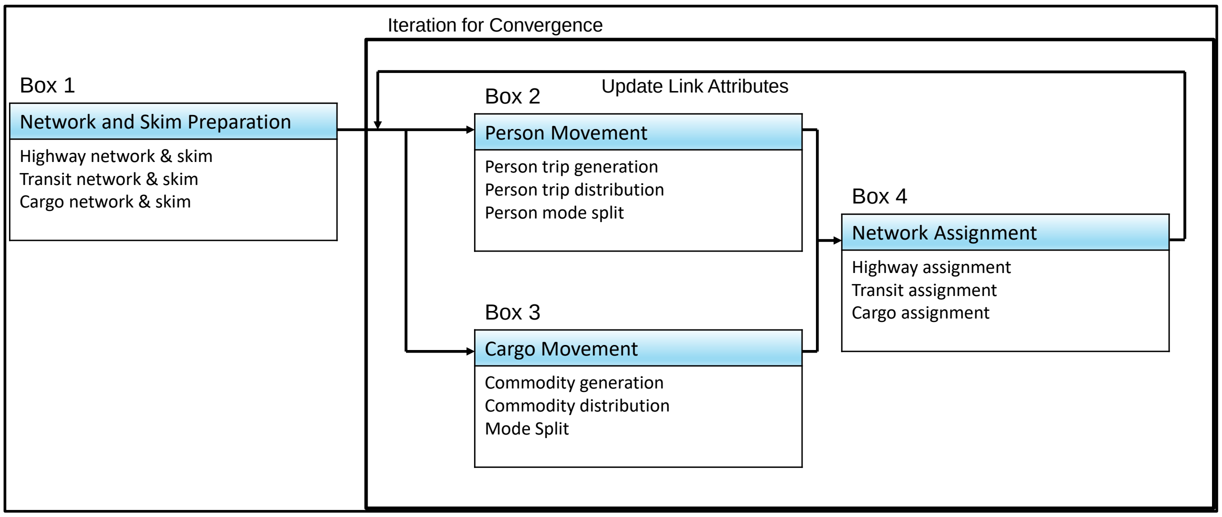



Source: TA team and MRTM

[43] In future, when other data sources become available, they can be readily linked into MRTM via the HS coding system.

64. This model structure depicted was harmonized to fit the software structure following the development of socio-economic data as illustrated in Figure V.6[44]. The model structure was divided into four steps as designated by the box numbers 1 to 4, that together incorporate all the steps shown in Figure V.5. The estimation of population and economic characteristics was a precursor to the steps shown in Figure V.6.

**Figure V.6: Model Flow within Software Structure**




Source: TA team and MRTM

### a. Trip generation

65. **Person trips.** Person demand or person generated trips were estimated by traffic zone via a relationship linking population and GDP per capita in a regression equation. The person trip generation equations for the MRTM were available from existing data sources. The generated trip function takes the following form for trips generated in each zone:

$Gen_i$ (Trips generated in zone i) = a* Population + b* GDP per capita. (The parameters for this equation are shown in Table V.3).

**Table V.3 Person Generation Parameters[45]**

| Locality | Description | a | B |
|---|---|---|---|
| 1 | Cambodia | 0.00306 | 2.49741 |
| 2 | Guangxi (PRC) | 0.00826 | 0.69535 |
| 3 | Yunnan (PRC) | 0.00707 | 0.59464 |
| 4 | Lao PDR | 0.00472 | 1.38404 |
| 5 | Myanmar | 0.00442 | 2.17969 |
| 6 | Thailand | 0.01601 | 5.59074 |
| 7 | Viet Nam | 0.01208 | 3.75992 |

Source: TA team and MRTM

66. **Freight trips.** Freight trips likewise are estimated by traffic zone via a relationship linking population and GDP per capita in a series of linear regression equations. The parameters in the equations in this incidence vary by locality and each of five commodity groups. There are therefore 35 equations that are tabulated in Appendix D.

44 The appendix provides further detail of the model structure.
45 The R squared value of the equations range from 0.7 to 0.9.

### b. Trip distribution

67. **Person trips.** The next step was the distribution of person and freight trips using a gravity model. The general form of the model is as follows:

$$T_{ij} = P_i \frac{A_j f(c_{ij}) K_{ij}}{\sum A_j f(c_{ij}) K_{ij}}$$

where:

| | |
|---|---|
| *$f(c_{ij})$* | F Factor, a function cost of travel |
| *$P_i$* | Generations at zone i |
| *$A_j$,* | Attractions at zone j |
| *$T_{ij}$* | Trips between zone i and zone j |
| *$K_{ij}$* | Parameter which describe the relationship between groups of zones |

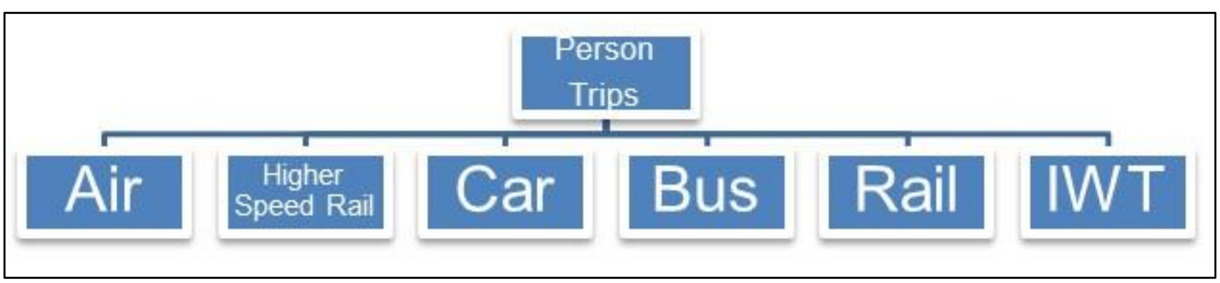
The F factor curve is in the form of a gamma function within the MRTM. The Gamma function takes the form: $f(c_{ij}) = c_{ij}X_1 * exp(X_2*c_{ij})$
where:
*$c_{ij}$ is the impedance of travel between zone i and j and $X_1$, $X_2$ are calibration constants.*
For MRTM, the value of $X_1$, $X_2$ are 1.13274, -0.00695854 respectively.

68. **Freight trips**. Freight trip distribution used the Fratar growth factor distribution method that takes as a base an existing distribution patterns sourced from earlier studies as specified in Table V.1. The freight generations by commodity group are then input as row and column totals into the distribution together with the base pattern matrix. The base pattern is then iteratively balanced until the new pattern matches the input freight generations.

### 3. Mode split

69. **Person trips.** For the person-mode split analysis, in addition to travel times that were calculated in the model, there was a requirement for information on passenger fares. The fare calculations were drawn from the fare tables of national models or from regional databases. The mode split structure is a single level mode split logit model with six modes as depicted in Figure V.7. In many cases, the mode choices were limited to car and bus since there was no logical route via other modes. Higher speed rail was only available in the base transport network at 2050.

**Figure V.7: Person Mode Split**




Source: TA team and MRTM; note: passenger movement by coastal shipping is assumed to be insignificant

70. Modal split for person trips was estimated with a logit function of the following form:[46]

$$P_{in} = \frac{\exp(V_i)}{\sum_j \exp(V_j)}$$

where:

| | |
|---|---|
| $P_{in}$ | Possibility of choosing transportation mode i from the set of choice modes |
| $V_i$ | Utility function of transportation mode i (time and cost) |
| | and Vi = a × ln(Travel Time[47] × VoT) + b × ln(Travel Cost[48]) + Modal Bias Constant |
| | where |
| | a and b: Scale parameters for Parameters for time and cost respectively; and |
| | VoT: Value of Time. |

71. **Freight trips.** The commodity movement cost and travel times are the key inputs into the freight mode split model. The mode split structure for freight is a hierarchical three-level mode split logit model as depicted in Figure V.8. The total freight trips were split across four modes. At the first level, coastal trips are separated while at the second level, inland water transport trips are separated, with the final level being the split between road and rail. In many cases, the mode choices were limited to road and rail since there was no logical route via other modes.

72. At each level, there is a logit model for each commodity group which takes the following form:

$$P_1 = \frac{\exp^{V_1}}{\exp^{V_1} + \exp^{V_2}}$$

where:

$P_1$: Modal share of mode *1*

$V_1$: Cost of travel via mode 1

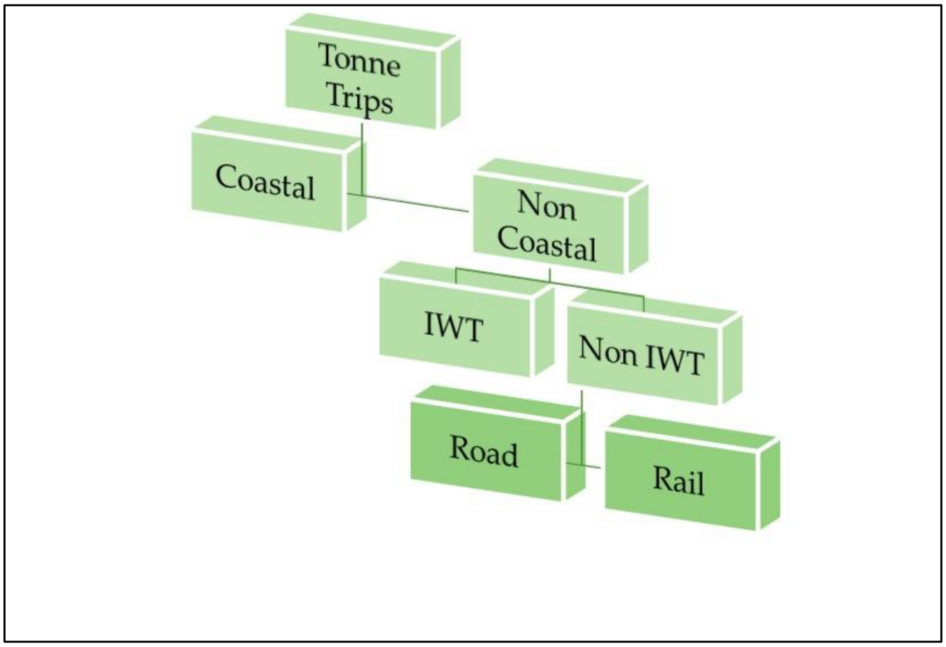
$V_2$: Cost of travel via the alternative. In the case when this is not a single mode, the cost is a weighted cost of the alternative modes. For the movement of freight, the access cost of the freight movement to the non-road modes is included in the movement cost.

[46] The model parameters are developed following a review of similar national models in Myanmar and Thailand. These parameter values are documented in the Appendix for both person and freight mode split analysis.

[47] In the case of travel time for transit this includes modal access, waiting time and long-haul travel time.

[48] As stated in Section I, all cost parameters are in constant 2010 USD.

**Figure V.8: Freight Mode Split**




Source: TA team and MRTM

### a. Trip assignment

73. The final step was the assignment or the allocation of the flow of people and freight to air, road, rail, inland waterway and coastal shipping networks. In the case of the road network, the movement of persons by car and bus were converted into equivalent passenger car units (pcu) together with the freight-carrying trucks on the network[49].

74. **Person trips.** It was necessary to convert person trips on the road network into vehicles via occupancy factors. The cars and bus vehicle trips were then converted into pcu trips. The remaining person trips that do not use the road network, except to access the non-road network such as airports, are then assigned to the non-road network.

75. **Freight trips.** A similar procedure was adopted for freight. It was necessary to convert those trips on the road network into vehicles via load factors. The remaining freight trips do not use the road network except for access to the non-road network (e.g. truck to seaport). In the case of truck trips there was also an implied back loading factor to allow for trucks returning from their destination without any load. The non-road trips are then assigned to their respective networks such as rail.

76. **Finding equilibrium**. Passenger and trucks share the road networks. For the traffic movements assigned to the road network, there is a feedback loop to adjust the road traffic speed until there is equilibrium across the network (i.e. that assumed input speeds match the actual output speeds after the traffic assignment). The travel time on the road network impacts the mode split of both person and freight movement. Thus, the mode split is also brought into equilibrium via this procedure. Assignments to the non-road systems is carried out separately. This is done for rail, inland water transport and coastal shipping in the case of freight. For person movements, the assignment is undertaken separately for air, high speed rail, rail and

[49] In addition to conversion of trucks into pcus, an empty truck factor is included to allow for empty backloading.

inland water transport[50]. All the assigned trips across all networks are combined into a single output network following the equilibrium procedure.

### b. Verification

77. As was stated earlier, there were only limited data available for MRTM verification. That is, a full model calibration could not be carried out without the availability of more extensive data on cross-border movements by type and mode and movements across key screenlines in the GMS. Accordingly, the MRTM has currently only been verified, in effect a 'lite' calibration, against the following main data sources namely:

- Traffic count screenline in Thailand;
- Truck tonne kilometers in Thailand; and
- Trade between Thailand and Guangxi and Yunnan.

78. Two screenlines are compared as shown in Figure V.9. In both cases, the comparison suggests that MRTM reproduces good results. There are also national freight statistics available via road for Thailand. Both traffic count and model result in terms of the pcu comparison are within ten percent. In the case of Thailand, the Ministry of Transport prepares data on the number of tonnes carried by road. The Ministry reports that there are 531.3 million tonne-kilometers each day in Thailand carried by road. MRTM prediction is 528 million tonne-kilometers carried by road. The MRTM estimate in 2015 shows less than a 1% difference.[51]

79. From the Thailand and Chinese customs database, it is possible to interpret and reconcile any differences in the database. These databases suggest that the trade between the two Chinese localities and Thailand is 1,409 tonnes on average per day in 2015 that is close to the model's prediction of 1,400 tones per day. The comparison is good.

80. During the small extension of the TA from April to July 2018, further verification using incoming passenger arrivals and departures for the GMS countries in 2015, by mode and in some cases by location, was undertaken to improve the model for later use as set out in the Attachment to Appendix D. This additional verification tended to confirm the verification reported here giving confidence in use of the model for preparing forecasts.

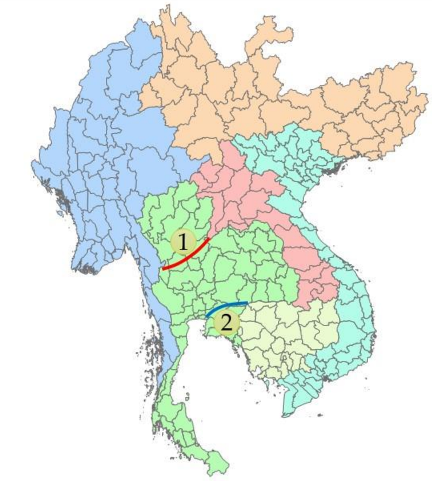
[50] Besides travel on road by the road modes of car, bus and truck, access to other modes via the road network is also included in the assignment procedure.

[51] Source: [http://www.news.mot.go.th/motc/portal/graph/np/index8.asp], accessed November 2017.

**Figure V.9: Screenline Comparison**

| Screenline | Observed ** | Estimated | %Diff |
|---|---|---|---|
| 1 | 97,088 | 104,340 | 7.5% |
| 2 | 167,774 | 156,894 | -6.5% |
| Total | 264,862 | 261,234 | -1.4% |

**Source:
Thailand National Model Traffic count 2015




Source: TA team and MRTM

## C. DEMAND PROJECTIONS

### 1. Base Case

81. Base Case model projections were prepared for 2025 and 2050 and compared to the base year of 2015. The demand projections required information on future transport projects and the future socio-economic forecasts described in Section II. The base case network at 2025 and 2050 excluded all of the 9 missing link projects to enable their individual effects to be tested even though the part of project 4 in the PRC, and all of project 5 in PRC/ Lao PDR, are currently under construction.

82. The total person trips (intra-locality and inter-locality) for the GMS was projected to grow from 5.3 million trips in 2015 to 11.1 million trips by 2050 in the base case, over a doubling of trip making over this period. There are however differential growth rates as depicted in Table V.4. The highest growth into the distant future horizon of 2050 are the localities with the smallest base namely Lao PDR and Cambodia with 3.2% per annum and 3.4% per annum respectively. This is followed by Myanmar at 2.8% per annum.

**Table V.4: Base Case Person Trip Projections**[52]

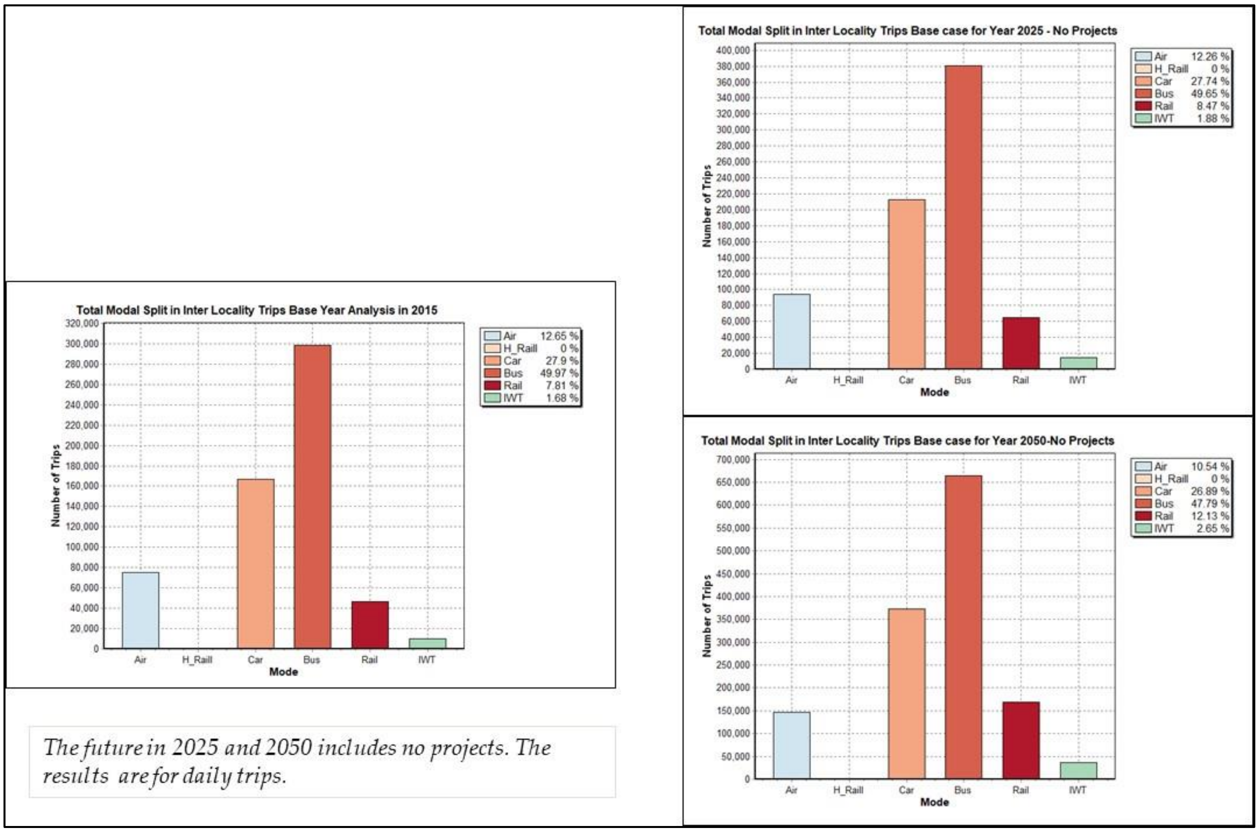
| Locality | 2015 | 2025 | 2050 | Growth rate 2015 – 2025 (% p.a.) | Growth rate 2025 – 2050 (% p.a.) | Growth rate 2015 – 2050 (% p.a.) |
|---|---|---|---|---|---|---|
| Cambodia | 109,215 | 161,018 | 349,806 | 4.0 | 3.2 | 3.4 |
| Guangxi, PRC | 442,394 | 519,781 | 817,849 | 1.6 | 1.8 | 1.8 |
| Yunnan, PRC | 367,602 | 422,931 | 655,022 | 1.4 | 1.8 | 1.7 |
| Lao PDR | 65,599 | 96,624 | 199,026 | 3.9 | 2.9 | 3.2 |
| Myanmar | 367,156 | 477,325 | 951,755 | 2.7 | 2.8 | 2.8 |
| Thailand | 2,500,189 | 3,041,669 | 5,226,049 | 2.0 | 2.2 | 2.1 |
| Viet Nam | 1,400,095 | 1,695,321 | 2,857,380 | 1.9 | 2.1 | 2.1 |
| **Total** | 5,252,250 | 6,414,669 | 11,056,887 | 2.0 | 2.2 | 2.1 |

Source: TA team and MRTM

52 The future year growth includes all projects and all trips within the Mekong subregion.

83. Similarly, over a doubling of inter-locality person trips (i.e. excluding intra-locality trips) was projected from 2015 – 2050 in the base case as depicted in Figure V.10[53]. It is projected that bus would continue to dominate the inter-locality person movements through to 2050 when its share of trips would remain at about 50%. Car is the next most significant mode with 26.9% of all trips at 2050. Rail systems are projected to carry 12.1%, air 10.5% and IWT 2.7% of all GMS inter-locality person trips at 2050 in the base case. Rail's share of 12.1% at 2050 is projected to have increased from 7.8% at 2015 in the base case.

**Figure V.10: Base Case Daily Person Inter-Locality Trip Growth 2015 from 2015 – 2050**




Source: TA team and MRTM

84. The total movement of freight in tonnes (intra-locality and inter-locality) is projected to grow from 2.0 million tonnes in 2015 to 8.0 million tonnes by 2050 representing a compound growth rate of 4.1% per annum as shown in Table V.5. There are marked differences by locality. The projections indicate that the localities with the highest growth rates from 2015 – 2050 are Yunnan and Myanmar with growth rates of 5.9% p.a. and 6.0% p.a. respectively. This is followed by Guangxi with 5.3% p.a. The growth rates in these localities are all projected to be above the regional average of 4.1% p.a.

85. This is also reflected in the almost 240% increase in overall inter-locality freight movement from 275,000 tonnes in 2015 to 925,000 tonnes in 2050 as depicted in Figure V.11.[54]

[53] The scale for each year is not the same. This is to ensure that it is easy to depict the major modes of travel. The mode H_Rail refers to the higher speed coastal rail corridor linking China to Bangkok via Hanoi, Ho Chin Minh City and Phnom Penh.

[54] The scale for each year is not the same. This is to ensure that it is easy to depict the major modes of travel. This figure also includes the impact in the increase in external tonne movements.

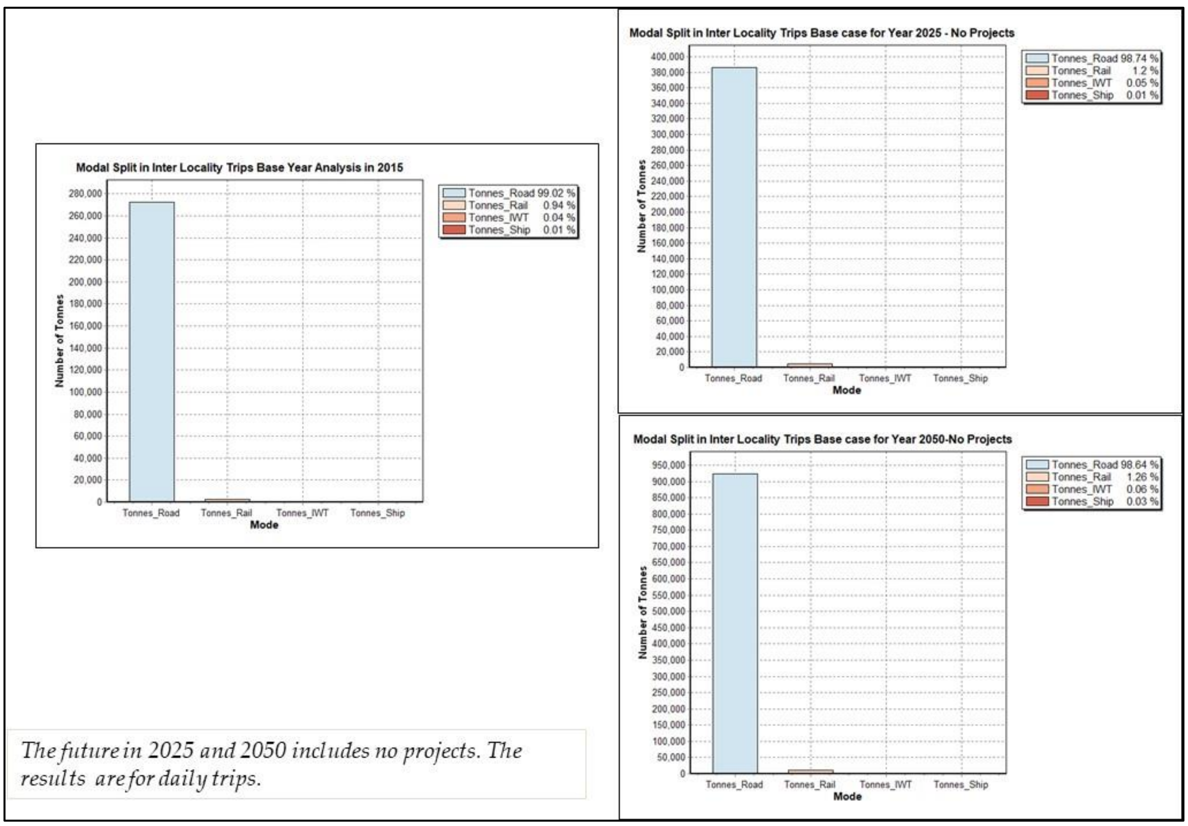
Truck is projected to continue as the dominant mode of freight transport even in the distant future with an estimated 98.6% share in 2050 in the base case. However, rail is projected to increase its share of inter-locality freight movements over 2015 – 2050 from 0.9% to 1.3% respectively in the base case as also shown in Figure V.11.

**Table V.5: Base Case Freight Trip Growth[55]**

| Locality | 2015 | 2025 | 2050 | Growth rate 2015 – 2025 (% p.a.) | Growth rate 2025 – 2050 (% p.a.) | Growth rate 2015 – 2050 (% p.a.) |
|---|---|---|---|---|---|---|
| Cambodia | 17,554 | 29,609 | 74,163 | 5.4 | 3.7 | 4.2 |
| Guangxi, PRC | 119,410 | 230,812 | 739,311 | 6.8 | 4.8 | 5.3 |
| Yunnan, PRC | 123,362 | 261,568 | 931,562 | 7.8 | 5.2 | 5.9 |
| Lao PDR | 6,123 | 10,611 | 24,926 | 5.7 | 3.5 | 4.1 |
| Myanmar | 54,224 | 111,062 | 413,099 | 7.4 | 5.4 | 6.0 |
| Thailand | 1,285,445 | 1,846,372 | 4,100,770 | 3.7 | 3.2 | 3.4 |
| Viet Nam | 381,028 | 600,383 | 1,675,860 | 4.7 | 4.2 | 4.3 |
| **Total** | 1,987,146 | 3,119,847 | 8,028,818 | 4.6 | 3.9 | 4.1 |

Source: TA Team and MRTM

**Figure V.11: Base Case Daily Tonnes Inter-Locality Trip Growth 2015 from 2015 – 2050**




Source: TA Team and Framework of MRTM

[55] The future year growth includes all trips within the Mekong subregion but does not include external movements

## 2. Project Case Demand – projections for the missing rail links

86. The analysis of the impact of proposed rail missing link projects, the project case, is made versus the base case (refer paragraph 79) for each of the forecast years. The objective was to test several combinations of the rail missing link projects alone or in combination in a series of 19 scenarios[56] developed by the TA team and with inputs of the railway bodies at the August 2017 workshop as shown in Table V.6. In this section, all demand projected for projects are daily totals comprising both inter-locality and other local trips (i.e. non inter-locality).

**Table V.6: The Project Scenarios**

| Scenario Case | Year | |
|---|---|---|
| | 2025 | 2050 |
| **Base** | No Projects | No Projects |
| **A** | 1 | 1 |
| **B** | 2 | 2 |
| **C** | 1+2 | 1+2 |
| **D** | 4 | 4 |
| **E** | 5 | 5 |
| **F** | 6 | 6 |
| **G** | 9 | 9 |
| **H** | - | 3, 7 and 8 |
| **I** | All Projects above | All Projects above plus Coastal Higher Speed Rail |

Source: TA team and MRTM

### a. Individual projects at 2025

87. Projections of daily person trips and person-kilometers by project for each scenario in 2025 are shown in Tables V.7 and V.8 respectively. Project 9 has the highest projected daily passenger demand at 2025 of 57,800 trips and 17.5 million passenger-kilometers per day respectively. The next highest demand is projected for Project 6 at about a quarter that of Project 9, followed by Projects 1, 5, 4 and 2 with lower demand.

88. Projects 1 and 2 when combined into Scenario Case C, are projected to attract 1.6% more passengers as shown in Table V.7 and 20% more passenger traffic in terms of person-kilometers as shown in Table V.8 than when the two projects are considered separately. These results indicate the Scenario C has higher average passenger trip lengths that are shown in Table V.9.

89. In Scenario Case I that combined all projects, the demand for the individual projects is in general not greatly different to when they were modeled alone. This effect is due to the relatively short average, passenger trip distances that have been estimated (Table V.9) to be around 450 km.[57]

[56] Total scenarios for 2025 and 2050 including base case in both years.

[57] However, in reality with improved network linkages the demand for longer trips may increase to a greater extent than currently projected as long as it is accompanied by growth in economic activities in key production zones and destinations. This effect has yet to be fully developed in the MRTM.

**Table V.7: Daily Person Trips by Project in 2025**

| Case | Projects, Included | Project Number | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| Base | Zero | - | - | - | - | - | - | - | - | - | - |
| A | 1 | 14,060 | - | - | - | - | - | - | - | - | 14,060 |
| B | 2 | - | 4,990 | - | - | - | - | - | - | - | 4,990 |
| C | 1,2 | 13,890 | 5,470 | - | - | - | - | - | - | - | 19,360 |
| D | 4 | - | - | - | 8,300 | - | - | - | - | - | 8,300 |
| E | 5 | - | - | - | - | 10,440 | - | - | - | - | 10,440 |
| F | 6 | - | - | - | - | - | 14,630 | - | - | - | 14,630 |
| G | 9 | - | - | - | - | - | - | - | - | 57,810 | 57,810 |
| I | 1,2,4,5,6,9 | 13,870 | 5,440 | - | 8,340 | 10,340 | 14,690 | - | - | 57,750 | 110,440 |

Source: TA team and MRTM

**Table V.8: Daily Thousand Person-Kilometers of Travel by Project in 2025**

| Case | Projects, Included | Project Number | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| Base | Zero | - | - | - | - | - | - | - | - | - | - |
| A | 1 | 6,382.0 | - | - | - | - | - | - | - | - | 6,382 |
| B | 2 | - | 2,432.0 | - | - | - | - | - | - | - | 2,432 |
| C | 1,2 | 7,048.0 | 3,512.0 | - | - | - | - | - | - | - | 10,558 |
| D | 4 | - | - | - | 4,453.0 | - | - | - | - | - | 4,453 |
| E | 5 | - | - | - | - | 4,071.0 | - | - | - | - | 4,071 |
| F | 6 | - | - | - | - | - | 6,759.0 | - | - | - | 6,759 |
| G | 9 | - | - | - | - | - | - | - | - | 17,531.0 | 17,531 |
| I | 1,2,4,5,6,9 | 7,026.0 | 3,462.0 | - | 4,609.0 | 4,058.0 | 6,486.0 | - | - | 17,607.0 | 43,248 |

Source: TA team and MRTM

**Table V.9: Projected Average Trip Length in 2025**

| Scenario Case | Projects, Included | Person | Freight |
|---|---|---|---|
| A | 1 | 453.8 | 434.5 |
| B | 2 | 487.9 | 428.8 |
| C | 1,2 | 545.5 | 482.2 |
| D | 4 | 536.4 | 385.7 |
| E | 5 | 389.8 | 402.5 |
| F | 6 | 461.9 | 407.5 |
| G | 9 | 303.3 | 208.1 |
| I | 1,2,4,5,6,9 | 391.6 | 251.0 |
| **Average trip distance (km)** | | **446 km** | **375 km** |

Source: TA team and MRTM; simple averages not weighted averages are shown.

90. Projected freight movements in terms of daily tonnes and tonne-kilometers for 2025 are shown in Tables V.10 and V.11 respectively. Project 6 is projected to have the highest demand at 5.0 million tonne-kilometers per day much greater than any other individual link. Project 9 has the second highest demand at 3.5 million tonne-kilometers per day. Project 5 has a high freight demand when included in the comprehensive network (Scenario Case I) apparently attracting traffic from Project 6. The other projects are not projected to have very high daily freight demand at 2025. As for passenger travel, projected average freight trip distances are about 375 km as shown in Table V.9, reducing the potential for more extended rail networks based on the current demand projections. However, these projections of freight demand do not however take the development of future mineral or other resource developments that could dramatically increase freight movements benefiting projects 4, 5 and 6 particularly.

**Table V.10: Daily Freight Tonnes by Project in 2025**

| Case | Projects, Included | Project Number | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| Base | Zero | - | - | - | - | - | - | - | - | - | - |
| A | 1 | 30 | - | - | - | - | - | - | - | - | 30 |
| B | 2 | - | 320 | - | - | - | - | - | - | - | 320 |
| C | 1,2 | 30 | 320 | - | - | - | - | - | - | - | 350 |
| D | 4 | - | - | - | 10 | - | - | - | - | - | 10 |
| E | 5 | - | - | - | - | 520 | - | - | - | - | 520 |
| F | 6 | - | - | - | - | - | 12,380 | - | - | - | 12,380 |
| G | 9 | - | - | - | - | - | - | - | - | 16,800 | 16,800 |
| I | 1,2,4,5,6,9 | 100 | 380 | - | 10 | 10,660 | 9,830 | - | - | 16,400 | 37,380 |

Source: TA team and MRTM

**Table V.11: Daily Thousand Tonne-Kilometers of Travel by Project in 2025**

| Case | Projects, Included | Project Number | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| Base | Zero | - | - | - | - | - | - | - | - | - | - |
| A | 1 | 12.6 | - | - | - | - | - | - | - | - | 12.6 |
| B | 2 | - | 137.2 | - | - | - | - | - | - | - | 137.2 |
| C | 1,2 | 23.4 | 144.9 | - | - | - | - | - | - | - | 168.3 |
| D | 4 | - | - | - | 2.7 | - | - | - | - | - | 2.7 |
| E | 5 | - | - | - | - | 209.3 | - | - | - | - | 209.3 |
| F | 6 | - | - | - | - | - | 5,044.9 | - | - | - | 5,044.9 |
| G | 9 | - | - | - | - | - | - | - | - | 3,495.7 | 3,495.7 |
| I | 1,2,4,5,6,9 | 159.0 | 266.4 | - | 2.7 | 4,345.9 | 1,308.9 | - | - | 3,301.6 | 9,384.5 |

Source: TA team and MRTM

### b. Individual projects at 2050

91. Projections of daily person trips and person-kilometers by project for each scenario in 2050 are shown in Table V.12 and V.13 respectively and shows demand levels about three times that at 2025. The relative pattern of demand at 2050 is similar to that for 2025. Project 9 alone shows the greatest impact with 146,800 daily passengers and 48.6 million daily passenger-kilometers of travel. The next highest demand is projected for Project 1 at about a third of that for Project 9, followed by Projects 6, 7, 5, 4 and 2 with lower demand.

92. Projects 1 and 2 when combined into Scenario Case C, attract 4.7% more daily passengers (Table V.12) but 22.9% more daily passenger-kilometers than 1 or 2 separately. In Scenario Case I, the scenario including all projects, overall passenger trips and passenger kilometers are about 20% lower than in the total for Scenarios C – H due to in general small declines on individual projects, that to some extent compete with one another.

## Table V.12: Daily Person Trips by Project in 2050

| Case | Projects, Included | Project Number | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| Base | Zero | - | - | - | - | - | - | - | - | - | - |
| A | 1 | 49,630 | - | - | - | - | - | - | - | - | 49,630 |
| B | 2 | - | 15,150 | - | - | - | - | - | - | - | 15,150 |
| **C** | 1,2 | 50,290 | 17,550 | - | - | - | - | - | - | - | 67,850 |
| **D** | 4 | - | - | - | 21,390 | - | - | - | - | - | 21,390 |
| **E** | 5 | - | - | - | - | 26,600 | - | - | - | - | 26,600 |
| **F** | 6 | - | - | - | - | - | 36,640 | - | - | - | 36,640 |
| **G** | 9 | - | - | - | - | - | - | - | - | 146,800 | 146,800 |
| **H** | 3,7,8 | - | - | 26,030 | - | - | - | 28,160 | 18,360 | - | 72,550 |
| **Total of passenger trips for Scenarios C – H** | | | | | | | | | | | **371,830** |
| **I** | 1,2,3,4,5,6,7,8,9 and HSR | 28,030 | 21,210 | 20,560 | 18,050 | 22,630 | 33,110 | 28,270 | 16,560 | 105,330 | **293,740** |
| **Total of passenger trips for Scenario I compared to Scenarios C – H** | | | | | | | | | | | **0.79** |

Source: TA team and MRTM

## Table V.13: Daily Thousand Person Kilometers of Travel by Project in 2050

| Case | Projects, Included | Project Number | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| Base | Zero | - | - | - | - | - | - | - | - | - | - |
| A | 1 | 21,316.0 | - | - | - | - | - | - | - | - | 21,316 |
| B | 2 | - | 7,551.0 | - | - | - | - | - | - | - | 7,551 |
| **C** | 1,2 | 24,152.0 | 11,323.0 | - | - | - | - | - | - | - | 35,475 |
| **D** | 4 | - | - | - | 12,026.0 | - | - | - | - | - | 12,026 |
| **E** | 5 | - | - | - | - | 11,437.0 | - | - | - | - | 11,437 |
| **F** | 6 | - | - | - | - | - | 19,237.0 | - | - | - | 19,237 |
| **G** | 9 | - | - | - | - | - | - | - | - | 48,629.0 | 48,629 |
| **H** | 3,7,8 | - | - | 13,778.0 | - | - | - | 12,993.0 | 7,993.0 | - | 34,764 |
| **Total of passenger-km for Scenarios C – H** | | | | | | | | | | | **161,568** |
| I | 1,2,3,4,5,6,7,8,9 and HSR | 13,810.0 | 11,966.0 | 10,393.0 | 9,882.0 | 9,038.0 | 16,105.0 | 13,403.0 | 7,509.0 | 32,442.0 | **124,548** |
| **Total of passenger-km for Scenario I compared to Scenarios C – H** | | | | | | | | | | | **0.77** |

Source: TA team and MRTM

## Table V.14: Projected Average Trip Length in 2050

| Scenario Case | Projects, Included | Person | Freight |
|---|---|---|---|
| A | 1 | 429.5 | 444.0 |
| B | 2 | 498.4 | 468.8 |
| C | 1,2 | 522.9 | 556.0 |
| D | 4 | 562.2 | 400.0 |
| E | 5 | 430.0 | 438.6 |
| F | 6 | 525.1 | 532.9 |
| G | 9 | 331.3 | 216.6 |
| H | 3,7,8 | 479.2 | 434.6 |
| I | 1,2,3,4,5,6,7,8,9 and HSR | 424.0 | 306.0 |
| **Average trip distance (km)** | | **467 km** | **422 km** |

Source: TA team and MRTM; simple averages not weighted averages are shown.

93. Projections of freight movement in terms of daily tonnes and tonne-kilometers for 2050 are shown in Table V.15 and V.16 respectively. In Scenario Case I, overall freight tonnes and tonne-kilometers are about double that for Scenarios C – H due to the more effective competition and the better-connected rail networks in the GMS provide to road transport. In terms of daily tonne-kilometers of travel, Projects 9 and 6 have the highest individual freight demand although projects 5 and 7 both have high freight demand when included in the comprehensive network (Scenario Case I).

94. Mean trip distances for person and freight travel for 2050 are shown in Table V.14 indicating 5% longer passenger trip distances and almost 13% longer freight trip distances at 2025 (refer Table V.9) indicating the beneficial effect of more connected railway networks.

**Table V.15: Daily Freight Tonnes by Project in 2050**

| Case | Projects, Included | Project Number | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| Base | Zero | - | - | - | - | - | - | - | - | - | - |
| A | 1 | 120 | - | - | - | - | - | - | - | - | 120 |
| B | 2 | - | 660 | - | - | - | - | - | - | - | 660 |
| **C** | 1,2 | 120 | 660 | - | - | - | - | - | - | - | 780 |
| **D** | 4 | - | - | - | 20 | - | - | - | - | - | 20 |
| **E** | 5 | - | - | - | - | 1,340 | - | - | - | - | 1,340 |
| **F** | 6 | - | - | - | - | - | 27,510 | - | - | - | 27,510 |
| **G** | 9 | - | - | - | - | - | - | - | - | 54,070 | 54,070 |
| **H** | 3,7,8 | - | - | 10 | - | - | - | 150 | 30 | - | 190 |
| **Total of freight tonnes for Scenarios C – H** | | | | | | | | | | | **83,910** |
| **I** | 1,2,3,4,5,6,7,8,9 and HSR | 90 | 1,250 | 10 | 20 | 37,400 | 32,230 | 60,670 | 650 | 53,050 | **185,360** |
| **Total of freight tonnes for Scenario I compared to Scenarios C – H** | | | | | | | | | | | **2.21** |

Source: TA team and MRTM

**Table V.16: Daily Thousand Tonne-Kilometers of Travel by Project in 2050**

| Case | Projects, Included | Project Number | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
| Base | Zero | - | - | - | - | - | - | - | - | - | - |
| A | 1 | 51.5 | - | - | - | - | - | - | - | - | 51.5 |
| B | 2 | - | 310.8 | - | - | - | - | - | - | - | 310.8 |
| **C** | 1,2 | 94.8 | 337.8 | - | - | - | - | - | - | - | 432.6 |
| **D** | 4 | - | - | - | 7.6 | - | - | - | - | - | 7.6 |
| **E** | 5 | - | - | - | - | 589.1 | - | - | - | - | 589.1 |
| **F** | 6 | - | - | - | - | - | 14,658.1 | - | - | - | 14,658.1 |
| **G** | 9 | - | - | - | - | - | - | - | - | 11,712.8 | 11,712.8 |
| **H** | 3,7,8 | - | - | 5.5 | - | - | - | 50.9 | 25.3 | - | 81.7 |
| **Total of freight tonne-km for Scenarios C – H** | | | | | | | | | | | **27,482** |
| | | | | | | | | | | | |
| **I** | 1,2,3,4,5,6,7,8 and 9 | 56.6 | 1,164.8 | 3.8 | 7.4 | 17,417.2 | 12,081.2 | 14,014.9 | 892.7 | 11,077.7 | **56,716** |
| **Total of freight tonne-km for Scenario I compared to Scenarios C – H** | | | | | | | | | | | **2.06** |

Source: TA team and MRTM

### c. Scenario I, all projects developed plus coastal higher speed rail in Viet Nam

95. The previous section provided projections of passenger and freight demand for each individual project and when they are combined into the comprehensive network (Scenario Case I). This section shows projections of passenger and freight demand for Scenario Case I as a whole across the entire GMS transport system (i.e. intra-locality and inter-locality) thus providing information on the projected transport task for rail and the other modes.[58]

96. **Passenger travel.** In 2050, in the base case without the 9 missing link rail projects, rail's market share of daily land passenger travel measured by passenger-kilometers is projected to be 15% compared to 7.8% at 2015 as shown in Table V.17. In Scenario Case I at 2050, with the 9 projects, rail passenger market share is projected to increase to 17.9%. In absolute terms, the impact of the inclusion of the 9 projects is to increase rail person-kilometers of travel in 2050 from 494 million in the base case to 602 million, an increase of 22%. Significant congestion relief would be experienced on the road network.

97. **Freight movement.** In 2050, in the base case without the 9 missing link rail projects, rail's market share of daily land-based freight travel measured by tonne-kilometers is projected to be 1.3% compared to 0.8% at 2015 as shown in Table V.18. In Scenario Case I at 2050, with the 9 projects, rail freight market share is projected to increase to 1.6%. In absolute terms, the impact of the inclusion of the 9 projects is to increase rail tonne-kilometers of travel in 2050 from 65 million in the base case to 97 million, an increase of 50%. This is presumably due to both the better connectivity provided by the 9 rail projects as well as the declining speed on roads due to congestion effects. The improvement of inter-locality connectivity by rail therefore appears to have the potential to make ail much more attractive for freight movement.

**Table V.17: Scenario I: Daily Thousand Person-Kilometers of Travel by Mode[59]**

| Year | Car | Bus | Rail | IWT | Total (excl. air) |
|---|---|---|---|---|---|
| 2015 base | 498,608 | 895,916 | 120,289 | 22,464 | 1,537,277 |
| | 32.4% | 58.3% | 7.8% | 1.5% | 100.0% |
| 2025-Base | 593,254 | 1,080,138 | 178,888 | 32,122 | 1,884,402 |
| | 31.5% | 57.3% | 9.5% | 1.7% | 100.0% |
| 2025-Case I | 590,517 | 1,070,698 | 193,072 | 33,816 | 1,888,103 |
| | 31.3% | 56.7% | 10.2% | 1.8% | 100.0% |
| 2050-Base | 969,951 | 1,798,184 | 494,348 | 84,910 | 3,347,393 |
| | 29.0% | 53.7% | 14.8% | 2.5% | 100.0% |
| 2050-Case I | 1,086,043 | 1,611,400 | 602,056 | 70,024 | 3,369,523 |
| | 32.2% | 47.8% | 17.9% | 2.1% | 100.0% |

Source: TA team and MRTM

[58] The rail passenger-kilometer and tonne-kilometer differences between the 2025 base case and the 2025 Project Case I (the comprehensive Scenario I), and the 2050 base case and the 2050 Project Case I, shown in Tables V.16 and V.17 respectively differ from those shown above for individual projects since some passenger and freight trips are common to individual projects. To the extent they are, they will be recorded against each individual project to which they apply. However, in Tables V.16 and V.17 they are only counted once.

[59] Only transport on land-based modes are included in this table. The air mode is not shown.

**Table V.18: Scenario I: Daily Thousand Tonne-Kilometers of Travel by Mode**

| Year | Truck | Rail | IWT | Sea | Total (excl. air) |
|---|---|---|---|---|---|
| 2015 base | 1,132,741 | 8,920 | 2,043 | 7,129 | 1,150,833 |
| | 98.4% | 0.8% | 0.2% | 0.6% | 100.0% |
| 2025-Base | 1,793,816 | 18,912 | 3,282 | 15,442 | 1,831,452 |
| | 97.9% | 1.0% | 0.2% | 0.8% | 100.0% |
| 2025-Case I | 2,218,801 | 27,110 | 10,023 | 16,758 | 2,272,692 |
| | 97.6% | 1.2% | 0.4% | 0.7% | 100.0% |
| 2050-Base | 4,817,184 | 64,990 | 12,105 | 108,373 | 5,002,652 |
| | 96.3% | 1.3% | 0.2% | 2.2% | 100.0% |
| 2050-Case I | 5,843,735 | 97,123 | 27,194 | 111,961 | 6,080,013 |
| | 96.1% | 1.6% | 0.4% | 1.8% | 100.0% |

Source: TA team and MRTM

# VI. PRIORITIZATION OF THE MISSING RAIL LINKS

98. The main means of prioritization of the missing rail link projects was a 'strategic' economic evaluation undertaken to the level relevant for a pre-feasibility study. A 'strategic' financial evaluation was also undertaken. The capital costs and estimated recurrent costs of each railway links (refer Section III) together with the projections of demand (Section V) were key inputs to both evaluations.

99. Other criteria relate to potential social and environmental risks that will need to be investigated at a later stage. The scope of this potential work is set out in Section IX. Socio-political perspectives are important and by default were provided by the GRMA during the March 2018 meeting.

## A. ECONOMIC EVALUATION

### 1. Key Parameters and Assumptions

100. General features of the economic evaluation framework are set out below and summarized in Table VI.1:

- An appraisal period comprising the implementation period (5 or more years) followed by 30 years of operation.
- Allowance was made for the residual value of assets only at the end of the evaluation period, in recognition of their capacity to generate benefits beyond the end of the evaluation period.[60]
- A central (real) discount rate of 10% was used with lower and higher discount rates adopted for sensitivity testing.
- The evaluation was conducted in USD using constant 2017 price units.
- All monetary values excluded taxes, excises and duties, which are transfer payments and hence do not reflect the real value of resources.
- Benefits of the project were calculated for 2025 and 2050 using outputs provided by the transport modeling.

**Table VI.1: Features of Evaluation**

| Feature | Description |
|---|---|
| Implementation period | 5 years |
| Year of opening | 2025 or 2040 |
| Evaluation period (duration of operations evaluated) | 30 years |
| Year in which residual value realized | 31 years |
| Central discount rate (real) | 10.0% pa |

Source: TA team

[60] Residual values were calculated for capital items such as structures, major civil works and Rights of Way.

### 2. Incremental Costs and Benefits

101. The evaluation took into account capital, maintenance and operating costs for the provision of the various project options compared to the continued operation of transport facilities, primarily roads, in the base case. The technical review of railway links by the railway engineering specialist provided capital cost estimates as set out in Section III. Assumptions on routine and periodic maintenance costs of railway track were also made as described in Appendix B. Information was also generated on train operating costs from information obtained from the regional railway organizations and other sources.

102. Differences in transport user and other costs between the base case and the project case constitute the (incremental) costs and benefits (or dis-benefits). The effects of potential induced demand and changes in use of routes and modes were taken into account by the methodology described below. Benefits were estimated taking into account the potential (as modeled) shift to rail with each project case from the alternative modes in each scenario. The estimates of the economic criteria were made to a level commonly associated with a pre-feasibility study as the cost estimates and demand projections are subject to uncertainty.

### 3. Economic Benefits

103. The economic analysis was carried out for all project options (and various cases or scenarios) at 2025 and 2050 as shown in Table VI.2 below. Allowing for the effect of externalities and changes in fatalities and serious injuries, the general form of benefits equation for deriving the expected improvement in economic welfare of a transport project can be written as:

$$\boldsymbol{A}: \boldsymbol{Consumer\ Surplus} + \boldsymbol{B}: \boldsymbol{Producer\ Surplus} + \\ \boldsymbol{C}: \boldsymbol{Change\ in\ value\ of\ externalities} + \boldsymbol{D}: \boldsymbol{Change\ in\ value\ of fatalities/other}$$

104. The first two terms, consumer surplus (A) and producer surplus (B), were calculated for each type of passenger and freight transport impacted by the project, mainly existing land based modes using any part of the road network including switching from other modes. Term C is the changes in externalities (air pollution and greenhouse gas emissions) and Term D is the change in safety and other impacts (e.g. fatalities and serious injuries, reductions in road damage etc.), for each mode. Table VI.2 provides further definition of the components of consumer surplus and producer surplus.

**Table VI.2: Type of Project Benefits Addressed**

| | **A** | | **B** | **C** | **D** |
|---|---|---|---|---|---|
| Description | Consumer Surplus or Shipper Surplus (taking account of time, reliability, opportunity cost of value of freight in transit, tariffs, and qualitative factors) | | Producer Surplus | Δ Externalities | Δ Other (e.g. fatalities, congestion and road damage) |
| Equivalent to >: | Existing user benefits | New user benefits (e.g. benefits to induced users e.g. tourists, those that change routes or modes e.g. inland waterway goods vessels) | Δ (Perceived costs - resource costs of transport operation) = unperceived vehicle operating cost | Δ Externalities | Δ Other (e.g. fatalities, congestion and road damage) |

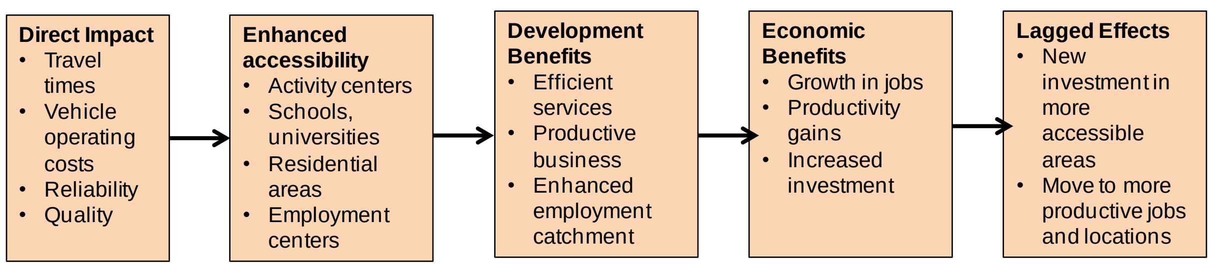
Source: TA team

105. Consumer surplus is commonly referred to as the travel time benefit although more correctly it is calculated as the change in perceived costs (e.g. that for passenger travel includes the value of time, fares/ tolls paid and other out-of-pocket costs e.g. fuel). Producer surplus is equivalent to the change in unperceived vehicle operating costs for transport evaluations.

106. Changes in shipper surplus for freight traffic would be based on differences in likely tariffs of project case rail facilities versus road and other modes in the base case. The analysis would also consider rail's potential role in providing large capacity capable of dealing, for example, with surges in seasonal demand that give it an edge over road-based modes at those periods. In other words, rail would have a perceived advantage over road at these times even if travel times and tariffs were the same.

107. The direct impacts of transport projects flow-on to land use and assist to improve the productivity of labor and firms. There may be other manifestations or indirect impacts of these economic impacts such as on changes in real estate value and new investment as illustrated in Figure VI.1. The former is a flow-on consequence of a reduction in travel time and vehicle operating costs. It is also a measure of the change in accessibility and connectivity. Inclusiveness and affordability are social impacts that deserve special treatment but are not additional economic benefits.

**Figure VI.1: From Travel Efficiency to Economic Benefits**




Source: TA team

108. For missing rail links located in economic corridors, as opposed to transport corridors, it was assumed that the benefits would be boosted by at least 10%. In proposed work for the future, it is anticipated that assessments of each economic corridor would be undertaken to assess whether there is in fact significant additional development occurring around key transport hubs, compared to the background trend for all corridors.

109. **Economic decision criteria.** For the economic evaluation methodology, key decision criteria were Net Present Value (NPV), Benefit-cost ratio (BCR) and Economic Internal Rate of Return (EIRR).

### 4. Economic Evaluation Results

110. The economic evaluations for each project scenario were carried out for an opening year of 2025 and 2040[61]. The full results are set out in Appendix C that provides the key inputs for the economic (and financial) analysis for each project.

[61] 2040 rather than 2050 was chosen since the latest year that demand projections were made was for 2050. For the purposes of the economic and financial evaluations assuming an opening year of 2050 would require use of demand projections entirely based on extrapolating demand for 30 years beyond 2050. Consequently, the second opening year evaluated was taken to be 2040 not 2050.

111. The decision criteria calculated by the main evaluations (i.e. best estimate) indicate that:

- **Project 9** – has the strongest economic case with an estimated EIRR of about 25.4% with an opening year of 2025 due to a high and established demand and relatively low capital costs.
- **Project 1** – has an apparently strong economic case (EIRR of 10.1% at 2025 and 19.4% at 2040) due to forecast high passenger demand and relatively low capital costs. A reduction in demand of 30% at 2025 and 2040 would reduce the EIRR to 2.9% and 9.2% respectively, both below the discount rate of 10% p.a. The results indicate the project has quite good potential in economic terms.

112. The main economic results for these two projects and the results of the key sensitivity tests are shown in Table VI.3 (both for an opening year of 2025). As indicated by the range of statistical tests, project 9's good economic performance is retained for each of the individual sensitivity tests and even with in test 7, the combination of a reduction in benefits of 30% and an increase in capital and recurrent costs of 40%, manages to achieve an estimated EIRR of 2.8%. Project 1 is sensitive to reduced demand, increases in cost and the combination of both.

**Table VI.3: Economic Evaluation Results for Projects 9 and 1 (opening year 2025)**

| Case | Project 9 | | | Project 1 | | |
|---|---|---|---|---|---|---|
| | **BCR** | **EIRR** | **NPV ($m)** | **BCR** | **EIRR** | **NPV ($m)** |
| **With best estimate of benefits using a discount rate of 10%** | **1.64** | **24.4%** | **1,455.6** | **1.01** | **10.1%** | **8.5** |
| *Sensitivity tests* | | | | | | |
| 1. Use a discount rate of 4% | 1.93 | 24.4% | 4,950.3 | 1.36 | 10.1% | 925.3 |
| 2. Use a discount rate of 15% | 1.39 | 24.4% | 543.5 | 0.76 | 10.1% | -195.7 |
| 3. Increase costs by 40% | 1.17 | 14.8% | 544.7 | 0.72 | 3.3% | -484.8 |
| 4. Decrease costs by 10% | 1.82 | 27.4% | 1,683.3 | 1.12 | 12.0% | 131.9 |
| 5. Increase benefits by 10% | 1.80 | 27.1% | 1,828.8 | 1.11 | 11.9% | 132.7 |
| 6. Reduce benefits by 30% | 1.15 | 14.2% | 335.7 | 0.70 | 2.9% | -364.0 |
| 7. Reduce benefits by 30% & costs up 40% | 0.82 | 2.5% | -575.1 | 0.50 | na | -857.4 |

Source: TA team; not available since cannot be calculated.

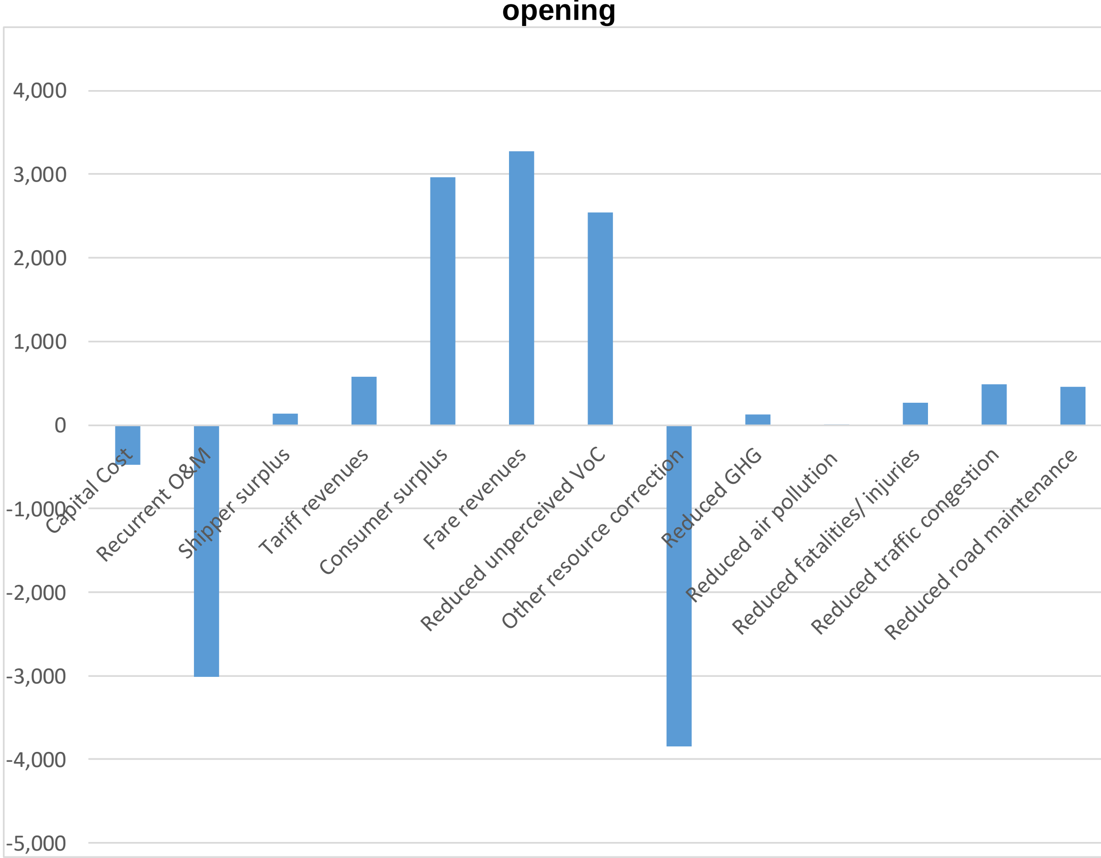
113. The present value of capital costs, recurrent train O&M costs (including capital purchases) and track maintenance and each category of benefit are shown in Figures VI.2 and VI.3 for project 9 and project 1 respectively for an opening date of 2025. The key benefits for the main evaluation of project 9 are: (i) savings in unperceived vehicle operating costs; (ii) passenger consumer surplus and fare revenues to the railway enterprise; and (iii) freight shipper surplus and tariff revenues to the railway enterprise. However, fare and tariff revenues are 'transfer payments' in terms of the economics and must be subtracted from the total and therefore appear as a 'resource correction.' Environmental, safety and reduced road damage benefits are positive but minor. The key benefits for project 1 follow a similar pattern.

114. As shown in Table B.2 of Appendix B, by 2040, no other project is projected to be economic in the main evaluations even with the higher projected demand but:

- Projects 1+2, 4 and 6 all improve to have EIRRs of over 5% but lower than the central discount rate used in the evaluation of 10%;
- Project 3 may also have an EIRR of a similar order but the 2015 feasibility study did not report evaluation results for a later start date;
- Project 4 has an EIRR of less than 3% at 2040 and maybe lower depending on the actual capital cost including the costs of all domestic upgrading; and
- Scenario I, the complete rail network at 2050, appears to have an EIRR of about 5% although the total rail network costs are very uncertain and maybe higher than the assumed $50 billion.

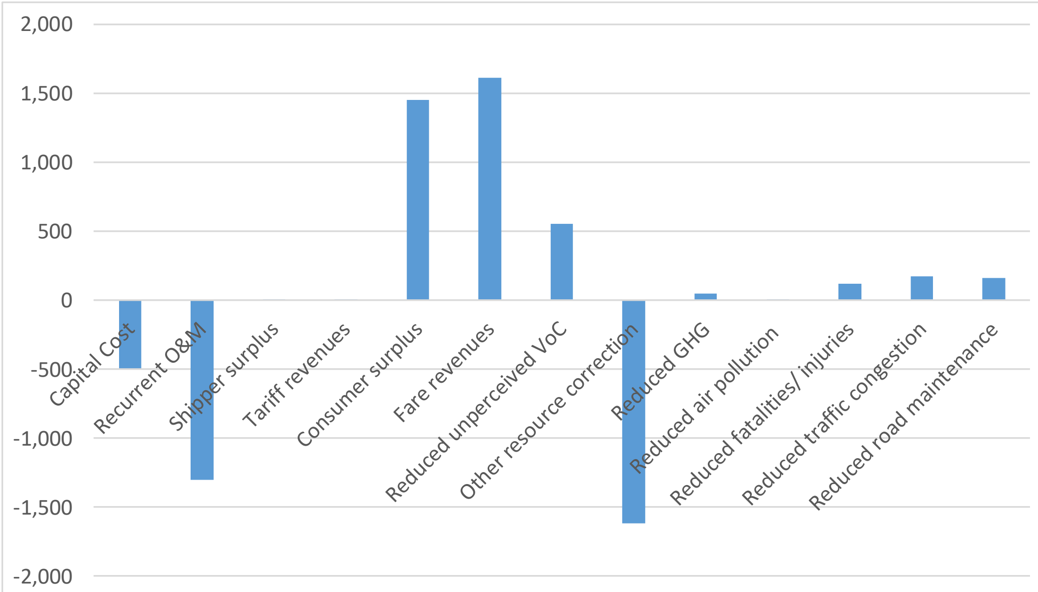
115. Project 5 is currently under construction and no evaluation was undertaken.

**Figure VI.2: Present Value of Costs & Benefits (USD m) for Project 9 – 2025 opening**




Source: TA team

**Figure VI.3: Present Value of Costs & Benefits (USD m) for Project 1 – 2025 opening**




Source: TA team

## B. FINANCIAL ANALYSIS

116. A pre-feasibility level financial analysis was also carried out. In contrast to the economic analysis only potential revenues and direct financial impacts were taken into account. In the first instance the ability of net project related revenues (i.e. revenues minus O&M costs) to amortize the project investment were assessed. The financial decision criteria included: financial Net Present Value (FNPV), Financial Internal Rate of Return (FIRR), and ability for project-revenues to recover O&M and reinvestment costs.[62] Appendix C also shows the main financial analysis results.

117. Projects 9 and 1, the two most economic projects, also exhibit the highest FIRRs:

- **Project 9 –** has the strongest financial case with an estimated FIRR of about 11.6% with an opening year of 2025 due to a high, established demand and relatively low capital costs. This FIRR rises to 17.2% for an opening year of 2040.
- **Project** 1 – has an estimated FIRR of 2.5% at 2025 and 6.3% with an opening year of 2040.

[62] This criterion is a measure of financial sustainability for a project after the initial investment is carried out.

118. The full financial results for these two projects and results of the key sensitivity tests are shown in Table VI.4. Even though the main financial evaluation of project 9 shows a good FIRR for 2025 opening, an increase in cost of 40% or a reduction in demand and revenues of 30%, indicates that the project would not be financial with a significantly negative FNPV. Project 1 has a respectable main FIRR for 2040 it would also be sensitive to reductions in cost and demand.

119. Due mainly to the high capital costs, but also demand risks, the other projects are not able to amortize the majority of their initial investments as shown in Appendix C.

**Table VI.4: Financial Evaluation Results for Projects 9 and 1 (opening year 2025)**

| Case | Project 9 | | Project 1 | |
|---|---|---|---|---|
| | FIRR | FNPV ($m) | FIRR | FNPV ($m) |
| **With best estimate of benefits using a discount rate of 10%** | **10.9%** | **61.8** | **2.5%** | **-373.0** |
| *Sensitivity tests* | | | | |
| 1. Use a discount rate of 4% | 10.9% | 992.1 | 2.5% | -149.4 |
| 2. Use a discount rate of 15% | 10.9% | -167.4 | 2.5% | -397.2 |
| 3. Increase costs by 40% | na | -950.3 | na | -921.1 |
| 4. Decrease costs by 10% | 14.7% | 314.8 | 5.3% | -235.9 |
| 5. Increase benefits by 10% | 14.3% | 321.0 | 5.0% | -273.2 |
| 6. Reduce benefits by 30% | na | -715.8 | na | -672.2 |
| 7. Reduce benefits by 30% & costs up 40% | na | -1,727.9 | na | -1,220.4 |

Source: TA team; not available since cannot be calculated.

120. The second financial assessment examined whether project-related revenues can recover O&M costs and, if not, how much recurrent public support would be required. As shown in Appendix C, net revenues (including savings in road maintenance costs) were estimated to exceed rail train O&M costs, including interest and depreciation charges and track maintenance by about 20%. It was therefore concluded that there are good prospects that projects once implemented would have sufficient revenues (or equivalent in reduced road maintenance costs) to be able to continue to service their ongoing recurrent costs.

## C. CONCLUSION

121. Based on the above analysis, principally the economic analysis, the priority project groupings are:

- 'A' being the highest priority – projects 9 and 1;
- 'B' being the second priority – projects 6 and 2; and
- 'C' representing the third or lowest priority – projects 3, 4 and 7 + 8.

122. This three level grouping of priorities does not fully account for country attitudes although the August 2017 workshop of GMS railway representatives that also identified a feasible sequence of network development as shown in Figure III.1 partly takes into account the perspectives of each country. The prioritization also does not take account of environmental and social issues.

**Table VI.5: Project Priorities**

| Projects | Name | Priority |
|---|---|---|
| 9 | Hekou – Lao Cai | A |
| 1 | Phnom Penh – Poipet - Thailand | A |
| 6 | Vientiane – Vu Ang | B |
| 2 | HCMC – Phnom Penh | B |
| 3 | Dawei – Laem Chabang | C |
| 4 | Kunming – Mandalay | C |
| 7 & 8 | Cambodia – Thailand – Viet Nam | C |

Source: TA team: Note: Project 5 is currently under construction as is Project 4 (on PRC side).

# VII. ENVIRONMENTAL AND SOCIAL SCREENING

123. This section summarizes the findings of the high-level environmental and social screening of the rail missing link projects. Specific comments on each of the links are provided in Table E.1 in Appendix E. Overall, the issues identified are all considered to be amenable to mitigation through careful project planning and management of implementation. A summary of the significant impacts is provided below.

1. **Biodiversity impacts.** Figure _ shows the biodiverisity areas in the GMS. Construction of the following links may have an impact on GMS biodiversity conservation initiatives.
   - No. 3. Dawei (MYA) - Ban Phu Nam Ron (THA)
   - No. 6. Vientiane - Thakhek (LAO) - Mu Gia - Vung An (VIE)
   - No 7. Thakhet-Pakse (Lao) – Savannakhet - Lao Bao - Dong Ha (LAO/VIE)
   - No 8. Pakse-Don Kralor (LAO) - Voun Kam-Snuol (CAM)

2. **Energy efficiency.** Studies undertaken by the International Energy Agency (IEA) and the International Union of Railways (UIC) [63]have shown the railway transportation is significantly more energy efficient when transporting large volumes of passengers or freight. Shifting passenger and freight demand onto railways from other modes (in particular short-haul aviation and long-haul trucking) is an effective way to make transportation more carbon efficient. Electrified railways are even more (15-30%) energy efficient than diesel-electric operations. Electrification of the railway links and associated lines should be considered where power supply is reliable.

3. **Re-settlement.** All of the developments, (including the rehabiliation of existing associated lines) will involve some degree of re-settlement. For safety and operational reasons, the right of way for new tracks should be (where practical) at least 50 meters either side of the track. The critical issues to be managed related to this are:
   - The need for advance planning and consultation with affected persons or households;
   - The need to develop effective compensation mechanisms for re-location and loss of income; and
   - Development of effective monitoring of re-settlement and compensation activites.

[63] The IEA estimates global averages for carbon intensity of passenger rail to be 30 - 60 gCO2eq/passenger-km (compared with 200 - 270 gCO2eq/passenger-km for air transport), and carbon intensity of freight rail to be 15 - 40 gCO2eq/tonne-km (compared with 190 - 300 gCO2eq/tonne-km for long distance trucking).

4. **Indigenous People.** Generally, construction of the missing links does not have a direct impact on a specific group of indigenous people – although there are indigenous people in each the project areas. The exception is link No. 4 between Lashio and Muse in Myanmar, which would be constructed in Shan State where the Shan State Army (SSA) is actively opposing the Union of Myanmar's military forces. As well, extension of the Lashio-Mandalay railway line to Kyauk Phyu has been mooted since 2010. This would involve construction of the railway line through Rakine State, which is the home of the Rohingya people, and currently a conflict area. (See Figure E.1 in Appendix E.)

# VIII. ANALYSIS OF PROCUREMENT MODALITES

124. An initial set of relevant risks to effective and efficient implementation and operations were identified. Relevant financing modalities were also identified and their ability to accommodate each type of risk was assessed qualitatively. The aim was to assess which financing modality would be likely to have the best Value for Money (i.e. least risk-adjusted Financial Net Present Value).

125. In conjunction with other members of the project team a range of potential risks were identified to project implementation and operation, taking into account the level of project preparation of each missing link, for example:

- Construction technical risk/ cost overrun and delay (optimism bias) due to unexpected changes in project scope, construction difficulties;
- Land acquisition delay;
- Environmental and social safeguards not implemented adequately;
- Train capital costs –risk of poor value for money;
- Demand risk – long ramp-up[64] and a lower level of demand than anticipated (optimism bias);
- O&M cost higher than anticipated or revenues lower due to competition, higher operating costs than anticipated; and
- Risk of poor integration of different lines and slow progress with cross-border facilitation.

126. All of the potential projects are highly vulnerable to these risks. Project 9, Hekou to Lao Cai, is the least vulnerable because of its low cost, short alignment and use of mainly existing rail corridor. Even though project 9 appears to have a good financial case in the main evaluation, if all risks were fully taken into account its actual financial performance would be lower. The other projects are expected to have poor financial performance without external financial support.

127. Consequently, a strong government role in financing infrastructure development, management of environmental and social safeguards, rail network management and regulation of rail operations appears important. However, there is good scope for involvement of the private sector or commercialized government corporations to supply trains, operate and maintain them and maintain rail track.

128. As this assessment in this TA is to a pre-feasibility level, the modalities for a mix of public and private financing and private sector participation needed to be realistic and provide insights into which modalities are likely to be most promising taking account of the qualitative assessment of risks. The above risks can be mitigated and managed by the choice of procurement and financing modality. A summary of the typical range of available public and financing modalities available for railways is shown in Table VIII.1. These vary from:

- **Public enterprise** – the whole project is implemented by the public sector as in many countries;
- **Public implementation with an operating concession** for train operations and maintenance of track and trains (example: Singapore);

[64] Period in which potential demand (i.e. passengers and freight shipping companies) adjust to the provision of new services, their prices and quality. Experience shows this ramp-up period can take from 1 to 3 years, and sometimes longer.

- **Public implementation with a train supply and operating concession** for trains with patronage and operating risk transferred (example: Purple Line mass transit Bangkok); and
- **Build-operate-transfer** (BOT or similar such as Build Lease Transfer) – net cost contract for whole project with private sector (example: Bangkok Skytrain).

129. The assessment of risks and how they would be mitigated by each of these four models is shown in Table VIII.2. Where governments are strong and capable, and given the likely general poor financial performance of projects, and the need for network integration, it would be desirable that governments retain control but seek to employ the private sector (or efficient state entities) to invest in trains and provide train operations and maintenance of trains and track. Thus, the third option of **Public Implementation with a Train Supply and Operating Concession** would be preferred**.** This option appears to provide the greatest amount of manageable risk transfer and is therefore likely to provide the most Value for Money.

**Table VIII.1: Features of Potential Delivery and Financing Models**[65]

| | Public Enterprise | Public Implementation with Operating Concession | Public Implementation with Train Supply and Operating Concession | Build, Operate & Transfer |
|---|---|---|---|---|
| **Delivery of:** | | | | |
| Civil Infrastructure and Fixed Equipment | Delivered through competitively tendered contracts to the government. | | | Delivered through competitively tendered *Net Cost* contract to the government. |
| Trains, train control and communications, and depot equipment | Delivered through competitively tendered contracts to the government. | | Delivered through a competitive tendered *Gross Cost* concession. | |
| Train services and infrastructure maintenance | Contract negotiated with a State-owned Enterprise (SOE). | Competitively tendered *Gross Cost* contract. | | |
| **Risk Transfer** | | | | |
| | Transfer of risk from the government is limited to the extent allowed in construction and equipment supply contracts. The government retains risk associated with operations through its ownership of the operator. | As for the Public Enterprise option but can transfer operating risk to the concessionaire. Some patronage risk can be transferred through the *Gross Cost* concession. The government retains operating risk related to mismatch between trains it provides and concessionaire needs. | The government transfers more risk to the concessionaire than in the PIOC option because the concessionaire purchases trains and can therefore bear more risk for operations because they have more control over service quality. | Transfers the greatest amount of risk from the government, but the government loses flexibility for change in policy and for public transport network integration. |

[65] A *Net Cost* concession involves a concessionaire providing train services and any assets that may be agreed, and covering the cost of these from revenue that it is able to collect from passengers and other agreed non-government sources. For example, a Build-Operate-Transfer (BOT) concession, or similar concession, awarded to a Special Purpose Vehicle (SPV) is a form of *Net Cost* concession. A *Gross Cost* concession involves the concessionaire providing train services and any assets that may be agreed, with the Authority paying the concessionaire the full cost of doing so and with the Authority retaining revenue that it is able to collect from passengers. A *concession* is a contract between the Public Authority and a concessionaire, where the latter is the organization that delivers train services (i.e. it includes the operator) and any other agreed activities.

| | Public Enterprise | Public Implementation with Operating Concession | Public Implementation with Train Supply and Operating Concession | Build, Operate & Transfer |
|---|---|---|---|---|
| **Finance** | | | | |
| Civil Infrastructure and Fixed Equipment | Capital provided by the government. | | Capital provided by the government. | Capital provided by the concessionaire. The government will need to pay for costs as specified in the contract (to cover both capital and O&M costs net of fare revenue, where fare revenue will be much less than the costs). |
| Trains, train control and communications, and depot equipment | Capital provided by the government. | | Capital provided by the concessionaire. The government pays for costs as specified in the contract (to cover both capital and O&M costs). | |
| Train services and infrastructure maintenance | The government pays all costs incurred by the SOE, including working capital | The government pays for operating and maintenance costs as specified in the contract. | | |
| Fare revenue | The government retains fare and other revenue (or pays SOE the difference between costs and revenue if the SOE retains the revenue). | Fare revenue accrues to the government. | | Concessionaire retains fare and other revenue. |

Source: RSC-C71557 (VIE), TA4862-VIE: Ho Chi Minh City Metro Rail System: Issues and Options for Private Sector Participation and Concession Template. Prepared for Asian Development Bank and Public Private Infrastructure Advisory Facility.

### Table VIII.2 Indicative Assessment of Delivery and Financing Models

| Criteria | Public Enterprise | Public Implementation with Operating Concession | Public Implementation with Train Supply and Operating Concession | Build, Operate & Transfer |
|---|---|---|---|---|
| **System Integration** | | | | |
| Minimize capital and operating costs | ✓ | ✓✓ | ✓✓✓ | ✓✓ |
| Provide integrated rail system for passengers | ✓✓✓ | ✓✓ | ✓✓✓ | ✘ |
| **Policy Flexibility for the Government** | | | | |
| Ability for the Authority to modify rail system | ✓✓✓ | ✓✓ | ✓✓ | ✘ |
| **Risk Transfer from the Government** | | | | |
| Civil infrastructure risk | ✓ | ✓✓ | ✓✓ | ✓✓✓ |
| Operating risk | ✘ | ✓ | ✓✓ | ✓✓✓ |
| Patronage risk | ✘ | ✓ | ✓✓ | ✓✓✓ |
| **Management of Operating Concession by the Government** | | | | |
| Firm contractual basis for operations | ✓✓ | ✓✓✓ | ✓✓✓ | ✓✓✓ |
| Ease of concession management | ✓✓✓ | ✓✓ | ✓✓ | ✓✓ |
| Incentive for contractor/-concessionaire to do the thing right | ✓ | ✓✓ | ✓✓✓ | ✓✓ |
| **Potential Value-for-Money** | | | | |
| Allowing for risk transfer, associated risk premiums and the cost of capital | ✓ | ✓✓ | ✓✓✓ | ✓✓ |

(1) Using a scale of up to 3 ticks, where 3 ticks indicates the best performance. A cross indicates the model cannot meet the criterion.

## IX. ACTIONS TO BRING PRIORITY RAIL LINKS TO TRANSACTION STAGE

130. As described in this report, this TA-9123 REG has, through establishing a good working relationship with the GMS railway representatives and the development of appropriate technical resources, been able to fulfil the 4 objectives of the TA:

(i) Prepare updated studies for the rail links;
(ii) Develop criteria to assess and prioritize the financing options for the viable rail links;
(iii) Identify potential financing modalities for the viable rail links; and
(iv) Identify actions needed to bring the priority rail links to transaction stage (as described below).

131. Two projects, 9 and 1, were shown to have high economic priority due to their relatively low capital cost and potentially high demand, even after allowing for upgrading of associated connecting domestic railway links. Project 9 is currently being studied by a joint PRC – Viet Nam feasibility study but to date the results have not been made available to this TA's study team.

132. Further technical work is needed to confirm their suitability for being taken to a more detailed level of feasibility study, and project preparation. However, a key first step was that at the GRMA Board meeting held during March 2018, in Vientiane, Lao PDR, there was general support shown for the priorities. Since that time, high-level environmental and social screening was carried out. The identified the issues identified are all considered to be amenable to mitigation through careful project planning and management of implementation.

133. Whatever projects are endorsed by the GRMA additional actions following this TA will be needed to bring the projects to transaction stage:

- Stakeholder analysis;
- Update demand forecasts and tariff studies using recent statistics and survey of passenger and freight movements in each corridor;
- Prepare freight and passenger fleet and operating needs and costs;
- Undertake engineering design and costing to at least detailed design level;
- Analyze and propose implementation arrangements – undertake capacity assessments for financial management and procurement;
- Update economic and financial analysis to confirm priority;
- Analyze procurement and financing modalities to assess the most efficient way of implementation and operation;
- Undertake environmental and social assessments; and
- Undertake detailed assessments of all risks and propose a risk mitigation plan.

## X. NEXT STEPS

134. The TA is scheduled to be completed by September, 2018. Future work is desirable to: (i) establish the preferred organization structure of the GMRA; (ii) develop an operational readiness plan for GMRA; (iii) update the GMS railway strategy; and (iv) update the GMS transport demand model.

## APPENDIX A: CAPITAL COST REVIEW

### Table A.1: Estimated Capital Costs of Missing Link Upgrading

| Link | | Construction - New Tracks | | | Small Bridges & Culverts | | Major Structures (large bridges, tunnels)[2] | Border stations | Other (EDI Systems, etc) | Rehabilitation of Existing National Network | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | kilometers[1] | Amount | | kilometers | Amount | | | | kilometers[1] | Amount | Other (bridges, etc) | |
| 1 | CAM | 6.6 | 33.0 | | | | | 1.0 | 1.0 | 346.5 | $ 519.8 | $ 75.0 | $ 629.8 |
| | THA | | | | | | | 1.0 | 1.0 | | | | $ 2.0 |
| 2 | CAM | 283.8 | 1419.0 | 14.2 | 10.0 | 75.0 | 300.0 | 1.0 | 1.0 | 11.0 | $ 16.5 | | $ 1,826.7 |
| | VIE | 141.9 | 709.5 | 7.1 | 5.0 | 37.5 | | 1.0 | 1.0 | 1898.6 | $ 2,847.9 | | $ 3,604.0 |
| 3* | MYA | | | | | | | | | | | | $ 5,500.0 |
| | THA | | | | | | | | | | | | |
| 4 | MYA | 156.0 | 779.9 | 9.3 | 33.0 | 247.5 | 350.0 | 2.5 | 1.0 | 344.3 | $ 516.5 | | $ 1,906.6 |
| | PRC | 4.4 | 22.0 | 1.5 | 1.0 | 7.5 | | 2.5 | 1.0 | 361.9 | | | $ 34.5 |
| 5 | PRC | | | | | | | | | | | | |
| | LAO | 458.7 | 2293.5 | 22.9 | 20.0 | 150.0 | 3500.0 | 1.0 | 1.0 | | | | $ 5,968.4 |
| 6 | LAO | 495.0 | 2475.0 | 24.8 | 10.0 | 75.0 | | 1.0 | 1.0 | | | | $ 2,576.8 |
| | VIE | 130.9 | 654.5 | 6.5 | 5.0 | 37.5 | | 1.0 | 1.0 | 1898.6 | $ 2,847.9 | | $ 3,548.4 |
| 7 | LAO | | | | | | | | | | | | $ 11,106.0 |
| | VIE | | | | | | | | | | | | |
| | THA | | | | | | | | | | | | |
| 8*** | LAO | | | | | | | | | | | | $ 2,000.0 |
| | CAM | | | | | | | | | | | | |
| 9 | VIE | 1.7 | 8.5 | | | | | 2.5 | 1.0 | 425.7 | $ 638.6 | | $ 650.5 |
| | PRC | | | | | | | 2.5 | 1.0 | | | | $ 3.5 |
| Totals | | 1679.0 | 8394.9 | 86.3 | 84.0 | 630.0 | 4150.0 | 17.0 | 11.0 | 5286.6 | $ 7,387.1 | $ 75.0 | $ 39,357.2 |

* Includes construction of missing link and rehabilitation of associated main tracks as noted.

Notes: (i) Costs for projects 3 and 7 & 8 (these two need to be developed together) were based on existing studies with the resultant capital costs shown in Section III. These projects are unlikely to be feasible before 2050; (ii) For project 2: A meeting of transport ministers of Viet Nam and Cambodia in February 2018, decided to change the alignment of link 2 to connect Phnom Penh and Ho Chi Minh City via Barvet in Cambodia rather than Snoul reducing the total length by about 140 km. The new alignment runs through sensitive environmental areas and will parallel the alignment of a proposed expressway. Functionally, link 2 as formulated originally and as investigated in this TA, and the new alignment would be expected to have a similar demand, but the link 2 investigated here would have a higher cost. The possibility of the lower cost was covered by the sensitivity testing in the economic and financial evaluations carried out in this TA. The environmental and social issues associated with the new alignment would need to be satisfactorily addressed.

Source: TA team based on capital cost review in June 2018

## APPENDIX B: ECONOMIC ANALYSIS PARAMETERS

Key parameters required for the economic evaluation are the unit rates and other items required to estimate the value of changes in new freight and passenger train purchase, and associated operating and maintenance costs, road vehicle operating costs (VOCs), consumer surplus for passenger travel (travel time), shipper surplus for freight switching to rail, vehicle emissions and road accidents.

**Standard Conversion Factor.** Financial costs below (and capital cost) converted to economic costs using a Standard Conversion Factor (SCF) of 0.90.

**Capital costs.** These were adopted for each project based on the available information. Investments were assumed to be implemented over five years. In the 10th and 20th years periodic refurbishment is assumed to be required at 20% of initial capital costs. At the end of the 30 year evaluation, the residual value was assumed to be realized in year 31 based on an economic life of 50 years, and using a straight line depreciation approach. The SCF was used to convert the project cost to economic terms.

**Rail track maintenance costs.** Track maintenance costs varies with freight traffic volume. Using Australian data, track maintenance per kilometre (USD in 2017) were assumed to have a fixed component of $10,000/km and a variable component of $1,000 per million tonnes per annum of freight carried. (Source: ARTC Melbourne–Brisbane Inland Rail Alignment Study Final Report July 2010, Appendix K, Operating Cost of Infrastructure)

**Train operating costs.** Both passenger and freight train capital and operating and maintenance costs were estimated using information obtained from several sources.[66] The resultant O&M costs were expressed in terms of 1,000 Gross Tonne-Km (GTK) for freight trains and 1,000 passenger-km for passenger trains. These values are shown below and include initial purchase, periodic refurbishment and replacement costs. Crew costs for 2017 were estimated in 2017 prices from various sources and projected to 2050 based on projections of real GDP per capita. Refer tables below.

**Vehicle operating costs.** These were estimated for large car, large bus, and large rigid truck (15 tonne payload) using the HDM-4 VOC model for a inter-urban highway in fair to good condition (at 70kph). Vehicle operating costs for a large articulated truck, (B-double with 45 tonne payload) that is considered likely to be common in coming years as roads are improved and cross-border facilitation takes effect, were adopted from Australia[67]. Crew costs for 2017 were estimated in 2017 prices from various sources and projected to 2050 based on projections on real GDP per capita. Refer tables below.

**Benefit of freight switching to trains.** It is quite likely that travel times by train will not be significantly faster than by road due to the need to transport goods to rail terminals and due to the relatively short corridors with steadily improving roads. However, cross border rail and train services today and when the first links are open, they will represent a new mode, that would attract some bulk or container traffic even if rail is slower than road. Rail offers a range of

[66] A survey of train purchase and operating costs was sent to all GMS railway organizations to which the State Railways of Thailand and Ministry of Transport, Cambodia responded. Additional information was obtained via an interview with Richard G. Bullock railway specialist on PRC's passenger and freight train operations plus comparable railway operations in Australia.

[67] Austroads 2015. National Guidelines for Transport System Management in Australia - Road Parameter Values [PV2].

benefits including the ability to handle large surges in (e.g. agricultural demand), reduced congestion in ports especially in the vicinity of urban areas, and higher reliability. Consequently, even if new rail is no faster than road on average, any tonne of freight transferred to rail must have a benefit. This was estimated as follows. Vehicles delayed at ports or border crossings incur a cost apart from passenger delay and crew working time costs. For trucks, delay costs were assumed to be represented by fuel costs while idling and moving slowly in queues, labour costs plus 50% of depreciation allocated to hours driven per annum. Estimated standing costs per hour including VOC and values of time vary from $1.1 for motorcycles and $5.2 for cars (both assuming no worked or business time), $9.0 for a heavy truck to $28.1 for large buses. The values for heavy trucks were used to estimate the impact of a 12 hour delay of a heavy truck with a 15 tonne payload at a port or terminal. A delay of 12 hours for a heavy truck was therefore estimated at $108 or $7.2 tonne. Taking into the probability of a delay, assumed at 10%, indicated the impact of delay at terminals is around $0.7 per tonne. Values up to $1.40/ tonne can be obtained if storage of goods is required for a day, for example, that may be incurred if a scheduled sailing from a port is missed due to congestion. It is likely that the perceived value of rail is even higher – a flat value of $2/ tonne was adopted for 2017 and future years (i.e. irrespective of haul length, given sources of delay are usually round ports, urban areas and specific locations. In addition, an opportunity cost of freight in transit of $0.30 per tonne-hour was used and is at the top of the range suggested by the HDM-4 default value for Asia to take account the potential for development in the economic corridors.

**Value of passenger (non-working) time.** A suitable equity-based value of non-work time for GMS in 2015 was estimated at $1.40 per person-hour for all vehicle types (including new passenger train services). These values were updated to account for rising incomes in future. Diversion to new train passenger services is assumed to occur only from buses with an average occupancy of 45 persons. New fast, comfortable train services in which passengers can effectively utilize their time, are likely to attract lower values of time than bus (or cars), thus accentuating the benefits of new train services. To account for this effect, an uplift factor of 1.50 was applied to estimated passenger travel time benefits (i.e. passenger consumer surplus).

**Rail freight and passenger revenues.** Revenues from new freight traffic and passengers accruing to new rail services are a transfer payment that are commonly shown as an economic benefit (as well as a financial benefit) to a new railway enterprise. However, if freight tariffs and passenger fares are shown as a benefit, they must be subtracted from the total economic benefit as a resource correction. This was the approach adopted in the current evaluations.

**Road injury rates**. Based on relevant experience, the road injury rate was assumed to be three fatalities and 30 serious injuries per 100 million VKT. World Bank 2008 suggests a central estimate of 70 x GDP per capita of $3,100 per capita (2015 prices) or $216,000 (in 2017 prices). Serious injuries were valued at 25% of the value of a fatality. These values were inflated over time to reflect increases in real income.

**Other benefits.** Reduced GHG emissions, vehicle emissions, road maintenance and road congestion are estimated to represent less than 15% of total benefits. The parameter values adopted are shown below.

**Daily to annual conversion factors.** A factor of 365 was adopted to convert daily demand figures to annual figures.

Summary of Key Parameter Values

**Values of non-working time ($/hour for adult, economic in 2017 prices)**

| | PRC | Thailand | Myanmar | Lao PDR | Vietnam | Cambodia | Ave. |
|---|---|---|---|---|---|---|---|
| 2017 | $3.4 | $2.3 | $0.5 | $0.9 | $0.8 | $0.5 | $1.4 |
| 2020 | $3.6 | $2.5 | $0.6 | $1.0 | $1.0 | $0.6 | $1.6 |
| 2025 | $5.1 | $3.1 | $0.9 | $1.5 | $1.4 | $0.8 | $2.1 |
| 2030 | $7.1 | $3.8 | $1.2 | $2.0 | $2.0 | $1.1 | $2.9 |
| 2035 | $10.0 | $4.6 | $1.7 | $2.8 | $2.6 | $1.5 | $3.9 |
| 2040 | $14.0 | $5.6 | $2.3 | $3.8 | $3.5 | $2.0 | $5.2 |
| 2045 | $18.7 | $6.8 | $3.1 | $5.3 | $4.7 | $2.6 | $6.9 |
| 2050 | $25.1 | $8.3 | $4.3 | $7.2 | $6.3 | $3.5 | $9.1 |

Source: Ken Gwilliam, The Value of Time in Economic Evaluation of Transport Projects, Infrastructure Note – Transport No. OT-5, World Bank, 1997, coupled with household GDP figures.

**Train crew (financial in 2017 prices)**

| | PRC | Thailand | Myanmar | Lao PDR | Vietnam | Cambodia | Average |
|---|---|---|---|---|---|---|---|
| 2017 | $3.5 | $3.0 | $1.2 | $1.5 | $2.2 | $1.2 | $2.1 |
| 2020 | $3.7 | $3.3 | $1.5 | $1.8 | $2.6 | $1.4 | $2.4 |
| 2025 | $5.2 | $4.0 | $2.1 | $2.5 | $3.6 | $2.0 | $3.2 |
| 2030 | $7.3 | $4.9 | $3.0 | $3.5 | $5.1 | $2.8 | $4.4 |
| 2035 | $10.2 | $5.9 | $4.1 | $4.7 | $6.8 | $3.7 | $5.9 |
| 2040 | $14.4 | $7.2 | $5.6 | $6.5 | $9.2 | $5.0 | $8.0 |
| 2045 | $19.2 | $8.8 | $7.6 | $8.9 | $12.2 | $6.7 | $10.6 |
| 2050 | $25.7 | $10.7 | $10.4 | $12.2 | $16.4 | $8.9 | $14.1 |

Source: Data from Cambodian MOT, Viet Nam Statistics office, PRC information on train driver salaries, Thailand State Enterprise driver salaries, and relative GDP per capital income between countries. Information above based on 2 persons were crew.

### Rollingstock Capital Costs (financial in 2017 prices)

For the purposes of the economic and financial evaluations, the capital costs of rollingstock were adopted as shown below:

Cost per locomotive: $3 million
Cost per freight wagon: $80,000
Cost per coach: $700,000

These costs are conservative and could be as much as 20-40% higher.

### Freight train operating costs (financial in 2017 prices)

| O&M costs per unit freight ($/1000 net tonne-km) | Adopted values |
|---|---|
| 2017 | $17.8 |
| 2025 | $17.9 |
| 2050 | $19.1 |

Note: assumed directional loadings 80%:20%

### Passenger train operating costs (financial in 2017 prices)

| O&M costs per unit ($/1000 passenger-km) | Adopted values |
|---|---|
| 2017 | $27.9 |
| 2025 | $28.1 |
| 2050 | $29.1 |

Note: assumed directional loadings 50%:50%

### Commercial vehicle operating cost ($/km), financial in 2017 prices

| | PRC | Thailand | Myanmar | Lao PDR | Vietnam | Cambodia | Ave. |
|---|---|---|---|---|---|---|---|
| **2017** | | | | | | | |
| ***Excluding labour*** | | | | | | | |
| Cars (large) | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 |
| Heavy truck | $0.53 | $0.53 | $0.53 | $0.53 | $0.53 | $0.53 | $0.53 |
| B-double | $1.60 | $1.60 | $1.60 | $1.60 | $1.60 | $1.60 | $1.60 |
| Large bus | $0.44 | $0.44 | $0.44 | $0.44 | $0.44 | $0.44 | $0.44 |
| ***2017 including labour at 70kph*** | | | | | | | |
| Cars (large) - no labour | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 |
| Heavy truck | $0.57 | $0.57 | $0.54 | $0.54 | $0.55 | $0.54 | $0.55 |
| B-double | $1.63 | $1.64 | $1.61 | $1.61 | $1.61 | $1.61 | $1.62 |
| Large bus | $0.48 | $0.49 | $0.45 | $0.46 | $0.46 | $0.45 | $0.46 |
| ***2020 including labour*** | | | | | | | |
| Cars (large) - no labour | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 |
| Heavy truck | $0.57 | $0.58 | $0.54 | $0.55 | $0.55 | $0.54 | $0.55 |
| B-double | $1.64 | $1.65 | $1.61 | $1.62 | $1.62 | $1.61 | $1.62 |
| Large bus | $0.48 | $0.49 | $0.45 | $0.46 | $0.46 | $0.45 | $0.47 |
| ***2025 including labour*** | | | | | | | |
| Cars (large) - no labour | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 |
| Heavy truck | $0.58 | $0.59 | $0.55 | $0.55 | $0.56 | $0.55 | $0.56 |
| B-double | $1.65 | $1.66 | $1.62 | $1.62 | $1.62 | $1.61 | $1.63 |
| Large bus | $0.49 | $0.50 | $0.46 | $0.46 | $0.47 | $0.46 | $0.47 |
| ***2050 including labour*** | | | | | | | |
| Cars (large) - no labour | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 | $0.36 |
| Heavy truck | $0.78 | $0.68 | $0.61 | $0.64 | $0.64 | $0.59 | $0.66 |
| B-double | $1.85 | $1.75 | $1.68 | $1.71 | $1.71 | $1.66 | $1.73 |
| Large bus | $0.69 | $0.59 | $0.52 | $0.55 | $0.55 | $0.50 | $0.57 |

Source: Analysis using World Bank's HDM RUC Model Version 200 plus data on driver/ crew incomes for Viet Nam, PRC and Thailand and GDP per capita data between countries. B Double operating costs for vehicle only adopted from Austroads 2015. National Guidelines for Transport System Management in Australia - Road Parameter Values [PV2]. For other analyses, heavy trucks were assumed to have a payload of 15 tonnes and a B Double 45 tonnes. Buses were assumed to have an average passenger load of 45 persons. Trucks were assumed to have a loading pattern by direction of 80%:20% as for freight trains and buses 50%:50% the same as passenger trains.

### Values of GHG per VKT avoided (cents/ VKT), economic in 2017 prices

| Vehicle type | Total value of GHG in cents per VKT avoided |
|---|---|
| Cars (gasoline) | 1.08 |
| B Doubles (diesel) | 5.54 |
| Heavy rigid trucks (diesel) | 5.21 |
| Buses (diesel) | 5.34 |

Note: Based on $50/tonne avoided GHG

## Air pollution costs, economic in 2017 prices

Vehicle air pollution damage costs (particulate matter)

| | PRC | Thailand | Myanmar | Lao PDR | Vietnam | Cambodia | Ave. |
|---|---|---|---|---|---|---|---|
| **2017** | | | | | | | |
| Heavy truck | $0.1596 | $0.1985 | $0.0403 | $0.0604 | $0.0691 | $0.0371 | $0.0000 |
| Large bus | $0.5947 | $0.7396 | $0.1500 | $0.2250 | $0.2573 | $0.1384 | $0.0009 |
| **2025** | | | | | | | |
| *Assumed technological improvement factor* | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | |
| Heavy truck | $0.1198 | $0.1490 | $0.0302 | $0.0453 | $0.0519 | $0.0279 | $0.0050 |
| Large bus | $0.4466 | $0.5554 | $0.1126 | $0.1689 | $0.1932 | $0.1039 | $0.0007 |
| **2040 and later** | | | | | | | |
| *Assumed technological improvement factor* | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | |
| Heavy truck | $0.0900 | $0.1119 | $0.0227 | $0.0340 | $0.0389 | $0.0209 | $0.0050 |
| Large bus | $0.3353 | $0.4171 | $0.0846 | $0.1269 | $0.1451 | $0.0780 | $0.0005 |

Source: Based on Table 1 contained in Sustainable Transport Initiative 2011, Note on Air Pollution (draft), prepared by the STI team ADB.

Rail air pollution emission rate (particulate matter)

European Loaded Freight Train 2000 - diesel, bulk

| **Grams/ MJ fuel 2000** |
|---|
| 0.05 |

Source: Huib van Essen, Olivier Bello, and Robert van den Brink, 2003. To Shift or Not to Shift that's the question. Delft.

Health damage cost due to particulate matter emissions from trains not calculated as damage costs are low and only applicable in urban areas or where exposed populations are large.

## Train fuel consumption and GHG emissions

| Parameter | Value |
|---|---|
| Fuel consumption (litres) per 1000 GTK | 4.5 |
| GHG tonnes/1000 GTK | 0.0120 |
| Value of GHG at $50/tonne in $/ 1000 GTK | $0.60 |

Source: fuel consumption from “Train O&M model”.

## Interim values for estimating value of life and injury for use in economic evaluation

| Item | Lower estimate | Central Estimate | Upper estimate |
|---|---|---|---|
| Value of a road crash Death | 60 x GDP /capita | 70 x GDP/capita | 80 x GDP /Capita |
| Value of a road crash Serious injury | 12 x GDP/capita ( = 20% of value of a death ) | 17 x GDP/Capita (=25% of value of a death) | 24 x GDP/Capita ( =30% of value of a death ) |
| Number of serious injuries to each death | 8 | 10 | 12 |

Source: McMahon, K. and Dahdah, S. 2008. The True Cost of Road Crashes: Valuing Life and the Cost of a Serious Injury. Prepared for World Bank.

**Adopted values of road fatalities and injuries, economic in 2017 prices**

| Values | Mid 2017 |
|---|---|
| $/life | $216,533 |
| $/serious injury | $54,133 |
| **Number saved per 100M VKT avoided** | |
| Lives | 3 |
| Serious injuries | 30 |
| **Value of saved per 100M VKT avoided 2025** | |
| Lives $ | $1,218,248 |
| Serious injuries $ | $3,045,622 |
| **Value of saved per 100M VKT avoided 2050** | |
| Lives $ | $4,973,715 |
| Serious injuries $ | $12,434,288 |

Source: Table above and GDP per capita figures and projections

**Road maintenance costs, economic in 2017 prices**

$0.15 per heavy vehicle km avoided – based on Table 3.5, Transport for New South Wales 2013. Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives, Transport Economic Appraisal Guidelines.

**Road de-congestion benefits, economic in 2017 prices**

$ per avoided VKT (passenger car unit-equivalent, pcu) 2017

| | |
|---|---|
| Heavy Congestion | $1.00 |
| Moderate Congestion | $0.70 |
| Light Congestion | $0.20 |

Value for light congestion adopted and applied to urban/ congested segments of line haul trip – assumed at 20% of the line haul distance.

## APPENDIX C: ECONOMIC AND FINANCIAL ANALYSIS OUTPUTS

Table C.1: Economic and Financial Results 2025 Opening

| | Case A | Case B | Case C | Case D | Case E | Case F | Case G | Case Ha | Case Hb |
|---|---|---|---|---|---|---|---|---|---|
| **Projects>** | **1** | **2** | **1+2** | **4** | **5** | **6** | **9** | **7+8** | **3** (information based on SRT feasibility study) |
| Capital cost (USD M) | 632 | 5,431 | 6,064 | 1,941## | 5,968 | 6,125 | 654 | 13,106 | 6,000 |
| Earliest implementation start date | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 |
| Earliest opening date | 2025 | 2025 | 2025 | 2025 | 2025 | 2025 | 2025 | 2025 | 2025 |
| **Rail Demand (from model) for opening date** | | | | | | | | | |
| Pax p.a. x 1000 | 5,104.5 | 3,313.3 | 7,027.3 | 2,739.3 | 3,446.2 | 4,828.9 | 12,524.8 | n.a. | - |
| Pax-hrs p.a. x 1000 | 33,095.2 | 23,092.0 | 54,761.1 | 20,992.7 | 19,191.9 | 31,863.9 | 82,646.1 | n.a. | - |
| Pax-km p.a. x 1000 | 2,316,666.0 | 1,616,43.0 | 3,833,280.0 | 1,469,490.0 | 1,343,430.0 | 2,230,470.0 | 5,785,230.0 | n.a. | - |
| Freight tonnes p.a. x 1000 | 11.2 | 2.3 | 126.7 | 2.05 | 171.6 | 4,136.2 | 2,866.0 | n.a. | Low: 18,400<br>High: 53,600 |
| Freight tonne-hrs p.a. x 1000 | 65.3 | 14.0 | 872.7 | 12.7 | 986.7 | 23,783.1 | 16,479.7 | n.a. | - |
| Freight tonne-km p.a. x 1000 | 4,573.9 | 980.1 | 61,092.9 | 891.0 | 69,069.0 | 1,664,817.0 | 1,153,581.0 | n.a. | - |
| **Economic Corridor Uplift Factor (included above)** | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |
| **Economic results** | | | | | | | | | |
| EIRR | 10.1% | n.a. | 3.9% | <1.7% | n.a. | -3.1% | 24.4% | n.a. | 2.5% |
| NPV (@ 10% p.a #.) USD millions | 8.5 | -3,934 | -2,677 | <-1,123 | -4,254 | -3,067 | 1,456 | n.a. | - 4.7 bn |
| BCR (@ 10% p.a.#) | 1.01 | 0.16 | 0.69 | <0.34 | 0.12 | 0.42 | 1.64 | n.a. | 0.32 |
| **Financial results** | | | | | | | | | |
| FIRR | 2.5% | n.a. | n.a. | n.a. | n.a. | n.a. | **10.9%** | n.a. | Low: -1.4%<br>High: 6.25% |
| NPV (@ 10% p.a #.) USD millions | -373 | -4,586 | -4,672 | <-1,621 | -5,117 | -4,954 | 61.8 | n.a. | Low: -2.9 bn<br>High: 1.9 bn |
| Recurrent revenue/ O&M cost ratio (@ 10% p.a. #) | 1.21 | 1.22 | 1.24 | <1.3 | 1.2 | 1.2 | 1.3 | n.a. | n.a. |

*# Except project 3 which uses a 12% p.a. discount rate for the economic calculation and the weighted average cost of capital of 3.56% p.a. for the financial analysis*
*## Excludes costs of all needed domestic upgrades that are not fully known.*

## Table C.2: Economic and Financial Results 2040 Opening

| | Case A | Case B | Case C | Case D | Case E | Case F | Case G | Case Ha | Case Hb | Case I |
|---|---|---|---|---|---|---|---|---|---|---|
| **Projects>** | **1** | **2** | **1+2** | **4** | **5** | **6** | **9** | **7+8** | **3** | **All + Domestic High Speed Train at 2050** |
| Capital cost (USD M) | 632 | 5,431 | 6,064 | 1,941## | 5,968 | 6,125 | 654 | 13,106 | See above | >50,000 |
| Implementation start date | 2035 | 2035 | 2035 | 2035 | 2035 | 2035 | 2035 | 2035 | n.a. | 2035 |
| Opening date | 2040 | 2040 | 2040 | 2040 | 2040 | 2040 | 2040 | 2040 | n.a. | 2040 |
| **Rail Demand (from model) for opening date** | | | | | | | | | n.a. | |
| Pax p.a. x 1000 | 14,736.9 | 8,758.6 | 24,628.5 | 7,059.4 | 8,777.7 | 14,764 | 37,321.8 | 15,897.6 | n.a. | 106,628.3 |
| Pax-hrs p.a. x 1000 | 110,538.7 | 62,363.4 | 183,963.2 | 56,694.0 | 53,917.3 | 90,688.7 | 229,251.0 | 108,827.4 | n.a. | 645,870.3 |
| Pax-km p.a. x 1000 | 7,737,708.0 | 4,365,438.0 | 12,877,425.0 | 3,968,580.0 | 3,774,210.0 | 6,348,210.0 | 16,047,570.0 | 7,617,918.0 | n.a. | 45,210,924.0 |
| Freight tonnes p.a. x 1000 | 35.1 | 5.9 | 282.4 | 5.6 | 443.2 | 11,027.5 | 8,811.7 | 63.7 | n.a. | 67,285.7 |
| Freight tonne-hrs p.a. x 1000 | 267.1 | 39.4 | 2,243.3 | 35.8 | 2,777.2 | 69,102.5 | 55,217.5 | 395.2 | n.a. | 294,114.5 |
| Freight tonne-km p.a. x 1000 | 18,694.5 | 2,758.8 | 157,033.8 | 2,508.0 | 194,403.0 | 4,837,173.0 | 3,865,224.0 | 27,660.6 | n.a. | 20,588,016.9 |
| **Economic Corridor Uplift Factor (included above)** | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | n.a. | 1.1 |
| **Economic results** | | | | | | | | | n.a. | |
| EIRR | 19.5% | n.a. | 0.6% | < 5.2% | n.a. | 6.6% | 41.3% | n.a. | n.a. | 4.1% |
| NPV (@ 10% p.a #.) USD millions | 704 | -3,575 | -2,840 | <-698 | -3,813 | -1,614 | 3,477.0 | -8,349.2 | n.a. | -21,475.6 |
| BCR (@ 10% p.a.#) | 1.39 | 0.28 | 0.35 | <0.61 | 0.23 | 0.72 | 1.98 | 0.22 | n.a. | 0.51 |
| **Financial results** | | | | | | | | | n.a. | |
| FIRR | 6.3% | n.a. | n.a. | n.a. | n.a. | n.a. | 16.3% | n.a. | n.a. | n.a. |
| NPV (@ 10% p.a #.) USD millions | -204 | -4,508 | -4,900 | < -1,558 | -5,050 | -4,728 | 438.0 | -11,031.8 | n.a. | -40,618.8 |
| Recurrent revenue/ O&M cost ratio (@ 10% p.a. #) | 1.24 | 1.22 | 1.24 | <1.3 | 1.2 | 1.2 | 1.3 | 1.2 | n.a. | 1.2 |

*## Excludes costs of all needed domestic upgrades that are not fully known.*

**APPENDIX D: STRUCTURE OF THE MEKONG REGION TRANSPORT MODEL**

# I. INTRODUCTION

## A. An Overview

1. This appendix documents the structure of the Mekong Region Transport Model (MRTM). A user of the model is able to change the inputs to any model scenario by modification of the input keys discussed below.

## B. Hardware Specification

2. The following computer and hardware are used for running MRTM model for this ADB project is presented in Table D.1: Hardware Specifications

**Table D.1: Hardware Specifications**

| Specification | Description |
|---|---|
| Processor: | Intel i7 |
| Operating System: | WINDOWS 10 Pro |
| Hard Drive Storage: | 1 Tetra Byte |
| RAM | 16 Mega Byte |

Source: TA Team

## C. Software License Requirements

3. This MRTM model was developed using Citilab's Cube platform. The model runs under Cube version 6.4.3. There are only two software components required to run the entire model, that is, Cube Base and Cube Voyager. It is understood that the reader of this appendix has a basic understanding of this software platform. ADB has not to date purchased a software license.

## D. File Structure

4. The file structure directory of MRTM is shown in Figure D.1. The structure is organized under task sub directories with all files for that particular task within that sub directory. Besides the scenario directory in which the scenario results are housed, there are five other sub directories namely preparation, skim development, person generation, cargo generation and assignment. The file directory structure is organized in the same logical order as the model flowcharts.

**Figure D.1: MRTM Directory Structure**

Model

- 0.Preparation
  - 0.1Inputs -- Prepare background information
  - 0.2Networks -- Prepare master network for specific scenario
  - 0.3Economics -- prepare socio-economic data for specific scenario for each locality
- 1.Skim_Developmen
  - 1.1Person Highway --- Develop highway skims
  - 1.2Person Transit --- Develop transit skims
  - 1.3Person Cargo --- Develop cargo skims
- 2.Person_Movement
  - 2.1Generation -- Develop person trip generation for specified scenario
  - 2.2Distribution -- Develop person trip distribution for specified scenario
  - 2.3Mode Split -- Develop person mode split for specified scenario
- 3.Cargo_Movement
  - 3.1Generation -- Develop cargo trip generation for specified scenario
  - 3.2Distribution -- Develop cargo trip distribution for specified scenario
  - 3.3Mode split -- Develop cargo mode split for specified scenario
- 4.Assignment
  - 4.1 Convergence --Convergence for feedback loop
- Scenario -----Scenario specific inputs
  - 2015
  - 2025
  - 2050

Source: TA Team

## E. The Model Structure

5. The model itself is developed from a set of key regional data sources as documented in Table D.2. As stated earlier in the main documentation, no new survey data collection was undertaken for this project. The model structure is shown in Boxes three through seven correspond model directory structure referenced in Figure D.2. Each of these boxes are the entrance flow points to the sub models of preparation, skim development, person generation, cargo generation and assignment. These sub models are discussed in the following five sections of this appendix document. The penultimate section of this Appendix tabulates the imbedded report structure and indicative results whilst the last section proposes future enhancements for the MRTM. It references a box in the CUBE flowchart for example, a three digit reference Box 5.2.5 refers to a level 3 flowchart box with the title, “Person Distribution.”

6. **Figure D.2**. It consists of a series of windows from left to right namely scenario, application, data, keys and the main model window.

7. The scenario window is the linkage to the scenario under evaluation. In its current format, the MRTM has been designed to examine the impact of twenty scenarios, nine in 2025 and ten in 2050 with a single base year scenario of 2015. It is thus designed to test nine rail projects in combinations or Scenarios. Scenario I as seen in Table is the scenario encompassing all railway projects.

8. The application window is the linkage to the applications in underlying model windows. This window allows quick access to the sub models such as Person Movement. The data

window is the linkage to the report structure and is discussed in further detail later in this appendix. The key window is the input to specific inputs related to each scenario. The keys are divided into three sets with reference to each studied scenario. The first of these three sets relates to a general input such as scenario model year and input network file. The second set relates to the availability of socio-economic data via locality whilst the final set is the input for the characteristics of the higher speed passenger rail service hereafter referred to as HSR.

**Table D.2: The Scenarios**

| Scenario Case | Year | |
|---|---|---|
| | **2025** | **2050** |
| Base | No Projects | No Projects |
| A | 1 | 1 |
| B | 2 | 2 |
| C | 1+2 | 1+2 |
| D | 4 | 4 |
| E | 5 | 5 |
| F | 6 | 6 |
| G | 9 | 9 |
| H | - | 3, 7 and 8 |
| I | All Projects above | All Projects above plus Coastal Higher Speed Rail |

Source: TA Team

**Table D.2: Regional Model Data Sources**

| Locality | Data Source |
|---|---|
| Cambodia | • Preparation Material for a Private Toll Road Study<br>• KOICA National Transport Plan, 2013 |
| Lao PDR | • The Comprehensive Study on Logistics System in Lao PDR, 2011 |
| Myanmar | • The Survey Program for the National Development Plan in the Republic of the Union of Myanmar, 2014 |
| Thailand | • Transport Data and Model Integrated with Multimodal and Logistics (TDL2), 2014<br>• Thailand Customs Data |
| PR China | • China Customs Data |
| Viet Nam | • The Comprehensive Study on the Sustainable Development of Transport System in Viet Nam (VITRANSS2), 2010 |
| Viet Nam/Lao PDR | • Interim Report of the Feasibility Study for the Railway Link from Vientiane in the Lao PDR to Vung Ang in Viet Nam, 2017 |
| Regional | • T.A. No. 6195-REG: GMS Transport Sector Strategy Study, 2006<br>• Greater Mekong Subregion Statistics on Growth, Infrastructure, and Trade Second Edition<br>• Initial Assessments of Road Transport Infrastructure and Transport and Logistic Services for Trade Facilitation in the GMS Countries, 2012<br>• ADB Collation of current passenger movements and recent trends, modes used and use of international gateways prepared as part of the GMS tourism work (http://www.mekongtourism.org/about/tourism-performance/) including the individual country reports. |

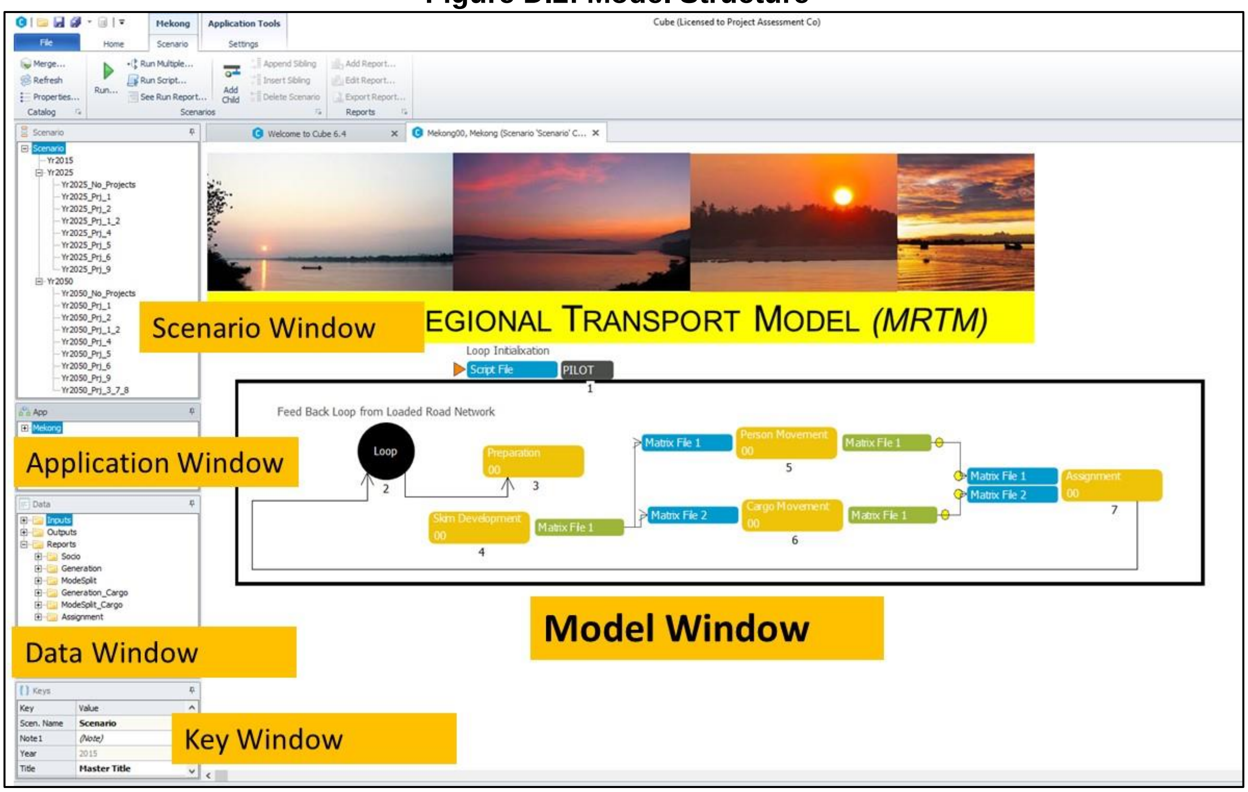
Source: TA team

9. The key that controls which projects are included in a scenario is described as the “List of Included Projects”. This key is an input text file of nine lines of text code. Each line has the following format, ”PRJ_1=0”. Each line of input text file represents a project. There are nine possible projects for inclusion in any scenario. If the project number is equal to unity then the project is included, otherwise the right hand side of the equality sign as shown in the example is set to zero. In that case the project is not included in the scenario.

10. The model window is the heart of MRTM. The box numbers within this window relate to the model structure and also the organization of the file structure. Boxes one and two are linked to the feedback and assignment loop. As such they are discussed as part of the assignment module or assignment sub model. The flowchart structure is presented in Figure D.3. All subsequent sections of the model are described in this format. The boxes designated in this simplified flowchart are reference throughout this manual.

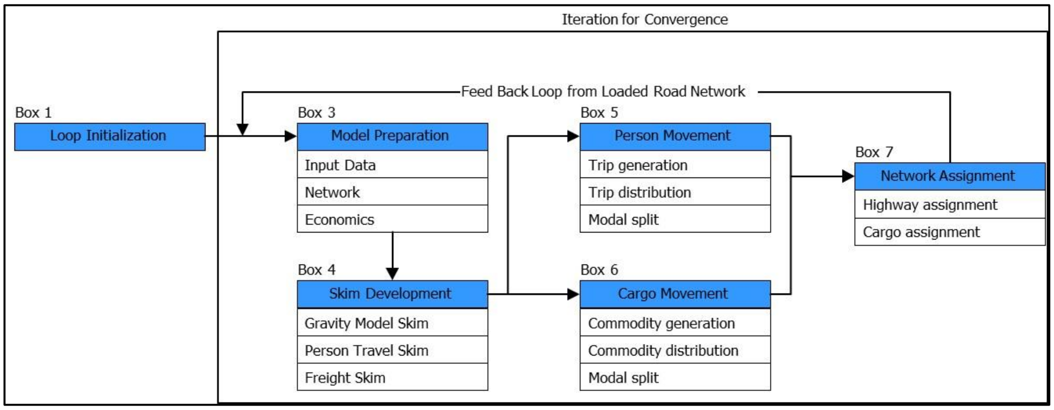
11. Boxes three through seven correspond model directory structure referenced in Figure D.2. Each of these boxes are the entrance flow points to the sub models of preparation, skim development, person generation, cargo generation and assignment. These sub models are discussed in the following five sections of this appendix document. The penultimate section of this Appendix tabulates the imbedded report structure and indicative results whilst the last section proposes future enhancements for the MRTM. It references a box in the CUBE flowchart for example, a three digit reference Box 5.2.5 refers to a level 3 flowchart box with the title, "Person Distribution."

**Figure D.2: Model Structure**




Source: TA Team

**Figure D.3: The Model Structure Flowchart**




Source: TA Team

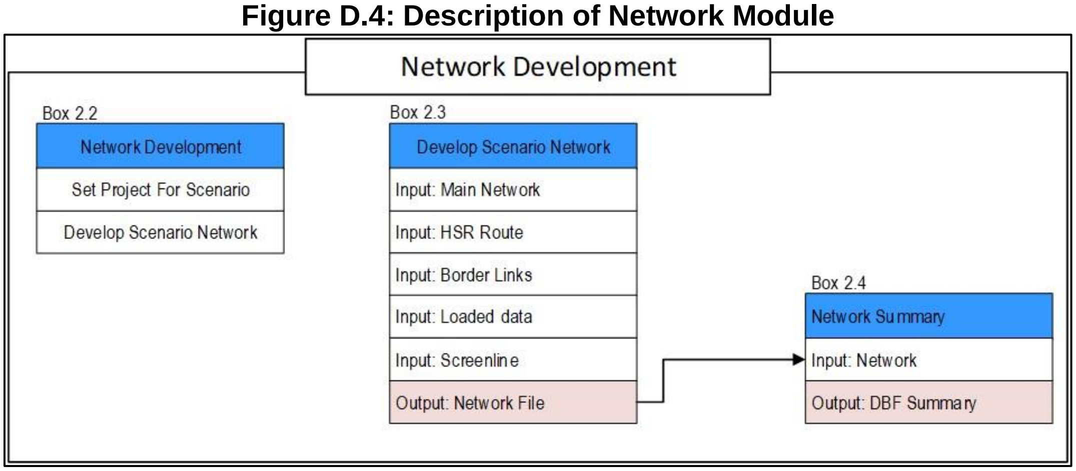
## II. MODEL PREPARATION (BOX 3 IN FIGURE D.3)

12. The first module of MRTM is the preparation of the model. This module or sub model includes the network development and the development of the socio-economic planning data which varies dependent on either the input year which accepts the base year value of 2015 or the two future year scenarios of 2025 and 2050. The potential network variation is likewise linked to the time horizon.

### A. The Network Development (Box 3 in Figure D.3)

13. The network module is presented in Figure D.4 which shows the model flowchart. The various significant input and files associated with the network module are tabled in Table D.4 (below Figure D.6). Box 2.4 shown in the figure below produces a network summary for the specified scenario.

**Figure D.4: Description of Network Module**




Source: TA Team

### B. Socio-Economic Development (Box 3.3 in Figure D.3)

Socio-economic development structure is presented in Figure D.5 and

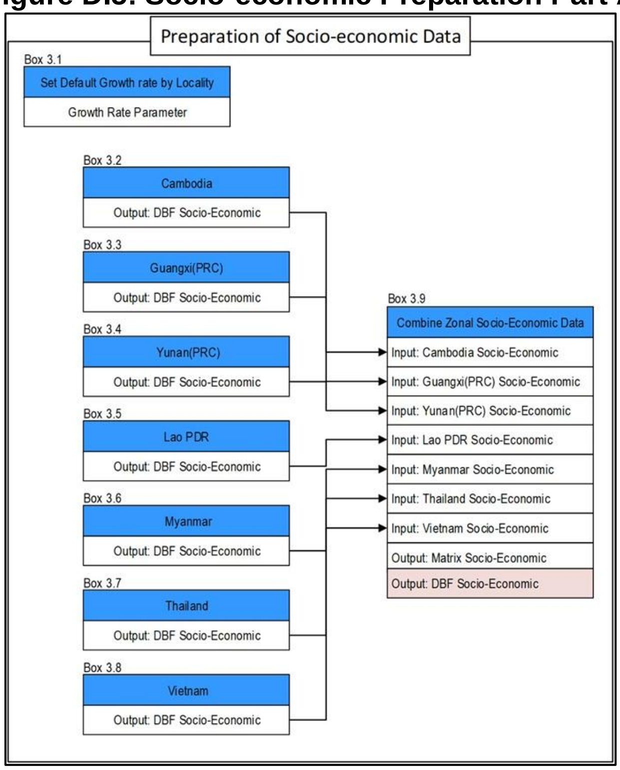
14. Figure D.6 which shows the model flowchart for socio-economic module Part A and Part B respectively. Part A determines which sets of socio-economic data for each of the seven specified localities are available from other studies whilst Part B produces socio-economic data by traffic zone.

15. The zoning system adopted is the same as that for the earlier GMS Transport Sector Strategy Study. Within the two provinces of China, there is an allocation of 30 zones. In Myanmar, there are 40 zones whilst Thailand has a total of 56 zones. There are 17 zones and 24 zones in Lao PDR and Cambodia respectively. Finally, Vietnam has a total of 49 zones. Thus, the model has a total of 216 internal zones. The total number of zones including externals is 254 with 30 of these externals identified as seaports. The decision was made not to significantly modify the number of zones to ensure compatibility with earlier work.

16. The zonal database includes the reference to its locality number as well as by a sector number. MRTM zoning system is divided into 25 summary sectors. Within the two provinces of China, there is an allocation of 6 sectors. In Myanmar, there are 5 sectors whilst Thailand has a total of 5 sectors. There are 3 sectors in both Lao PDR and Cambodia. Finally, Vietnam has a total of 3 sectors.

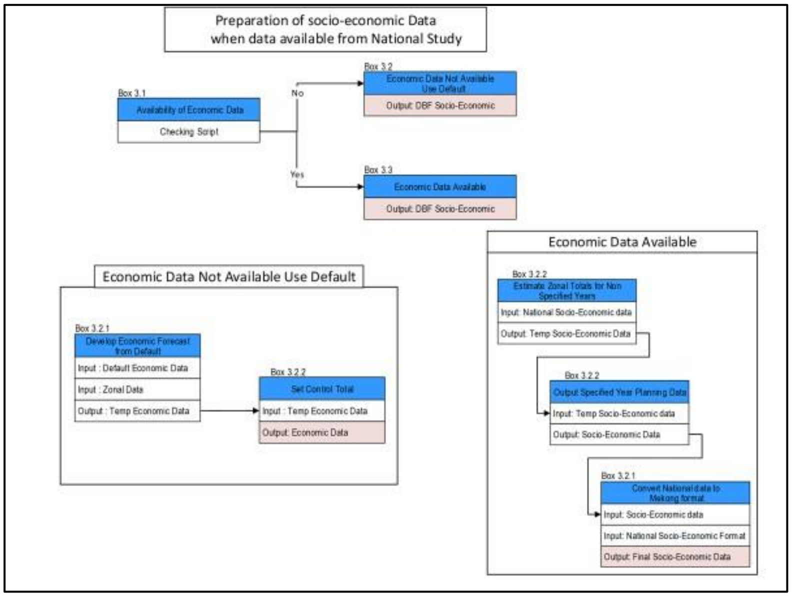
17. In 2015, the total population of all seven localities in 2015 is 341.4 million people increasing to an estimated 371.1 million people in 2025 and finally to 454.0 million people by 2050. During the same time frame, the regional GDP is estimated to grow from 1,054 billion in 2015 to an estimated 1,920 billion in 2025 and finally to 6,550 billion by 2050 as measured in constant USD with a base year of 2010.

**Figure D.5: Socio-economic Preparation Part A**




Source: TA Team

## Figure D.6: Socio-economic Preparation Part B




Source: TA Team

## Table D.4: Description of all Files in Model Preparation

| **Box/Filename** | **Description** |
|---|---|
| *Box 3.1.1* | *Check Loop Count* |
| Input File Name | |
| PRPIL00A.S | Check Loop Count and Convergence |
| *Input–Output of Box 3.2* | *Network Development* |
| Box 3.2.2 | Set Projects for Scenario |
| Input File Name | |
| {Key} Project_All.txt | Project Description referenced in Network 1- Inclusion---0- Exclusion |
| Box 3.2.3 | Develop Scenario Network |
| Input File Name | |
| GMS_Rv2.NET | Master GMS Network |
| Kum_Han_Ban_HSR.dbf | HSR Indicator in the master network |
| Border_LNK.dbf | Indicator or Border Links |
| Loaded_Dump.DBF | Pre-Load Network to Setup Initial Speed |
| Screenline_TH15.dbf | Screenline Locations |
| Output File Name | |
| Scenario_Net.net | Comprehensive network for specific scenario |
| Net_Link.dbf | Comprehensive network for specific scenario in DBF format |
| Box 3.2.4 | Network Summary |
| Input File Name | |
| Net_Link.dbf | Comprehensive network for specific scenario in DBF format |
| Output File Name | |
| Summary_Net.DBF | Summary network in DBF format |
| *Input–Output of Box 3.3* | *Preparation of Socio-economic Data* |
| Box 3.3.1 | Set Projects for Scenario |
| Input File Name | |
| ECPIL00A.S | Default growth rates by locality |
| Box 3.3.2 | Cambodia Socio Economic Data |
| Output File Name | |
| Camb.dbf | Cambodia Socio Economic Data |
| Box 3.3.3 | Guangxi (PRC) |
| Output File Name | |

| Box/Filename | Description |
|---|---|
| Guang.dbf | Guanixi (PRC) Socio Economic Data |
| Box 3.3.4 | Yunnan g(PRC) |
| Output File Name | |
| Yunan.dbf | Yunnan (PRC) Socio Economic Data |
| Box 3.3.5 | Loas (PDR) |
| Output File Name | |
| Laos.dbf | Lao PDR Socio Economic Data |
| Box 3.3.6 | Myanmar |
| Output File Name | |
| Myan.dbf | Myanmar Socio Economic Data |
| Box 3.3.7 | Thailand |
| Output File Name | |
| Thai.dbf | Thailand Socio Economic Data |
| Box 3.3.8 | Vietnam |
| Output File Name | |
| Viet.dbf | Vietnam Socio Economic Data |

Source: TA Team

## III. SKIM DEVELOPMENT (BOX 4 IN FIGURE D.3)

18. Travel skims are needed as input into both the distribution and the mode split for both the movement of people and cargo across the Mekong region. Three sets of travel skim are prepared namely time, distance and cost of travel. The skims are produced for each origin and destination pair of traffic zones within the model geographic region.

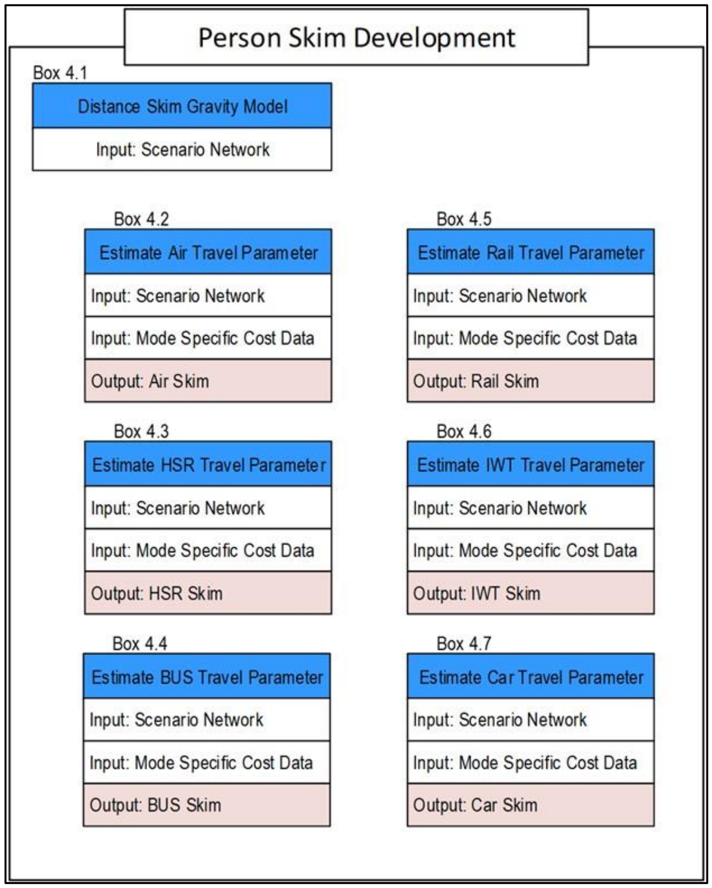
### A. The Skims by Mode for Person

19. The structure of the person skim development is shown in Figure D.7:. The various significant input and files associated with the network module are tabled in Table D.5. This table includes the file names for both person and cargo skims.

20. For persons the skims are prepared for the modes of air, higher speed rail[68], car, bus, rail and Inland water transport (IWT). For the transit modes, the travel time includes access, wait as well as long haul time. The transit cost[69] includes access cost as well as the long-haul time.

[68] The speed of higher speed rail is a model input but for the purpose of this project is designated at 200 kph.
[69] All cost parameters are in constant 2010 USD. All locality currencies were converted into constant 2010 USD.

**Figure D.7: Person Skim Development**



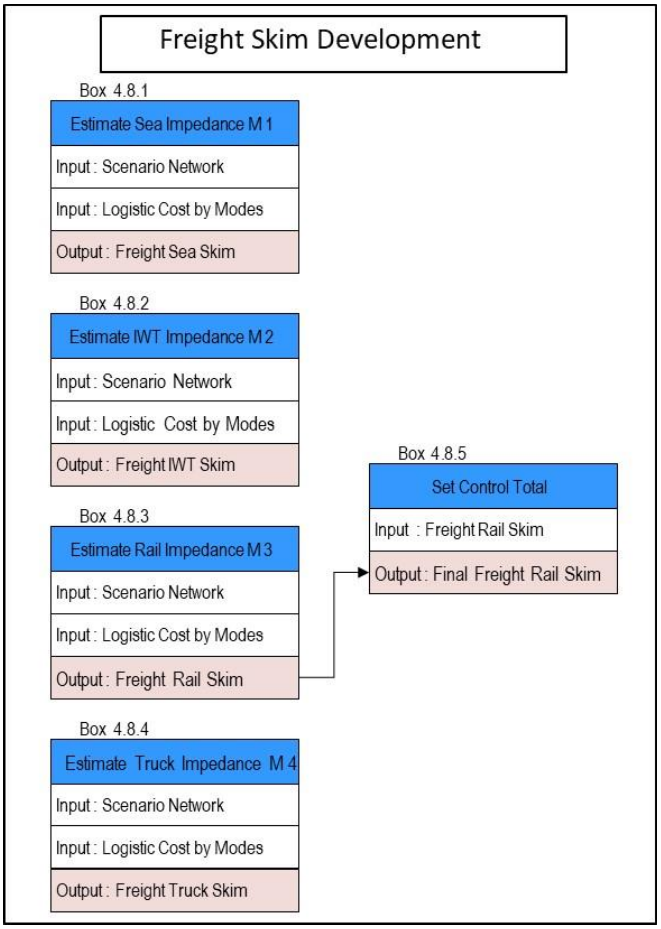

Source: TA Team

## B. The Skims by Mode for Freight

21. The structure of the freight skim development is shown in Figure D.8. The various significant input and output files associated with the network module are tabled in Table D.5. This table includes the file names for both person and cargo skims.

22. Cargo skims are prepared for truck, rail, inland water transport and sea or coastal shipping. In the case of non-road skims access time and access cost is also included in the skim estimation. Within the cargo skim development as with person skim development, there is also an in-built review to determine if a non-road skim is actually a viable path for a particular trip between any zone pair.

**Figure D.8: Cargo Skim Development**




Source: TA Team

**Table D.5: Description of all Files in Model Skim Development**

| Box/Filename | Description |
|---|---|
| *Input–Output of Box 4* | ***Person Skim Development*** |
| Box 4.1 | Distance Skim for Gravity Model |
| Input File Name | |
| Scenario_Net.net | Comprehensive network for specific scenario |
| Output File Name | |
| ROAD_SKIM.MAT | Road Skim Matrix |
| Box 4.2 | Estimate Air Travel Parameters |
| Input File Name | |
| Scenario_Net.net | Comprehensive network for specific scenario |
| Mode_Cost.dbf | Mode Specific Cost |
| Output File Name | |
| Air_Skim.MAT | Air Skim Matrix |
| Box 4.3 | Estimate Higher Speed Rail(HSR) Travel Parameters |
| Input File Name | |
| Scenario_Net.net | Comprehensive network for specific scenario |
| Mode_Cost.dbf | Mode Specific Cost |
| Output File Name | |
| HSR_Skim.MAT | HSR Skim Matrix |
| Box 4.4 | Estimate Bus Travel Parameters |
| Input File Name | |
| Scenario_Net.net | Comprehensive network for specific scenario |

| Box/Filename | Description |
|---|---|
| Mode_Cost.dbf | Mode Specific Cost |
| Output File Name | |
| Bus_Skim.MAT | Bus Skim Matrix |
| Box 4.5 | Estimate Rail Travel Parameters |
| Input File Name | Description |
| Scenario_Net.net | Comprehensive network for specific scenario |
| Mode_Cost.dbf | Mode Specific Cost |
| Output File Name | |
| Ral_Skim.MAT | Rail Skim Matrix |
| Box 4.6 | Estimate IWT Travel Parameters |
| Input File Name | |
| Scenario_Net.net | Comprehensive network for specific scenario |
| Mode_Cost.dbf | Mode Specific Cost |
| Output File Name | |
| IWT_Skim.MAT | IWT Skim Matrix |
| Box 4.7 | Estimate Car Travel Parameters |
| Input File Name | |
| Scenario_Net.net | Comprehensive network for specific scenario |
| Mode_Cost.dbf | Mode Specific Cost |
| Output File Name | |
| _Car_Skim.MAT | Car Skim Matrix |
| *Input–Output of Box 4.8* | ***Freight Skim Development*** |
| Box 4.8.1 | Estimate SEA Impedance (Mode 1) |
| Input File Name | |
| Scenario_Net.net | Comprehensive network for specific scenario |
| Logis_cost.csv | Logistic cost for each travel Modes |
| Output File Name | |
| Sea_Skim.MAT | Ship Skim Matrix |
| Box 4.8.2 | Estimate IWT Impedance (Mode 2) |
| Input File Name | |
| Scenario_Net.net | Comprehensive network for specific scenario |
| Logis_cost.csv | Logistic cost for each travel Modes |
| Output File Name | |
| IWT_Skim.MAT | Inland Water Way Skim Matrix |
| Box 4.8.3 | Estimate RAIL Impedance (Mode 3) |
| Input File Name | |
| Scenario_Net.net | Comprehensive network for specific scenario |
| Logis_cost.csv | Logistic cost for each travel Modes |
| Output File Name | |
| Rail_Skim.MAT | Rail Skim Matrix |
| Box 4.8.4 | Estimate Truck Impedance (Mode 4) |
| Input File Name | |
| Scenario_Net.net | Comprehensive network for specific scenario |
| Logis_cost.csv | Logistic cost for each travel Modes |
| Output File Name | |
| Truck_Skim.MAT | Truck Skim Matrix |
| Box 4.8.5 | Check if rail route is practical |
| Input File Name | |
| Rail_Skim.MAT | Person Rail Skim |
| Output File Name | |
| SFMAT00A.MAT | Temporary Rail Skim Mat – following checking that a route is viable by rail. |
| Box 4.8.6 | Copy Final Rail Skim |
| Input File Name | |
| SFMAT00A.MAT | Temporary Rail Skim Mat |
| Output File Name | |
| Rail_Skim.MAT | Revised Rail Skim Matrix |

Source: TA Team

## IV. PERSON TRIPS (BOX 5 IN FIGURE D.3)

23. The movement of people throughout the region is estimated in the person trip module which consists of three further sub models of generation, distribution and mode split. The structure of the person trip module[70] is shown in Figure D.9 for generation and distribution. For mode split it is presented in Figure D.10.

### A. Trip Generation

The various significant input and output files associated with the person generation module are tabled in Table D.7. The generated trip function takes the following form for trips generated in zone i:

$Gen_i$ = a* Population + b* GDP per capita. (The parameters for the equation are shown in Table D.6).

**Table D.6: Person Generation Parameters[71]**

| Locality | Description | A | b |
|---|---|---|---|
| 1 | Cambodia | 0.00306 | 2.49741 |
| 2 | Guangxi(PRC) | 0.00826 | 0.69535 |
| 3 | Yunnan(PRC) | 0.00707 | 0.59464 |
| 4 | Lao PDR | 0.00472 | 1.38404 |
| 5 | Myanmar | 0.00442 | 2.17969 |
| 6 | Thailand | 0.01601 | 5.59074 |
| 7 | Vietnam | 0.01208 | 3.75992 |

Source: TA Team

### B. Trip Distribution

The structure of the person trip distribution module is shown in Figure D.9. The various significant input and output files associated with the person distribution module are also shown in Table D.7. The equation for trip distribution takes the form of a gravity model. The general form of the equation is as follows:

$$T_{ij} = P_i \frac{A_j f(c_{ij}) K_{ij}}{\sum A_j f(c_{ij}) K_{ij}}$$

where:

$f(c_{ij})$ : F Factor, a function cost of travel;
$P_i$ : Generations at zone i;
$A_j$, : Attractions at zone j;
$T_{ij}$ : Trips between zone i and zone j; and
$K_{ij}$ : Parameter which describe relation between groups of zones.

The F factor curve is in the form of a gamma function within the MRTM. The Gamma function takes the form:

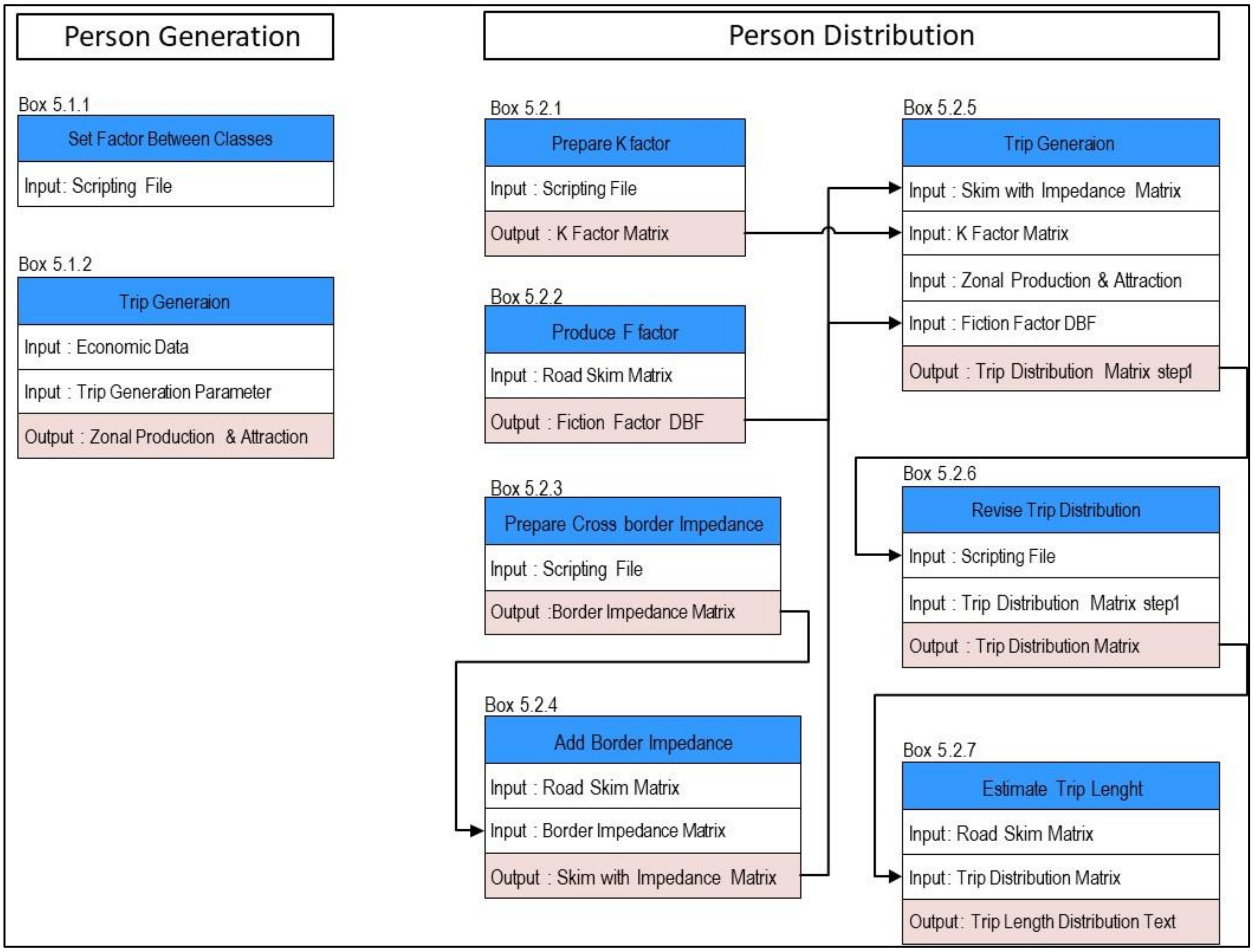
$f(c_{ij}) = c_{ij} X_1 * \exp(X_2 * c_{ij})$

where:

*$c_{ij}$ is the impedance of travel between zone i and j ; and*
*$X_1$, $X_2$ are calibration constants[72].*

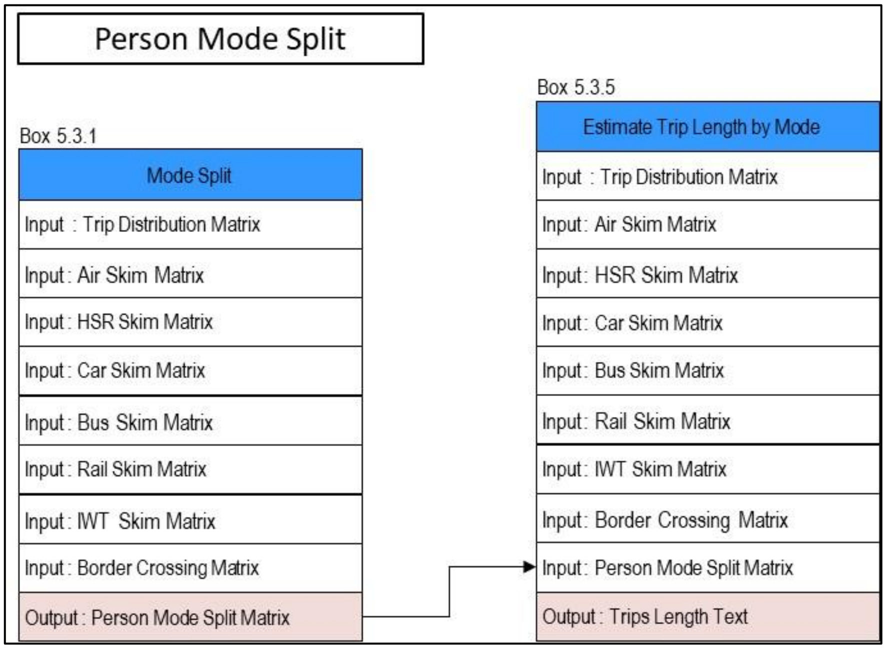
[70] The person trips are characterized by three different classes namely business, private and leisure. Separate equations are currently only available for mode split. Hereafter referred simply as Classes, one two and three.
[71] The R squared value of the equations range from 0.7 to 0.9.
[72] For MRTM, the value of $X_1$, $X_2$ are 1.13274, -0.00695854 respectively.

**Figure D.9: Person Trips – Part A**




Source: TA Team

**Figure D.10: Person Trips – Part B**




Source: TA Team

**Table D.7: Description of all Files in Person Trip Module-Part A**

| Box/Filename | Description |
|---|---|
| Input–Output of Box 5.1 | **Person Generation** |
| Box 5.1.1 | Set Factor between Classes |
| Input File Name | |
| PGPIL00A.S | Set Factor between Classes |
| Box 5.1.2 | Trip Generation |
| Input File Name | |
| Socio_Econ.dbf | Socio Economics Data by Zone |
| gen_eqn_param.dbf | Generation Parameter By locality |
| Output File Name | |
| PGGEN00A.DAT | Zonal Production & Attraction in Text Format |
| PGGEN00A.DBf | Zonal Production & Attraction in DBF format |
| Input–Output of Box 5.2 | **Person Distribution** |
| Box 5.2.1 | Prepare K Factors for Three Purposes |
| Input File Name | |
| PDMAT00A.S | Scripting File for Create K Factor Matrix |
| Output File Name | |
| K_factor.mat | K factor Matrices for 3 Purpose trips |
| Box 5.2.2 | Produce F Factors |
| Input File Name | |
| Road_skim.MAT | Road Skim Matrix File |
| Output File Name | |
| F_fact.dbf | F Factor File for Distribution |
| Box 5.2.3 | Prepare Cross Border Impedance |
| Input File Name | |
| PDMAT00I.S | Scripting file for Create Impedance Matrix |
| Output File Name | |
| PDMAT00D.MAT | Border Crossing Impedance Matrix |
| Box 5.2.4 | Add Border Impedance |
| Input File Name | |
| Road_skim.MAT | Road Skim Matrix File |

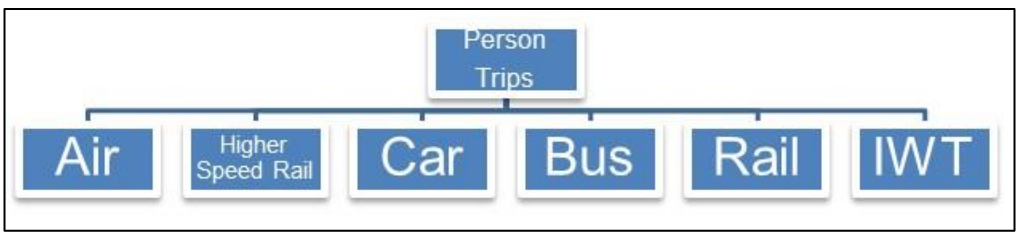
| Box/Filename | Description |
|---|---|
| PDMAT00D.MAT | Border Crossing Impedance Matrix |
| PGGEN00A.DAT | Zonal Production & Attraction in Text Format |
| F_fact.dbf | F Factor File for Distribution |
| Output File Name | |
| TRIP_DIST_Temp.MAT | Intermediate Person Trips Distribution |
| Box 5.2.5 | Person Trip Distribution |
| Input File Name | |
| PDMAT00E.MAT | Final Skim Matrix for Trips Distribution |
| K_factor.mat | K factor Matrices for 3 Purpose trips |
| Ral_Skim.MAT | Freight Rail Skim |
| Output File Name | |
| SFMAT00A.MAT | Temporary Rail Skim Mat |
| Box 5.2.6 | Fix Problem with Distribution |
| Input File Name | |
| SFMAT00A.MAT | Temporary Rail Skim Mat |
| Output File Name | |
| Trip_Dist.MAT | Final person Trips Distribution Matrix File |

Source: TA Team

## C. Mode Split

24. The structure of the person trip module is shown earlier in Figure D.10. The various significant input and output files associated with the network module are tabled in Table D.9. For the mode split analysis, fare and commodity cost are also required. These costs were drawn from the national models or where not available from national models are derived from regional databases. The mode split structure is a single level mode split logit model as depicted in Figure D.11:. The mode split model mainly allocated trips to car and bus as especially in the base year there was no logical route via other modes.

**Figure D.11: Person Mode Split**




Source: TA Team

25. The mode choice model[73] is a logit function and takes the following form:

$$P_{in} = \frac{\exp(V_i)}{\sum_j \exp(V_j)}$$

where,

$P_{in}$ : Possibility of choosing transportation mode i from the set of choice modes;

$V_i$ : Utility function of transportation mode i (time and cost); Vi = a × ln(Travel Time[74] × VoT) + b × ln(Travel Cost[75]) + Modal Bias Constant; a and b are scale parameters for Parameters for time and cost respectively (refer Table D.8)

$i$ : Mode; and VoT: Value of Time[76].

[73] The model parameters are developed following a review of similar national models in Myanmar and Thailand

[74] In the case of travel time for transit this includes modal access, waiting time and long-haul travel time.

[75] As stated earlier, all cost parameters are in constant 2010 USD.

[76] The weighted value of time across all localities is 1.41 USD per hour.

**Table D.8: Mode Split Scale Parameters**

| Variable | Class 1 | Class 2 | Class 3 |
|---|---|---|---|
| Time Scale Factor | -1.3325 | -1.3943 | -1.2672 |
| Cost Scale Factor | -0.8887 | -1.2586 | -1.3204 |

Source: TA Team

26. The perceived cost of travel via the various modes is considered by locality. The travel by car is considered as simply the perceived fuel operating cost at approximately 6 US cents per kilometer. The cost of inland water travel is around half a US cent per kilometer whilst that of bus and rail mode in the range of one to two US cents per kilometer. However, in the case of air travel the cost is 0.107 USD per km[77] across all localities whilst the included cost of higher speed rail is 0.057 USD per km similarly across all localities. Table D.9 shows all files used in the mode split process for person trips.

**Table D.9: Description of all Files in Person Trip Module-Part B**

| Box/Filename | Description |
|---|---|
| Input–Output of Box 5.3 | **Person Mode Split** |
| Box 5.3.1 | Mode Split |
| Input File Name | |
| Trip_Dist.MAT | Final person Trips Distribution Matrix File |
| Air_skim.mat | Air impedance skim |
| HSR_skim.Mat | HSR impedance skim |
| Car_skim.Mat | Car impedance skim |
| Bus_skim.mat | Bus impedance skim |
| Ral_skim.mat | Ral impedance skim |
| IWT_skim.mat | IWT impedance skim |
| Int_bord_cross.Mat | Internal border crossing impedance |
| Output File Name | |
| Final_person.mat | Person Mode Split Matrix file |
| Box 5.3.5 | Estimate Trip length by Mode |
| Input File Name | |
| Final_person.mat | Person Mode Split Matrix file |
| Air_skim.mat | Air impedance skim |
| HSR_skim.Mat | HSR impedance skim |
| Car_skim.Mat | Car impedance skim |
| Bus_skim.mat | Bus impedance skim |
| Ral_skim.mat | Rail impedance skim |
| IWT_skim.mat | IWT impedance skim |
| Output File Name | |
| PMMAT00E.PRN | Printout report for trip length by mode |

Source: TA Team

## V. CARGO TRIPS (BOX 6 IN FIGURE D.3)

27. The movement of cargo throughout the region is estimated in the cargo trip module which consists of three further sub models of generation, distribution and mode split.

### A. Trip Generation

28. The structure of the cargo trip module is shown in Figure D.12:. The various significant input and output files associated with the network module are tabled in Table D.10. Demand or

[77] Air travel cost is estimated by a regional examination of fare and the higher speed rail cost is simply a proportion of that fare.

cargo generated trips are estimated by traffic zone are estimated via a relationship linking population increase with the increase in GDP per capita. The parameters in the equations vary by locality and commodity group. Five commodity groups were devised based on the international Harmonized codes. Broadly the commodity groups in numerical order one through to five are agriculture, processed food, wood products, chemicals and miscellaneous.

29. The generated trip function takes the following form for trips generated with the parameters defined in Table  by locality and commodity to produce generated tonnes in zone i defined by the following equation:

$Gen_i$ = a* Population + b* GDP per capita (refer Table D.11 for the parameters).

30. In 2015, the dominant cargo in terms of tonnes generated is from the principal economy, Thailand. The locality of Thailand generated 65% with the two Chinese localities only contributing 12% of tonne movements within the GMS at 2015.

**Table D.10: Description of all Files in Cargo Module-Part A**

| Box/Filename | Description |
|---|---|
| Input–Output of Box 6.1 | **Cargo Generation** |
| Box 6.1.1 | Earlier GMS Matrices for External Demand |
| Input File Name | |
| OD_2004.MAT | Earlier 2004 GMS Matrices |
| OD_2015.MAT | Earlier 2015 GMS Matrices |
| Output File Name | |
| CGMAT00A.DBF | Forecast External Demand in DBF format |
| Box 6.1.2 | Trip Generation |
| Input File Name | |
| Socio_Econ.dbf | Socio Economics Data by Zone |
| PA_Factor.dbf | Factor file |
| Gen_parm.csv | Generation Parameter |
| Attr_parm.csv | Attraction Parameter |
| CGMAT00A.DBF | Forecast External Demand in DBF format |
| Output File Name | |
| COMMODIT_PA0.DBF | Cargo Generation by Commodity step 1 |
| COMMODITY_SUMM.CSV | Commodity generation Summary report |
| Box 6.1.3 | Prepare Correction Factor to External Growth |
| Input File Name | |
| COMMODIT_PA.DBF | Base Cargo Generation by Commodity |
| COMMODIT_PA0.DBF | Cargo Generation by Commodity step 1 |
| Output File Name | |
| CGMAT00B.PRN | Correction Factor file |
| Box 6.1.3 | Correct Externals |
| Input File Name | |
| COMMODIT_PA0.DBF | Cargo Generation by Commodity step 1 |
| Output File Name | |
| COMMODITY_PA.DBF | Final Cargo Generation |
| | |
| Input–Output of Box 6.2 | **Cargo Distribution** |
| Box 6.2.1 | Prepare Base Matrix |
| Input File Name | |
| Od2015_Upd.mat | Revised Base Matrix |
| Road_skim.mat | Road Skim Matrix File |
| COMMODITY_PA.DBF | Final Cargo Generation |
| Locality_group.dbf | Zonal equivalence to Locality Group |
| Output File Name | |

| Box/Filename | Description |
|---|---|
| Base_Matix.MAT | Revised Base OD Marix |
| Future_PA.DBF | Prepared Production Attraction DBF file |
| Box 6.2.2 | Estimate Future Growth |
| Input File Name | |
| Base_Matix.MAT | Revised Base OD Marix |
| Future_PA.DBF | Prepared Production Attraction DBF file |
| Output File Name | |
| Cargo_dist.mat | Cargo Distribution step 1 |
| Box 6.2.3 | Prepare Final distribution Correction |
| Input File Name | |
| Output File Name | |
| CDMAT00D.MAT | Correction factor Matrix file |
| Box 6.2.4 | Final Distribution Matrix |
| Input File Name | |
| Cargo_dist.mat | Cargo Distribution step 1 |
| CDMAT00D.MAT | Correction factor Matrix file |
| Output File Name | |
| CDMAT00E.MAT | Temporary Cargo Distribution |
| Box 6.2.5 | Copy File |
| Input File Name | |
| CDMAT00E.MAT | Temporary Cargo Distribution |
| Output File Name | |
| Cargo_dist.mat | Final Cargo Distribution |

Source: TA Team

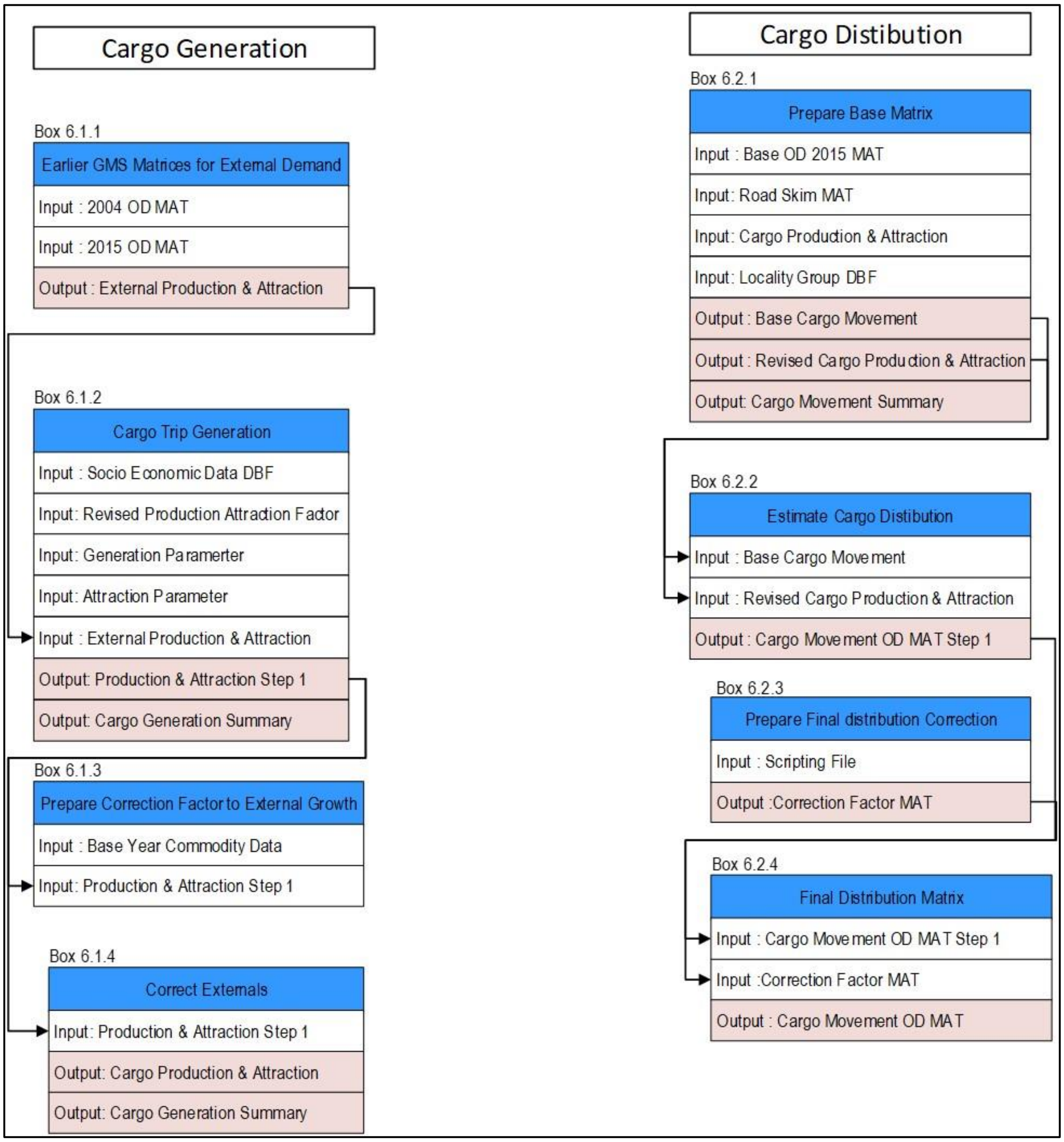
**Table D.11: Cargo Generation Parameters**

| Locality | Commodity Group | a | b |
|---|---|---|---|
| 1 | 1 | 0.004693 | 648.0323 |
| 1 | 2 | 5.32E-05 | 7.348499 |
| 1 | 3 | 0.00036 | 49.71174 |
| 1 | 4 | 0.000142 | 19.62071 |
| 1 | 5 | 0.000122 | 16.81034 |
| 2 | 1 | 0.000417 | 57.5793 |
| 2 | 2 | 9.6E-05 | 13.25844 |
| 2 | 3 | 0.001674 | 231.0958 |
| 2 | 4 | 0.000197 | 27.19167 |
| 2 | 5 | 0.002987 | 412.3983 |
| 3 | 1 | 0.000417 | 57.5793 |
| 3 | 2 | 9.6E-05 | 13.25844 |
| 3 | 3 | 0.001674 | 231.0958 |
| 3 | 4 | 0.000197 | 27.19167 |
| 3 | 5 | 0.002987 | 412.3983 |
| 4 | 1 | 0.001722 | 237.8511 |
| 4 | 2 | 0.000175 | 24.20333 |
| 4 | 3 | 0.00197 | 272.0057 |
| 4 | 4 | 0.000885 | 122.2179 |
| 4 | 5 | 0.000617 | 85.24555 |
| 5 | 1 | 7.59E-05 | 10.47773 |
| 5 | 2 | 1.04E-05 | 1.438556 |
| 5 | 3 | 0.00521 | 719.3965 |
| 5 | 4 | 5.82E-05 | 8.0307 |
| 5 | 5 | 1.58E-05 | 2.180079 |
| 6 | 1 | 0.001205 | 166.346 |
| 6 | 2 | 0.000511 | 70.57821 |
| 6 | 3 | 0.002817 | 389.0478 |
| 6 | 4 | 0.000487 | 67.27102 |
| 6 | 5 | 0.00035 | 48.2806 |

| Locality | Commodity Group | a | b |
|---|---|---|---|
| 7 | 1 | 0.000772 | 106.5347 |
| 7 | 2 | 0.000326 | 45.0698 |
| 7 | 3 | 0.00142 | 196.0885 |
| 7 | 4 | 0.000219 | 30.30607 |
| 7 | 5 | 0.002633 | 363.5245 |

Source: TA Team

**Figure D.12: Cargo Trips – Part A**




Source: TA Team

## B. Trip Distribution

31. The structure of the person trip module is shown in Figure D.12. The various significant input and output files associated with the network module are tabled in Table D.10. The equation for trip distribution in the case of cargo takes the form of a Fratar model. The Fratar

model as a base uses the existing distribution patterns sourced from earlier studies. The revised generation by commodity group are then factored and balanced using the change in the demand cargo generation.

## C. Mode Split

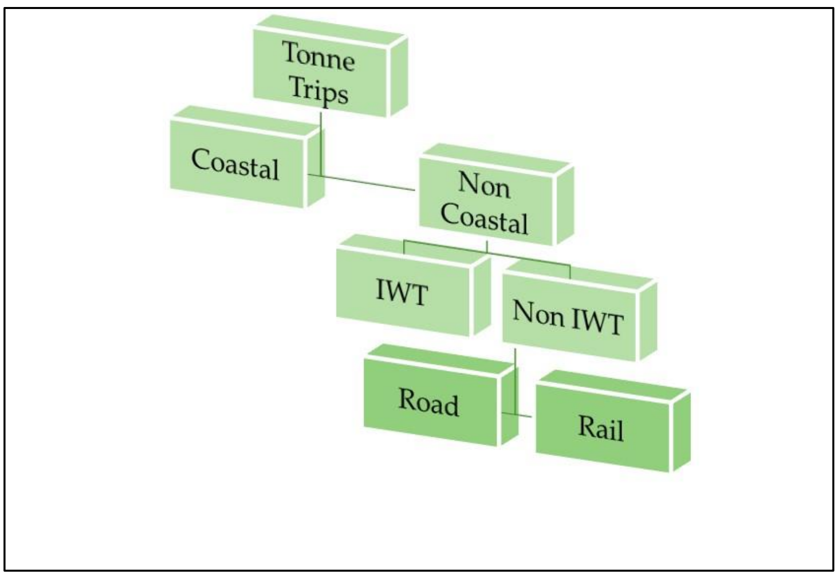
32. For the mode split analysis, commodity cost is required. These costs are drawn from the national models or where not available from national models are derived from regional databases. The costs are tabled in Table D.12. The mode split structure is a hierarchical three level mode split logit model as depicted in Figure D.13. The total cargo trips are split across four modes. The first level coastal trips are separated whilst at the second level, inland water transport trips are separated with the final level being the split between road and rail. For many origin-destination pairs of trips the mode split is essentially split between truck and rail only as there is no logical route via other modes, particularly in the base case.

**Table D.12: Cargo Cost in USD per Tonne-Kilometer by Mode[78]**

| Locality | Description | IWT | Road | Rail |
|---|---|---|---|---|
| 1 | Cambodia | 0.002 | 0.006 | 0.009 |
| 2 | Guangxi(PRC) | 0.011 | 0.029 | 0.042 |
| 3 | Yunnan(PRC) | 0.009 | 0.024 | 0.035 |
| 4 | Lao PDR | 0.003 | 0.009 | 0.012 |
| 5 | Myanmar | 0.038 | 0.033 | 0.044 |
| 6 | Thailand | 0.014 | 0.037 | 0.053 |
| 7 | Vietnam | 0.004 | 0.01 | 0.014 |

Source: TA Team

**Figure D.13: Cargo Mode Split**




Source: TA Team

[78] The cost for coasting shipping is constant across all localities at 0.045 USD per tonne kilometer.

33. At each level, there is a logit model for each commodity group which takes the following form:

$$P_1 = \frac{\exp^{V_1}}{\exp^{V_1} + \exp^{V_2}}$$

where:

$P_i$: Modal share of mode *1*

$V_i$: Generalized Cost of mode i of travel is a function of time and cost with the scale parameters associated with the generalized cost defined in Table D.13.

34. The structure of the cargo mode split module is shown in Figure D.14. The various significant input and output files associated with the network module are tabled in Table D.14. Cargo mode split is dominated by road cargo movements.

**Table D.13: Mode Split Scale Parameters**

| Variable | Equation | Commodity Group | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Time Scale Factor | Coastal /Non Coastal | -0.2244 | -0.0004 | -0.0858 | -0.0355 | -0.0355 |
| Cost Scale Factor | | -0.0001 | -0.0004 | -0.0004 | -0.0004 | -0.0004 |
| Time Scale Factor | IWT/ Non IWT | -0.0194 | -0.0387 | -0.0732 | -0.0169 | -0.0173 |
| Cost Scale Factor | | -0.0001 | -0.0004 | -0.0006 | -0.0004 | -0.0001 |
| Time Scale Factor | Road/ Rail | -0.3892 | -0.2078 | -0.176 | -0.5941 | -0.5891 |
| Cost Scale Factor | | -0.0008 | -0.0003 | -0.0008 | -0.0034 | -0.0006 |

Source: TA Team

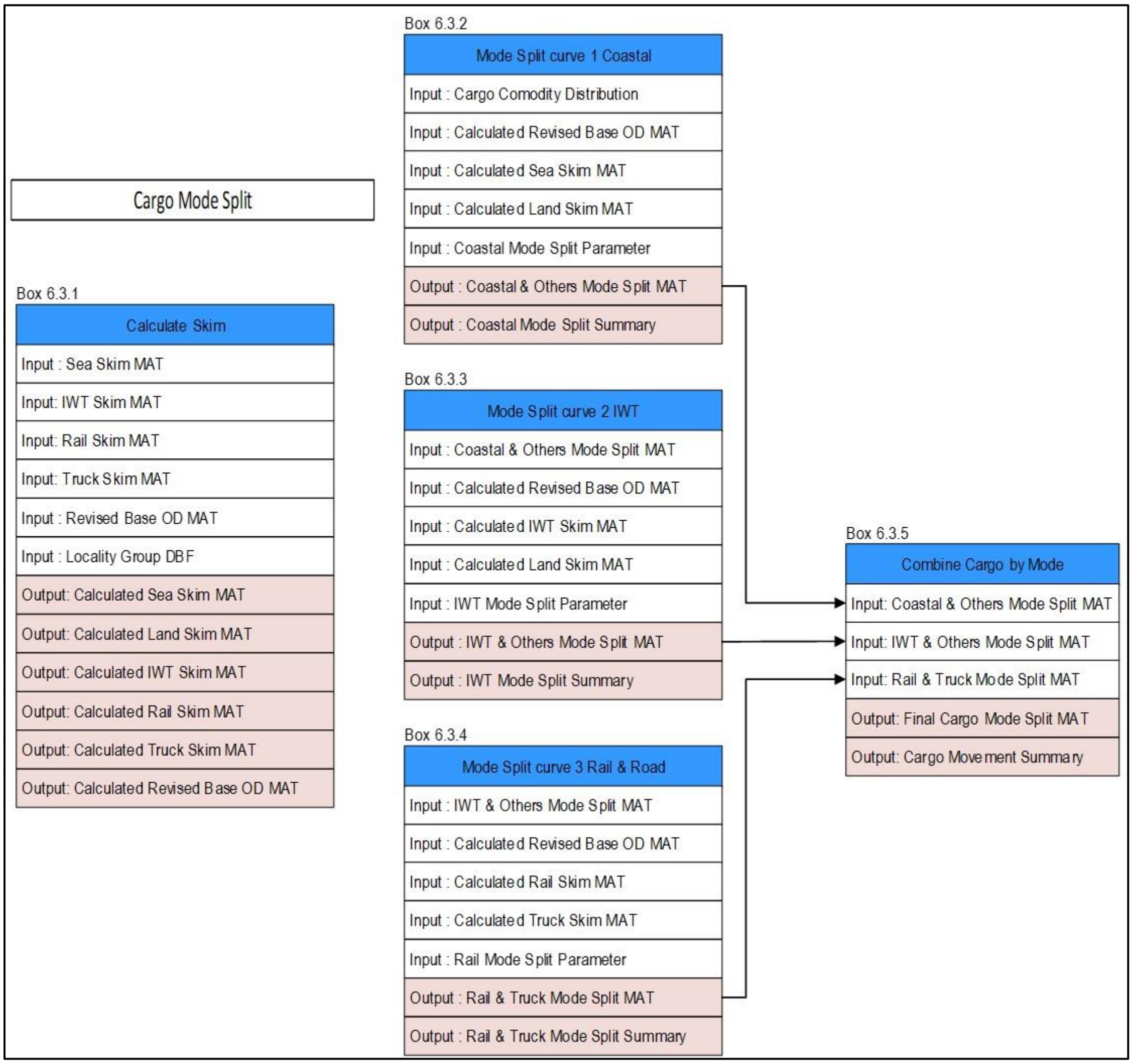
**Table D.14: Description of All Files in Cargo Module-Part B**

| Box/Filename | Description |
|---|---|
| Input–Output of Box 6.3 | **Cargo Mode Split** |
| Box 6.3.1 | Calculate Skim |
| Input File Name | |
| Sea_skim.mat | Sea impedance skim |
| IWT_Skim.mat | Inland Waterway impedance skim |
| Rail_skim.Mat | Rail impedance skim |
| TRCK_skim.Mat | Truck impedance skim |
| Od2015_Upd.mat | Revised Base Matrix |
| Locality_group.dbf | Zonal equivalence to Locality Group |
| Output File Name | |
| Sea_skim.mat | Ship transport Impedance skim matrix |
| LAND_skim.mat | Land transport Impedance skim matrix |
| IWT_skim.MAT | Truck transport Impedance skim matrix |
| Rail_skim.mat | Rail transport Impedance skim matrix |
| Truck_Skim.mat | Truck Impedance skim matrix |
| CMMAT00C.MAT | Revised Base Matrix |
| Box 6.3.2 | Mode Split curve 1 Coastal |
| Input File Name | |
| Cargo_dist.mat | Final Cargo Distribution |
| CMMAT00C.MAT | Revised Base Matrix |
| Sea_skim.mat | Ship transport Impedance skim matrix |
| LAND_skim.mat | Land transport Impedance skim matrix |
| MS_1_Param.CSV | Mode Split curve 1 parameter |
| Output File Name | |
| CMMAT00G.MAT | Mode Split result for Coastal and Others |
| Box 6.3.3 | Mode Split curve 2 IWT |
| Input File Name | |

| **Box/Filename** | **Description** |
|---|---|
| CMMAT00G.MAT | Mode Split result for Coastal and Others |
| CMMAT00C.MAT | Revised Base Matrix |
| IWT_skim.MAT | Truck transport Impedance skim matrix |
| LAND_skim.mat | Land transport Impedance skim matrix |
| MS_2_Param.CSV | Mode Split curve 2 parameter |
| Output File Name | |
| CMMAT00F.MAT | Mode Split result for IWT and Others |
| Box 6.3.4 | Mode Split curve 3 Rail and Raod |
| Input File Name | |
| CMMAT00F.MAT | Mode Split result for IWT and Others |
| CMMAT00C.MAT | Revised Base Matrix |
| Rail_skim.mat | Rail transport Impedance skim matrix |
| Truck_Skim.mat | Truck Impedance skim matrix |
| MS_3_Param.CSV | Mode Split curve 3 parameter |
| Output File Name | |
| CMMAT00H.MAT | Mode Split result for Rail and Truck |
| Box 6.3.5 | Combine Cargo by Mode |
| Input File Name | |
| CMMAT00G.MAT | Mode Split result for Coastal and Others |
| CMMAT00F.MAT | Mode Split result for IWT and Others |
| CMMAT00H.MAT | Mode Split result for Rail and Truck |
| Output File Name | |
| FINAL_CARGO.MAT | Final Mode Split result |

Source: TA Team

**Figure D.14: Cargo Trips Part B**




Source: TA Team

## VI. THE ASSIGNMENT (BOX 7 IN FIGURE D.3)

35. In any transport model, the final step infrastructure is the allocation of movement of trips either by people or cargo to the network whether it is on the road network or the other dedicated non-road network. This is the assignment process. The first step is the organization or combination of cargo trips prior to the assignment. The structure of the assignment module is shown in Figure D.15. The various significant input and output files associated with the assignment module are tabled in Table D.15.

### A. Combination of Cargo and Person Trips

36. For person trips, it is necessary to convert those trips on the road network into vehicles via occupancy factors. The cars and bus vehicle trips are then converted into passenger car unit or pcu trips. The remaining trips do not use the road network accept for access to the non-road network. For cargo trips, it is necessary to convert those trips on the road network into

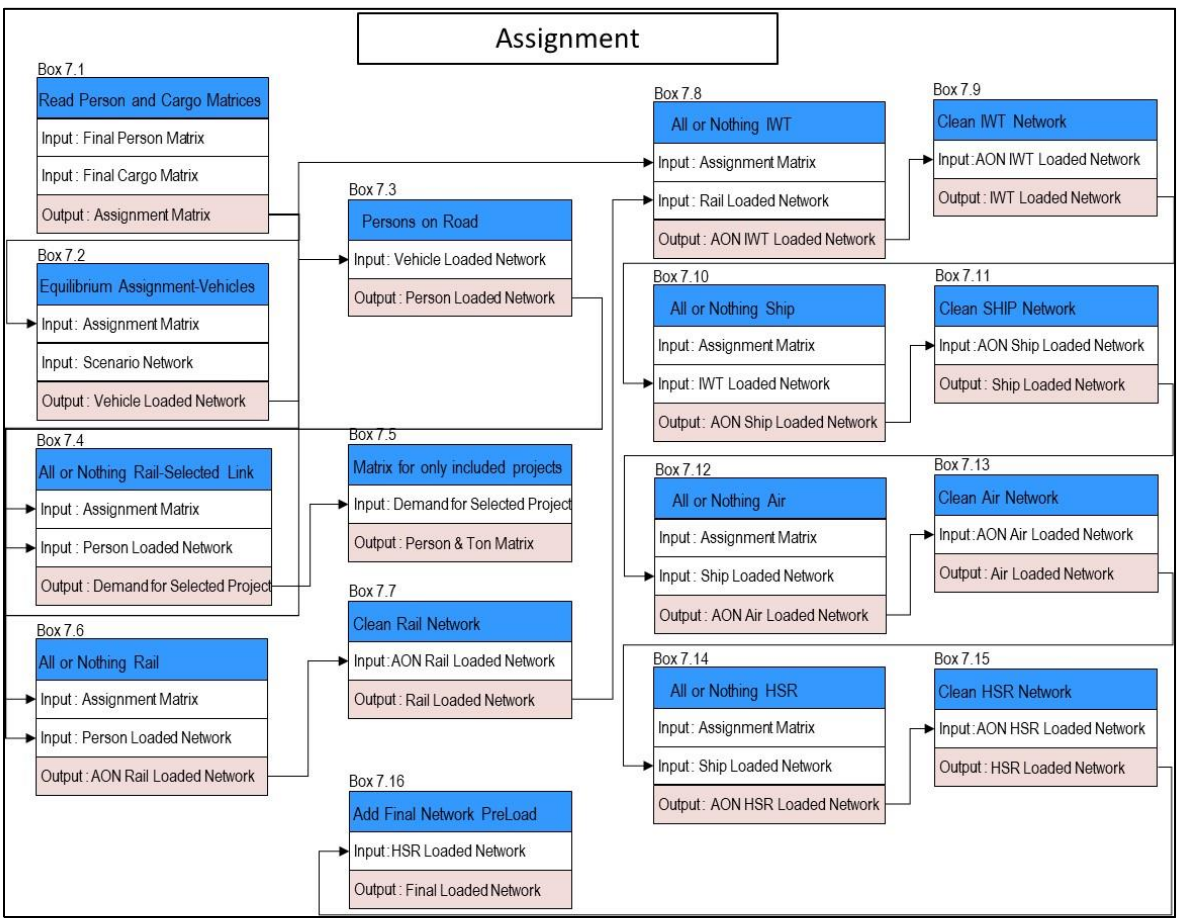
vehicles via load factors. The truck vehicle trips are then converted into trips. The remaining trips do not use the road network accept for access to the non-road network. In the case of truck trips there is also an implied back loading factor to allow for trucks returning from their destination empty.

## B. The Assignment

37. The first stage is the assignment of a total pcu matrix that includes car, bus and truck. Cars are assigned first followed by bus and truck in a capacity restrained equilibrium assignment. As the assignment is a road vehicle assignment, non-road links are excluded from the assignment. For the non-road assignment, the non-road mode of transport is assigned to the master network with other modes excluded except for the access road links.

38. At the end of the procedure, the networks are combined to produce a single output network for each scenario. It is at this time that any trips that used the road network as access are also included in the road assignment. This final assigned network is the basis for the reporting of modal network volumes.

**Figure D.15: The Assignment**




Source: TA Team

**Table D.15: Description of all Files in Assignment Module**

| Box/Filename | Description |
|---|---|
| Box 7.1 | Read Person and Cargo Matrices |
| Input File Name | |
| Final_Person.MAT | Final Person Mode Split Matrix |
| FINAL_CARGO.MAT | Final Cargo Mode Split |
| Output File Name | |
| ASMAT00A.MAT | Person and Cargo Demand Matrix |
| Box 7.2 | Equilibriuml Assignment-Vehicles |
| Input File Name | |
| ASMAT00A.MAT | Person and Cargo Demand Matrix |
| Scenario_Net.net | Comprehensive network for specific scenario |
| Output File Name | |
| ASHWY00A.NET | Vehicle Loaded Network |
| Box 7.3 | Persons on Road |
| Input File Name | |
| ASHWY00A.NET | Vehicle Loaded Network |
| Output File Name | Description |
| ASNET00A.NET | Preload Network |
| Box 7.4 | All or Nothing Rail-Selected Link |
| Input File Name | |
| ASMAT00A.MAT | Person and Cargo Demand Matrix |
| ASNET00A.NET | Preload Network |
| Output File Name | |
| Per_Tonne_Temp.MAT | Demand Using Rail Network for Specific Projects |
| Box 7.5 | All or Nothing Rail-Selected Link |
| Input File Name | |
| Per_Tonne_Temp.MAT | Demand Using Rail Network for Specific Projects |
| Output File Name | |
| Per_Tonne.MAT | Revised Demand Using Rail Network for Specific Projects |
| Box 7.6 | All or Nothing Rail |
| Input File Name | |
| ASMAT00A.MAT | Person and Cargo Demand Matrix |
| ASNET00A.NET | Preload Network |
| Output File Name | |
| ASHWY00G.NET | Loaded Network with Rail Demand |
| Box 7.7 | Clean Rail Network |
| Input File Name | |
| ASHWY00G.NET | Loaded Network with Rail Demand |
| Output File Name | |
| ASNET00B.NET | Revised Loaded Network with Rail Demand |
| Box 7.8 | All or Nothing IWT |
| Input File Name | |
| ASMAT00A.MAT | Person and Cargo Demand Matrix |
| ASNET00B.NET | Revised Loaded Network with Rail Demand |
| Output File Name | |
| ASHWY00G.NET | Loaded Network with IWT Demand |
| Box 7.9 | Clean IWT Network |
| Input File Name | |
| ASHWY00G.NET | Loaded Network with IWT Demand |
| Output File Name | |
| ASNET00C.NET | Revised Loaded Network with IWT Demand |
| Box 7.10 | All or Nothing Shipping |
| Input File Name | |
| ASMAT00A.MAT | Cargo Demand Matrix |
| ASNET00C.NET | Revised Loaded Network with IWT Demand |
| ASHWY00D.NET | |
| ASHWY00G.NET | Loaded Network with IWT Demand |

| | |
|---|---|
| Box 7.11 | Clean Shipping Network |
| Input File Name | |
| ASHWY00G.NET | Loaded Network with Air Demand |
| Output File Name | |
| ASNET00F.NET | Revised Loaded Network with Air Demand |
| Box 7.12 | All or Nothing Air |
| Input File Name | |
| ASMAT00A.MAT | Person and Cargo Demand Matrix |
| ASHWY00E.NET | Revised Loaded Network with Air Demand |
| ASHWY00D.NET | |
| ASHWY00F.NET | Loaded Network with Demand |
| Box 7.13 | Clean Air Network |
| Input File Name | |
| ASHWY00F.NET | Loaded Network with Air Demand |
| Output File Name | |
| ASNET00F.NET | Revised Loaded Network with Air Demand |
| Box 7.14 | All or Nothing HSR |
| Input File Name | |
| ASMAT00A.MAT | Person and Cargo Demand Matrix |
| ASHWY00E.NET | |
| Output File Name | |
| ASHWY00F.NET | Loaded Network with Demand |
| Box 7.15 | Clean Air Network |
| Input File Name | |
| ASHWY00F.NET | Loaded Network with Air Demand |
| Output File Name | |
| ASNET00G.NET | Revised Loaded Network with Air Demand |
| Box 7.16 | Final Network |
| Input File Name | |
| ASHWY00F.NET | Loaded Network with Air Demand |
| Output File Name | |
| LOADED_NET.NET | Final Loaded Network with All Demand |

Source: TA Team

### C. Convergence

39. At the end of a scenario model, there is an estimation of the total network vehicle and kilometers hours of travel. This leads to an estimation of an average network travel speed. As travel time is an important input into mode split of both cargo and person movement, it is important that this travel speed is stable. To ensure stability, after the first model run for any scenario, the travel speed on each individual links are then input back into the start of the model, thus the feedback loop. This process of feedback iterations continues until the specified difference in network vehicle and kilometers hours of travel is within a certain specified range. At that point, the model convergence is achieved and the model iteration process stops for a specified scenario.

## VII. INDICATIVE RESULTS AND VERIFICATION

40. All modules of MRTM are reported in the earlier documentation. Now there is only the output for consideration.

## A. The Report Structure

41. As part of MRTM, a series of standard reports are available for any model scenario. Reports automatically available within the model structure are documented in Table D.16.

**Table D.16: The Standard Report Structure**

| Category | Name | Description | Reports included |
|---|---|---|---|
| Socio-Economic | Socio | Socio Economic Summary | Population, regional GDP, car ownership by locality and sector |
| | Socio_1 | Distribution between locality | Graphical distribution of socio-economics |
| Generation | Gen | Trip generation summary | Person trips by locality |
| | Gen_Cargo | Trip generation summary | Cargo trips by locality |
| Mode Split | Ms_Rpt | Mode split for Mekong region | Person tips by mode by category in tabular and graphical format |
| | Ms_Rpt_Inter | Mode split for Mekong region by locality | Person tips by mode by category in tabular and graphical format |
| | Ms_Reg | Mode split by locality | Person trips mode split by locality in percentage tabular format |
| | Ms_Rpt_Cargo | Mode split for Mekong region | cargo tips by mode in tabular and graphical format |
| | Ms_Rpt_Inter_Cargo | Mode split for Mekong region by locality | Cargo tips by mode in tabular and graphical format |
| | Ms_Reg_Cargo | Mode split by locality | Cargo trips mode split by locality in percentage tabular format |
| Assignment | Assign | Assignment Summary | A series of tables, person and cargo kilometers of travel by mode in tabular and graphical format. Similar tables for each project. |
| | Assign_2 | Assignment Summary | Tabular travel information by each project for a particular case for cargo and person. |
| | Assign_3 | Assignment Summary | Tabular travel information by each project for a particular case for cargo and person across the whole network |

Source: TA Team

## B. Model Verification in 2015

42. As is stated earlier, there is only limited data available for MRTM verification, the model was initially verified against the following sources[79]:

- Traffic count screenline in Thailand;
- Truck tonne kilometers in Thailand;
- Trade between Thailand and Guangxi and Yunnan;
- Registered cars in Thailand;
- Comparison with Lao PDR Feasibility Study.

43. Two screenlines are compared as shown in Figure D.16. In both cases, the comparison suggests that MRTM reproduces good results. There are also national cargo statistics available via road for Thailand. Both traffic count and model result in terms of the pcu comparison are within ten percent.

[79] During the small extension of the TA from April to July 2018, further verification was undertaken to improve the model for later use. Refer the Attachment to this Appendix.

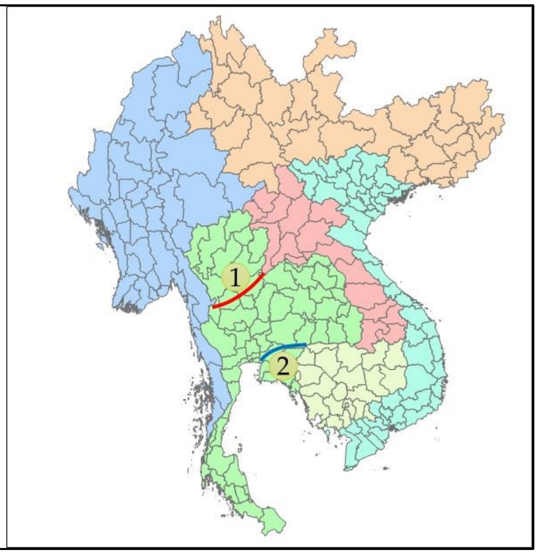
44. In the case of Thailand, the Ministry of Transport[80] prepares data on the number of tonnes carried by road. The Ministry reports that there are 531.3 million tonne-kilometers each day in Thailand. MRTM prediction is 528 million tonne-kilometers carried by road. The MRTM estimate in 2015 is within a few percent.

45. From big data namely the Thailand and Chinese customs database, it is possible to interpret and reconcile any differences in the database. These databases suggest that the trade between the two Chinese localities an Thailand is 1,409 tonnes on average per day in 2015 compared to an observed volume of 1,400 tonnes per day. The comparison is good.

**Figure D.16: Screenline Comparison**

| Screenline | Observed ** | Estimated | %Diff |
|---|---|---|---|
| 1 | 97,088 | 104,340 | 7.5% |
| 2 | 167,774 | 156,894 | -6.5% |
| Total | 264,862 | 261,234 | -1.4% |

**Source:
Thailand National Model Traffic count 2015



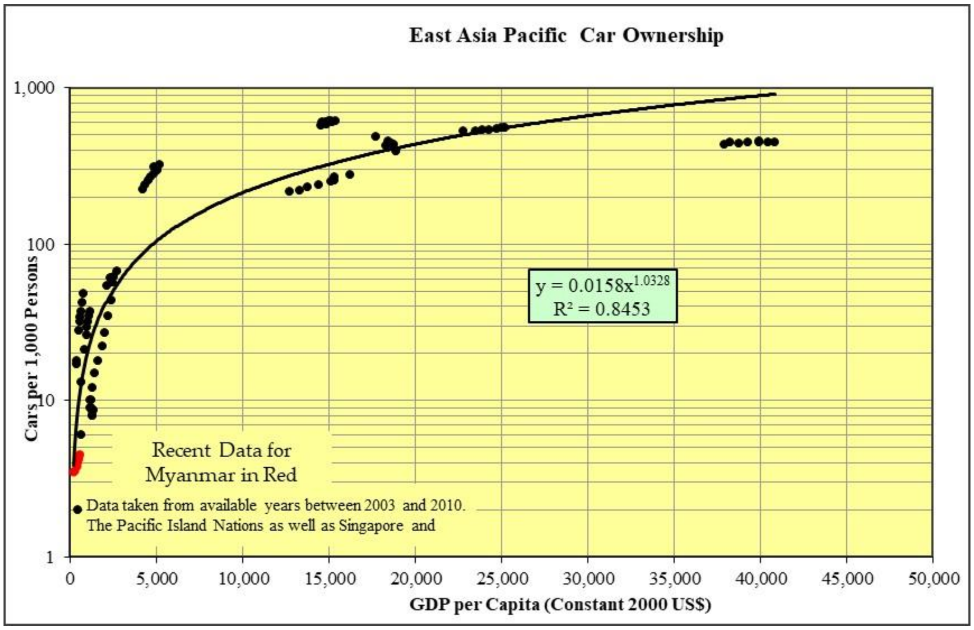

Source: TA Team

46. Finally in comparison for the base year, there is an estimation on the number of cars within a locality. The estimation is based on time series data from the World bank reflected in Figure D.17. MRTM suggests that there are 7.7 million cars which closes reflects the data of the government of Thailand[81].

[80] Source: http://www.news.mot.go.th/motc/portal/graph/np/index8.asp

[81] The 2015 Thailand vehicle registration as available from Department of Land Transport.

**Figure D.17: Relationship between Car Ownership and GDP per Capita**




Source: World Bank

47. In a comparison to ensure the reasonableness of the results in contrast to other recent project analysis reports. It is therefore at this point in the documentation, there is a comparison of the results from MRTM with a recent feasibility study. The usage of project six was recently considered in a pre-feasibility study[82]. The feasibility suggested that this project in 2025 would attract annually 2.41 million passenger kilometers and 2.34 million tonne kilometers. The results from MRTM suggested that this same project in 2025 would attract annually 2.45 million passenger kilometers and 5.34 million tonne kilometers[83]. One would not expect the projections from two different analytical procedures to be the same especially when one is a detailed feasibility study. It is thus good that the results from MRTM are of a similar order as that of the detailed feasibility study. This comparison provides confidence in the results of MRTM.

## C. Projections

48. Model projections are described in Section C of Section V of the main text.

# VIII. FUTURE DIRECTIONS

49. The MRTM is indeed a broad tool which should now be available for any Mekong region ADB project possibly with adaptation. All transport surveys undertaken for any ADB project within the Mekong Region should be used to improve the model verification. It is desirable that this remains a living model under continued development.

## A. Model Maintenance

50. MRTM hast been developed for the specific evaluation of nine railway projects. However, this model has the capability with refinement if necessary to form the foundation of

[82] The reference is "Feasibility Study for the Railway Link from Vientiane in the Lao PDR to Vung Ang in Vietnam."
[83] The distance is estimated as the complete trip not simply that part of the trip using the project.

any regional transport infrastructure within the Mekong Region. It is not applicable for the analysis of city projects.

## B. Enhancement

51. During the model developed several enhancements were identified for future development that were not possible during the timeframe available for the current version of the model. These enhancements include:

- Travel time probability;
- Additional air passenger model;
- Transit Line files for non-road modes;
- Traffic census across all localities to improve verification; and
- Detailed cargo movement census.

52. Although the model is developed on a particular software platform, there is no reason why the model cannot be shifted to other transport modelling software platform. However, this is possibly not in the interest of the ADB. Once the model is established across more than one software platform, the ADB may lose the ability for comparison of results. One option for consideration by the ADB is to consider the establishment of a regular program of model training and maintenance whether this is undertaken internally or externally is a subject for consideration by the ADB. In any case, it is most likely a good idea for the ADB to take the initiative in the training of regional government staff in the usage and capability of MRTM.

## Attachment – Further Verification Carried out in June 2018

53. During the small extension of the TA from April to July 2018, further verification was undertaken to improve the model for later use.

54. Two features are now incorporated within the framework and documentation of the MRTM namely a validation against person arrival data into the seven localities and the incorporation of person movements external to the GMS.

55. This additional validation feature which now considers the datasets from the inbound passenger arrival data[84]. The detail provided within the aforementioned datasets also provided a source for the mode of travel. Broadly the mode of arrival travel was dominated by land and air. Myanmar and Laos had the highest number of arrivals by land with 90% and 80% respectively. Cambodia followed with 50% of arrivals by land. Thailand and Lao PDR had around 15% of arrivals by land[85].

56. The comparison between observed and the model estimation is presented in **Error! Reference source not found.** for the MRTM base year of 2015. The table also incorporates person movement arriving from outside of the subregion. Thus, as a consequence, external person movements are now incorporated within the model.

57. The comparison of arrival person movements between observed and estimated as seen in Table 1 is good across all localities and the overall total. At each comparison the difference between observed and estimated person movement is less than 10%. The highest difference between observed and estimated is the locality of Yunnan.

[84] The source of the data is National Statistical databases and ADB Scorecard: Key Indicators for GMS Tourism Performance 2015.
[85] In the case of the two provinces within the PRC, the subregional average was adopted for these localities.

**Table D.18: Daily Arrival Comparison**

| Locality | Observed | Estimated | % Difference |
|---|---|---|---|
| 1-Cambodia | 19,931 | 19,453 | 2.5% |
| 2-Guangxi, PRC[86] | 9,082 | 9,598 | -5.4% |
| 3-Yunnan, PRC | 16,037 | 14,682 | 9.2% |
| 4-Lao PDR | 18,570 | 20,000 | -7.2% |
| 5-Myanmar | 18,722 | 17,855 | 4.9% |
| 6-Thailand | 123,095 | 130,246 | -5.5% |
| 7-Viet Nam | 37,760 | 38,387 | -1.6% |
| **Total** | 243,197 | 250,221 | -2.8% |

Source: TA team and MRTM

58. The incorporation of external movement feature into each of the seven localities is a derivative of the review of arrival passenger data. There is no significant change in the screenlines previously compared in Figure D.16 as a consequence of the inclusion of this MRTM feature.

59. The feature incorporating the estimation of external traffic is included within the Mode Split Person Module of MRTM. When and if additional detailed data becomes available, this feature will be updated within the framework of MRTM.

86 In the case of the two provinces of PRC, the estimate is an estimate from the whole of the PRC dataset. It does not include travel between Guangxi and Yunnan.

## APPENDIX E: ENVIRONMENTAL AND SOCIAL SCREENING

This section provides support to Section VII in the main text. A description of the assessed effects in presented in Table E.1 for each rail missing link.

**Table E.1: Environmental and Social Screening**

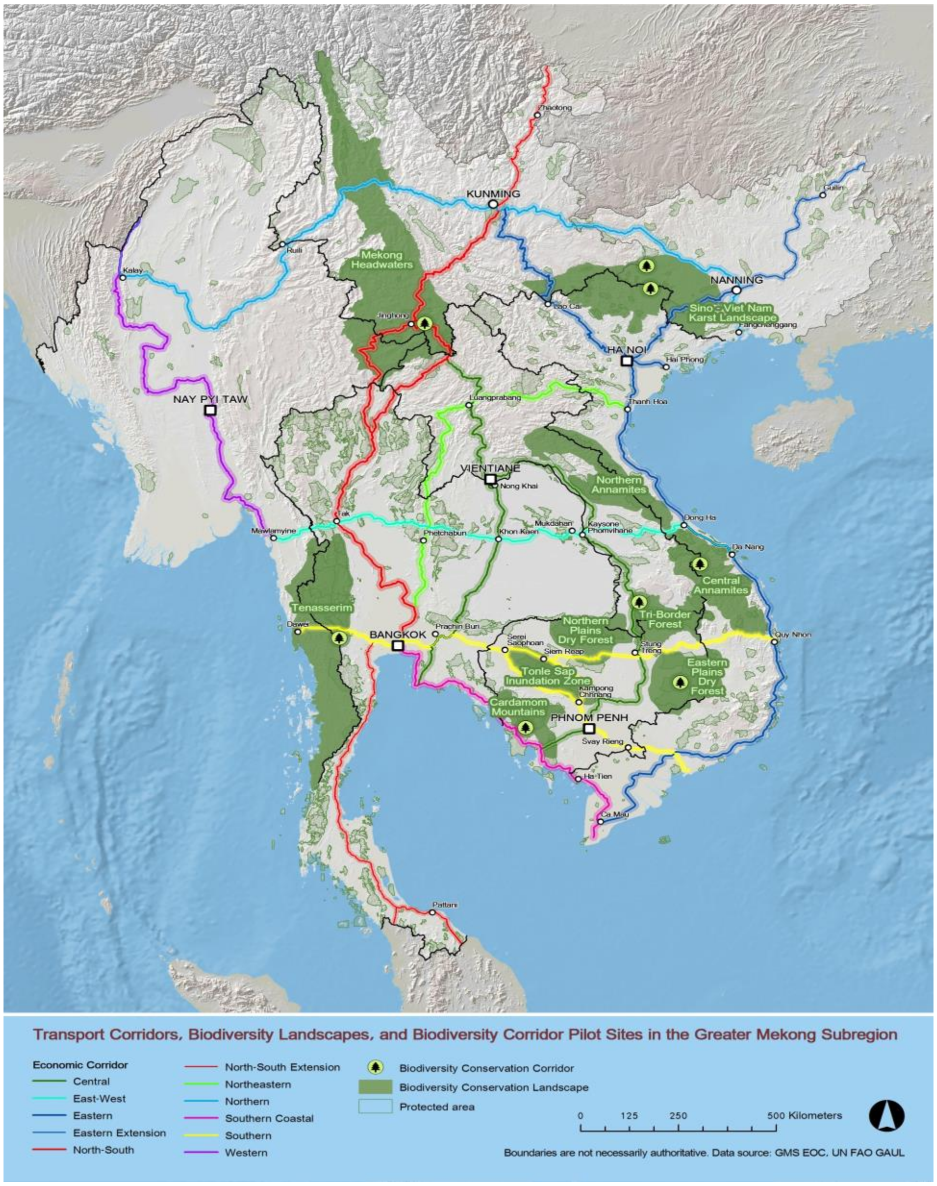
| Project | Main Physical Features | Environmental Issues | Social Issues | Indigenous People | Comments |
|---|---|---|---|---|---|
| 1 | Primarily flat land. Cultivated area with dry season rice that is inundated in the wet season. | Drainage modification to reduce impact of flooding. | Re-settlement is in progress and is monitored by ADB. Level crossings need improvement and barriers. | | The link from Poipet to Thailand is complete and the railway line is now open from Poipet through to Phnom Penh. However significant rehabilitation of track and bridges from Battambang to Phnom Penh is still required to allow higher speeds and axle loads. |
| 2 | Primarily Flat land. Cultivated area with dry season rice that is inundated in the wet season. | Construction in Mekong River wetlands. Drainage modification to reduce impact of flooding. Two major bridges to be built (1000m across Mekong River and 1500m across Tonle Sap River) | Land acquisition could be a problem. (At least 50 m either side of right of way is preferred.) There has been tension between Cambodia and Vietnam about land ownership near border area. | | Cambodia and Vietnam considering a change to the routing - a new route from Phnom Penh to HCMC via Bavet/Srey Veng. This would involve construction in Mekong Delta. (Possible water resource management issues.) |
| 3 | Myanmar: Mountainous and forested. Thailand: Primarily flat land. Cultivated area with dry season rice that is inundated in the wet season. | Myanmar: Requires 32 km of tunnels and 28 km bridges. Alignment is within a GMS biodiversity zone. Thailand: Alternate alignments were assessed to avoid watershed areas and reduce construction and operating costs. The initial environmental examination (IEE) did not identify any significant impacts. | Significant land acquisition cost in Thailand. (No details available for Myanmar section.) | | The FS study was undertaken for Thailand. Hence, details and environmental and social impacts in Myanmar are limited. Similarly, public consultation was undertaken in Thailand as part of FS but not in Myanmar. |

| Project | Main Physical Features | Environmental Issues | Social Issues | Indigenous People | Comments |
|---|---|---|---|---|---|
| 4 | Mountainous | Difficult alignment from Lashio to Muse. Construction of tunnels and bridges is required. | Strong opposition from public has prevented implementation. Original plan (to construct a line from Muse to Kyauk Phyu) was cancelled in 2014. No decision has been taken by Myanmar whether to connect to China and if project is approved, whether to construct a new line from Mandalay to Kyauk Phyu or to use existing route from Mandalay to Yangon. | Railway line from Mandalay to Kyauk Phyu would run through Rakine State, home to many Rohingya people. Lashio - Muse section is in Shan State. (Shan State Army is active.) | Section from Dali to Riuli in China is under construction. A connection would be required from Riuli to Muse in Myanmar. Opposition to a connection has been raised in Myanmar. |
| 5 | Project is under implementation | | | | |
| 6 | Mix of mountainous and hilly (karst) terrain and flat land. | Near to protected areas in both Lao and Vietnam. Lao: Hin Namno conservation area (Khammouane Province). Vietnam: Phong Nha-Kẻ Bàng National Park and UNESCO World Heritage Site in the Bố Trạch and Minh Hóa districts of central Quảng Bình Province. Bridge needed across Mekong at Thakhek. | The section through the Mu Gia pass is part of the former Ho Chi Minh trail. Unexploded ordinance. (UXO) | | |
| 7 | Mix of topography. | Section from Thakhek to Pakse follows the Mekong River and is in the floodplain. From Pakse southward the alignment borders the Dong Hua Sao national protected area and the Beung Kiat Ngong Ramsar wetlands area in Champassak Province. There | The "link" is a complicated routing that will require a tri-lateral agreement (Lao, Thailand, Vietnam). Information/studies on the actual alignments for the routes are scant and as a result there is very little information on social impacts of the railway(s). | Section in Lao from Savannakhet to Lao Bao will parallel Highway No. 9 in Lao and AH 16 in Vietnam. Area is home to Bru ethnic minority. | |

| Project | Main Physical Features | Environmental Issues | Social Issues | Indigenous People | Comments |
|---|---|---|---|---|---|
| | | are no studies on environmental impact in the section from Savannakhet-Lao Bao-Dong-Ha. (Lao approved a project (Giant Corporation, Malaysia) to build a railway from Savannaket to Lao Bao in 2012 but the project has not yet started.) Environmental assessment of the alignment in Thailand have been approved but have not yet started. | | | |
| 8 | Primarily flat land. Cultivated area with dry season rice that is inundated in the wet season. Area has extensive forest coverage. | Cambodia: Construction in the Mekong River wetlands. Wildlife conservation area in Kratie province. Drainage modification to reduce impact of flooding. Lao: Borders the Dong Hua Sao national protected area and the Beung Kiat Ngong Ramsar wetlands area in Champassak Province. | Land acquisition could be a problem. (At least 50 m either side of right of way is preferred.) | Seven indigenous groups in area: Bunong, Kouy, Mil, Khonh, Kraol, Steang, and Thamoun. | |

| Project | Main Physical Features | Environmental Issues | Social Issues | Indigenous People | Comments |
|---|---|---|---|---|---|
| 9 | Urban area and existing railway line | Construction of a short standard gauge railway track (1.5 km in an urban area) to connect Hekou, China to Lao Cai Vietnam. (Includes new bridge across Nanxi River). Plan is to convert the existing 1000 mm (meter) gauge railway from Lao Cai to Haiphong to a 1435 mm (standard) gauge or dual gauge railway line. Main issue is disruption/disturbance during construction. | The section of the railway from Lao Cai to Yen Vien was rehabilitated through an ADB Project (Loan 2302) from 2006 to 2016. People were re-settled and compensation was paid. Social and re-settlement impacts were not assessed on the section of the railway line from Yen Vien to Haiphong will be needed to determine impact of new project works. | Hmong peoples in project area | ADB Project to rehabilitate sections of the railway from Lao Cai to Yen Vien was completed in 2016. The project was completed without any major complaint on environmental management and there are no outstanding re-settlement issues. |

**Figure E.1: Transport Corridors, Biodiversity Landscapes and Biodiversity Pilot Sites in the GMS**




Source: ADB

## APPENDIX F: LIST OF MEETINGS AND ATTENDEES

### Inception Meeting, 8-9 November 2016, ADB Thailand Resident Mission

LIST OF PARTICIPANTS

1. Sota Ouk, Ministry of Public Works and Transport, Cambodia
2. Cui Yanping, National Railway Administration, PRC
3. Pang Shujian, National Railway Administration, PRC
4. Lan Xi, CREEC, PRC
5. Senthavisay Malivang, Department of Railways, Lao PDR
6. Hinphet Lakhonvong, Department of Railways, Lao PDR
7. Maung Maung Than, Myanma Railways
8. Thanaphon Charanwanitwong, Ministry of Transport, Thailand
9. Takun Indarachome , State Railway of Thailand
10. Chitkamon Pondate, State Railway of Thailand
11. Chaiya Kotcharat, State Railway of Thailand
12. Tran Thi Thanh Mai, Viet Nam Railway Authority
13. Jamie Leather, ADB
14. Phil Sayeg, Consultant, ADB
15. Pam Nacpil, Consultant, ADB

### In-Country Consultations

Cambodia, 2 February, Phnom Penh

| | |
|---|---|
| ADB | Phil Sayeg, ADB Consultant<br>Pam Nacpil, ADB Consultant |
| CAMBODIA | Ouk Sota, Deputy Director, Railway Department<br>Chreung Sok-Tharath, Deputy Director, Railway Department<br>Ouk Ourk, Deputy Director, Railway Department |

PRC, 10 January, Beijing

| | |
|---|---|
| ADB | Phil Sayeg, ADB Consultant<br>Pam Nacpil, ADB Consultant |
| PRC | Beijing Jiaotong University, School of Traffic and Transportation, Railway Transport Planning and Management Department<br>Prof. YANG Hao<br>Prof. WEI Yuguang<br>Prof. ZHANG Jinchuan (associate)<br>National Railway Administration (NRA)<br>CUI Yanping<br>PANG Shujuan |

Lao PDR, 6 February, Vientiane

| | |
|---|---|
| ADB | Phil Sayeg, ADB Consultant<br>Pam Nacpil, ADB Consultant |
| LAO PDR | Sonesack Nhansa Deputy Director General, Railway Department |

Bounchanh Saybounheuang, Director of Administration and Personnel
Hinphet Lakhonvong, Railway Department

Myanmar, 31 January, Nay Pyi Taw

ADB Jamie Leather, Principal Transport Specialist, SETC
Phil Sayeg, ADB Consultant
Pam Nacpil, ADB Consultant
MYANMAR Aung Win, General Manager, Technical and Administration
Ba Myint, General Manager, Inspection
Maung Maung Thwin, General Manager, Civil
Hla Hla Win, General Manager, Finance
Kyay Kyaw Myo, Deputy General Manager
Maung Maung Than, Deputy General Manager
Htaung Sian Kan, Deputy General Manager

Thailand, 1 February, Bangkok

ADB Jamie Leather, Principal Transport Specialist, SETC
Phil Sayeg, ADB Consultant
Pam Nacpil, ADB Consultant
THAILAND State Railway of Thailand (SRT)
Mr. Araya Pindhatisha, Director, Traffic Operation Department
Mr. Pinyo Chanmaha, Director, Project Planning and Development Center, Special Project and Construction Department
Mr. Chaiya Kotcharat, Chief, Thungsong Traffic Inspector, District Traffic Division 5, Traffic Operation Department
MOT-Office of Transport and Traffic Policy and Planning
Mr. Thanaphon Charanwanitwong, Professional Project and Plan Analyst, Rail Project Development Office

Viet Nam, 13 January, Ha Noi

ADB Phil Sayeg, ADB Consultant
Pam Nacpil, ADB Consultant
VIET NAM Nguyen Ngoc Thuyen, Deputy Director General, MoT
Dang Sy Manh, Deputy Director General, VNRA
Nguyen Tien Thinh, VNRA

**Working Group Meetings**

16-17 August 2017, ADB Thailand Resident Office

1. Sota Ouk, Ministry of Public Works and Transport, Cambodia
2. Cui Yanping, National Railway Administration, PRC (via videoconference)
3. Hinphet Lakhonevong, Department of Railways, Lao PDR
4. Aung Thu Latt, Myanma Railways
5. Thanaphon Charanwanitwong, Ministry of Transport, Thailand
6. Pinyo Chanmaha, State Railway of Thailand
7. Nguyen Tien Thinh, Viet Nam Railway Administration
8. Jamie Leather, ADB

9. Takeshi Fukayama, ADB
10. Phil Sayeg, Consultant
11. Len Johnstone, Consultant
12. Pam Nacpil, Consultant
13. Boonchuay Tongkam, Observer

<u>12 December 2017, ADB Thailand Resident Office</u>

Cambodia
Mr. Sota Ouk, Ministry of Public Works and Transport
Mr. Keo Thona, Ministry of Public Works and Transport
Mr. Sok Khoeun, Ministry of Foreign Affairs and International Cooperation
Mr. Theam Vuth, Ministry of Foreign Affairs and International Cooperation

PRC
Ms. Cui Yanping, National Railway Administration

Lao PDR
Mr. Ketsana Soukkhamthath, Department of Railways

Myanmar
Mr. Aung Thu Latt, Myanma Railways

Thailand
Mr. Thanaphon Charanwanitwong, Ministry of Transport
Mr. Suphalerk Soodyodprasert, Ministry of Transport
Mr. Pinyo Chamnaha, State Railway of Thailand

Viet Nam
No representative

ADB/Consultants/Presenter
Mr. James Leather, Chief, Transport Sector Group
Mr. Phil Sayeg, Consultant
Mr. Paul Power, Consultant
Ms. Pam Nacpil, Consultant
Mr. Boonchuay Tongkam, Presenter

**GMRA 3rd Board of Directors (BoD) Meeting**
**22 March 2018, Vientiane, Lao, PDR**
**(Members of the delegations also attended the Working Group Meeting, 21 March)**

**External Participants (Non-Lao PDR)**

| COUNTRY | | NAME | POSITION | ORGANIZATION |
|---|---|---|---|---|
| 1 | CAMBODIA | Mr. Ly Borin (BoD) | Under-secretary of State | Ministry of Public Works and Transport |
| 2 | CAMBODIA | Mr. Srun Thirith | Deputy Director, First Check Point Department | Council of Ministers, Lawyer Board |
| 3 | CAMBODIA | Mr. Nam Sokleang | Deputy Head, Planning and Customs Policies Bureau | Ministry of Economy and Finance, General Department of Customs and Excise |
| 4 | CAMBODIA | Mr. Sok Khoeun | Director | Ministry of Foreign Affairs and International Cooperation, Border Department |
| 5 | CAMBODIA | Mr. Yi Phealy | Deputy Director, First Check Point Department | Ministry of Interior, General Department of Immigration |
| 6 | CAMBODIA | Mr. Ouk Ourk | Acting Director | Ministry of Public Works and Transport, Railway Department |
| 7 | CAMBODIA | Mr. Chreung Sok-Tharath | Deputy Director | Ministry of Public Works and Transport, Railway Department |
| 8 | PRC | Mr. Liu Keqiang (BoD) | Deputy Administrator | National Railway Administration |
| 9 | PRC | Mr. Wang Jiayu | Deputy Director General | National Railway Administration, Department of External Relations |
| 10 | PRC | Ms. Cui Yanping | Director | National Railway Administration, Department of External Relations |
| 11 | PRC | Ms. Qin Fangyun | Official | National Railway Administration, Department of External Relations |
| 12 | PRC | Zhao Yanrui | Attache | Department of Treaty and Law |
| 13 | PRC | Wang Leiyun | Official | Customs General Administration, Department of Policy and Legal Affairs |
| 14 | PRC | Shen Qiankun | Official | Customs General Administration, Department of Customs Control and Inspection |
| 15 | MYANMAR | Mr. Aung Win (BoD) | General Manager | Myanma Railways |
| 16 | MYANMAR | Mr. Aung Thu Latt | Deputy General Manager | Myanma Railways |
| 17 | MYANMAR | Mr. Han Win Naing | Director | Ministry of Foreign Affairs |

| | | | | |
|---|---|---|---|---|
| 18 | MYANMAR | Ms. Khin Khin Phyu | Deputy Director | Union Attorney Generals Office |
| 19 | MYANMAR | Ms. May Su Aung | Assistant Director | Customs Department |
| 20 | THAILAND | Ms. Duddao Charoenpol (BoD rep) | Principal Advisor on | Ministry of Transport, Land Transport Economics |
| 21 | THAILAND | Mr. Sujit Chaosirikul | Director | State Railway of Thailand, Freight Service Department |
| 22 | THAILAND | Ms. Dollaya Panthanont | Transport Technical Officer | Ministry of Transport, International Affairs Division |
| 23 | THAILAND | Mr. Thanaphon Charanwanitwong | Professional Policy and Plan Analyst | Office of Transport and Traffic Policy and Planning, Rail Project Development Office |
| 24 | THAILAND | Mr. Pongsiri Ta-In | Customs Technical Officer | Customs Department |
| 25 | THAILAND | Mr. Chitkamon Pondate | Chief, Information and System Development Section | State Railway of Thailand, Research Planning Development and Information Division, Traffic Business Strategy Bureau |
| 26 | VIET NAM | Mr. Nguyen Tien Thinh (BoD rep) | Head of Planning, Investment and International Cooperation Divison | Ministry of Transport, Viet Nam Railway Authority |
| 27 | VIET NAM | Ms. Nguyen Thi Tuyet Giang | Head of International law and Human Rights Divison | Ministry of Justice, International Law Department |
| 28 | VIET NAM | Ms. Ngo Thi Phuong | Official | Ministry of Foreign Affairs, Economic Affairs Department |
| 29 | VIET NAM | Ms. Nguyen Thi Thu Huong | Official, International Cooperation Department | Ministry of Finance, General Department of Customs |
| 30 | ADB | Mr. Hiroaki Yamaguch (BoD) | Director, SETC | ADB |
| 31 | ADB | Mr. Yasushi Negishi | Country Director, Lao Resident Mission | ADB |
| 32 | ADB | Mr. Kang Hang Leung | Senior Finance Specialist, SETC | ADB |
| 33 | ADB | David Martin | Consultant, TA 8748 | ADB |
| 34 | ADB | Paolo Vergano | Consultant, TA 8748 | ADB |

| | | | | |
|---|---|---|---|---|
| 35 | ADB | Philip Sayeg | Consultant, TA 9123 | ADB |
| 36 | ADB | Len Johnstone | Consultant, TA 9123 | ADB |
| 37 | ADB | Paul Power | Consultant, TA 9123 | ADB |
| 38 | ADB | Pam Nacpil | Consultant, TA 9123 | ADB |

Lao PDR participants

| | Name and First Name | Oranization |
|---|---|---|
| 1 | Mr. Xaygnalath SOUKSIVONGXAY | Lao Railways |
| 2 | Mr. Phouthasenh ARKHAVONG | Department of Housing and Urban Planning |
| 3 | Mr. Chantoula PHANALASY | Department of Inspection, MPWT |
| 4 | Mr.Bouaphanh THEDDAVANH | Department of Water ways, MPWT |
| 5 | Mr. Siriphone INTHIRATH | Department of Personnel, MPWT |
| 6 | Mr. Phomma VEORAVANH | Department of Water supply, MPWT |
| 7 | Mr. Khampet INTHIDETH | Public Work and Transport Research Institute, MPWT |
| 8 | Mr.Thenekham THONGBONH | Public Work and Transport Training Institute, MPWT |
| 9 | Mr. Amphayvanh CHANTHAPHALY | Representative of AEC |
| 10 | Mr. Vandy VORASAK | Lao Transport Engineering Consultant, LTEC |
| 11 | Mr. Xaysana XAPHAKDY | Department of Planning and Cooperation |
| 12 | Dr. Arounyadeth RASPHONE | DIC, MPI |
| 13 | Mr. Thadsaphone NORASENG | Department of Treaties and Law, MOFA |
| 14 | Somthavy | Department of Food and Drug, MOH |
| 15 | Mr. Phoummachanh  BODHISANE | Department of Economic Affairs, MOFA |
| 16 | Mr Bounsouane PHONGPHICHTH | Ministry of Agriculture and Forestry, LAO PDR |
| 17 | Mr. Sengdarith KATTIGNASACK | Director General, DPC |
| 18 | Mr. Kitsana CHANTHAVIENG | Deputy Permanent Secretary, MPWT |
| 19 | Mr. Khammoune BOUAPHANH | Deputy Director General, DAL |
| 20 | Mr. Chanthaphone PHANVISOUK | Department of Planning and Cooperation |
| 21 | Mr. Hinphet LAKHONEVONG | Department of Railways |
| 22 | Miss. Douangsamone VILAYCHIT | Department of Railways |
| 23 | Ms. Chanthanom SOULINGO | Permanent of Secretariat Office, MPWT |
| 24 | Ms.  Chindalay VONGXAY | Permanent of Secretariat Office, MPWT |
| 25 | Mr. Chanthavong BOUNSOMBATH | Department of Planning and Cooperation |

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| 26 | Ms. Sengchanh BOUTDAXAY | Department of Railways |
| 27 | Miss. Amphaiphan KHAMSOMPHOU | Department of Railways |
| 28 | Ms. Phongsavai PHAVILARDORSY | Department of Railways |
| 29 | Ms. Daophet SILIPHOKHA | Department of Planning and Cooperation |
| 30 | Mr. Phasouk PHOUTTHAVONG | Department of Railways |
| 31 | Mr. Ketsana SOUKKHAMTHATH | Department of Railways |
| 32 | Mr. Sithad HEAUANGVONGSA | Department of Railways |
| 33 | Mr. Sonthanou THONGXAYYO | Department of Railways |
| 34 | Ms. Sayphavanh VONGDALASENE | Department of Railways |
| 35 | Ms. Latdavanh SINPASEUT | Department of Railways |
| 36 | Ms. Souphavanh XAYYAVONG | Department of Railways |
| 37 | Ms. Dalavhan CHANTHAVANTHONG | Department of Railways |
| 38 | Chanthaly CHANSOMPHENG | MPI |
| 39 | Soukkhongthong VORAPHET | Department of Civil Aviation |
| 40 | Phanthaphap PHOUNSAVATH | Department of Transport |
| 41 | Ms. Souhany HEUANGKEO | DOT |
| 42 | Sokthavath | |
| 43 | Leth | DOI |
| 44 | Saykham | PTTI |
| 45 | Sompong | DDG of DWS |