

## Evaluating Impacts of Transport Infrastructure Development on Freight Modal Share

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**Abstract:** This study is to evaluate the impacts of transport infrastructure development on freight modal share. A national freight transport model was developed and used to evaluate the impacts. Scenarios tested were based on the Thai government's infrastructure plan and pricing policy. The study found that transport infrastructure development with pricing policy could achieve significantly modal shift from road to the alternatives. However, road transport share is still rather high. In order to achieve higher modal shift, rail network should be significantly expanded. Freight rail speed needs to be increased. Inland water way should also be expanded. Connection hubs between road and rail, and between road and inland water port are the key issue of modal shift. Moreover, pricing policy needs to be set up appropriately to encourage the modal shift and also to reflect externality costs.

**Keywords:** Freight modal share, transport infrastructure, freight transport model

### 1. INTRODUCTION

Within the process of value chain, government has a primary role in development of the transport infrastructures, including road, railway, water way, as well as transport facilities. Thai government has a strong focus on the development of transport infrastructures in order to support logistics process in Thailand and neighbour countries. Strategic plans for logistics development in Thailand Volume 1 (2007-2011) and Volume 2 (2012-2017) aims to reduce logistics costs with a main indicator which is proportion of logistics cost per gross domestic product (GDP). During last 10 years, the proportion of logistics cost per GDP has been declined on average 0.3% per year. In 2012, the proportion of logistics cost per GDP is 14.3%, in which about 50% is transport cost.

So far, the Thai Government has been developed mainly road network and infrastructure to cover all over the country. This results more than 80% of cargos in Thailand was transported on roads. The development of alternative forms of freight transport (rail and water transport) has been limited. Facilities at the connection point between the transport modes are still lack of efficiency. Multi-modal transport is not successful.

Road transport is the most convenient to move cargos from origins to destinations, but it is the most expensive one (as shown in Table 1). Transports by rail and ship are much cheaper, but they are unreliable.

Table 1. Freight modal share and transport cost of each model in Thailand (OTP, 2014)

<b>Transport modes</b>	<b>Freight modal share (%)</b>	<b>Transport cost (baht/ton-km)</b>
Road	87.50	2.12
Rail	1.40	0.95
Water	11.08	0.65
Air	0.02	10.00

A major strategy proposed by the government to reduce the cost of transport is to reduce the share of road transport and shift to rail and water transport instead. Therefore, the main purpose of this study is to evaluate the impacts of transport infrastructure development on freight modal share.

## 2. THE NEED OF FREIGHT MODALSHIFT AND NATIONAL MASTER PLANS

There are a number of studies confirming that rail and water transport have lower cost than road transport. In order to achieve the modal shift, development of multi-modal transport is needed (OTP, 2009). This includes development of rail and water transport facilities, as well as well connection facilities with road transport at the multimodal centres.

Freight volumes will increase continuously to all regions of the country. Without the development and improvement of rail transportation network, road transport will increase significantly. This will cause delay in freight, so higher transport costs. A study by TRF (2013) found that development of transportation network and infrastructure can cause a change in the forms of freight transportation. This improvement should be integrated all transport modes. With the improvement of rail transport services by reducing rail transport costs, proportion of road transport in terms of tones-km could reduce from 92% to 88%, and the proportion of rail transport could increase from 4% to 8%. However, to increase more freight transport by rail, additional projects are needed including expansion of the railway network, increasing speed and reliable, and improvement of services at the connections between truck and rail freight, and between railways and sea ports.

Overall, freight transport in Thailand has been mainly depended on road transport, handling more than 80% of domestic freight volume. This is because road network (more than 200,000 kilometres of highway) reaches to everywhere which door-to-door service can be provided easily. Rail network (about 4,000 kilometres of single track) is limited. Water transport (a few hundred kilometres) can service only in some rivers in the north of Bangkok, and some costal ports are used in the South of Thailand. Also the connectivity between modes of transport is not convenient, so it causes some delay and unreliable.

However, the responsible authorities in Thailand have developed strategic plans that clearly and directly relate to the development of the transport infrastructure. The relevant plans including (1) the Eleventh National Economic and Social Development Plan. (2012 – 2016) (NESDB, 2012), (2) National Transport and Traffic Master Plan (2011-2020) (OTP, 2011), (3) Strategic plans for Logistics Development in Thailand Volume 1 (2007-2011) (NESDB, 2007) and Volume 2 (2012-2017) (NESDB, 2012), and (4) Strategies to improve transportation infrastructure in Thailand (2015-2022) (OTP, 2015).

The Eleventh National Economic and Social Development Plan. (2012 – 2016) (NESDB, 2012) has a strategy that relates to transport infrastructure development. The strategy is for creating regional connectivity for social and economic stability. This is to develop connectivity in transport and logistics systems under regional cooperation

frameworks. This is suggested to be achieved through the development of efficient transport and logistics services that meet international standards. Multimodal transport could play a key

National Transport and Traffic Master Plan (2011-2020) (OTP, 2011) was developed by Ministry of Transport in accordance with the Eleventh National Economic and Social Development Plan. This plan defines vision and objectives, as well as, provides a master plan for each transport sector in Thailand.

Strategic plans for Logistics Development in Thailand Volume 1 (2007-2011) (NESDB, 2007) and Volume 2 (2012-2017) (NESDB, 2012) mentions on development of transport services to improve efficiency of logistics network on main corridors. Rail, water and air transport need to be improved and integrated.

Lately, strategies to improve transportation infrastructure in Thailand (2015-2022) (OTP, 2014) were developed by the government in order to push forward the development of transport infrastructure in to practice. The strategies are set to tackle some defined challenging issues; including: (1) modal shift from road transport to alternative modes which provide lower transport cost per unit, (2) connectivity of neighbouring countries, (3) mobility of people and commodity throughout the country, and (4) enhancement of laws and regulations relating transport and logistics services. These lead to several mega-projects which can be categorised into five groups; including: (1) intercity rail infrastructure, (2) mass transit system in Bangkok, (3) road infrastructure, (4) water transport infrastructure, and (5) air transport infrastructure.

Obviously, all plans and strategies relating to transport infrastructure development aim to promote railway and water transport in order to compete with road transport.

### **3. FREIGHT TRANSPORT MODEL**

Although, fewer studies (e.g. Chisholm and O'Sullivan, 1973; Williams, 1977; Daugherty, 1979; Gary, 1982; McFadden et al., 1985; Harker and Friesz, 1986; Fowkes and Tweddle, 1988; Crainic et al., 1990; Tavasszy, 1996; Jiang et al., 1999; WSP, 2002; Tavasszy, 2006) have been conducted on modelling freight rather than passenger demand, some freight transport models have been developing since the early 1970s. In the beginning, the model was developed and adapted from travel demand model e.g. four steps model (trip distribution, trip generation, modal split and network assignment). However, freight transport is different from passenger transport. Cargos cannot travel by themselves; they need transport process from origins to destinations. At one production place, raw materials may come from various places. Finishing production from the plant may be delivered to other plants as an intermediate raw material or it may be an end product and be delivered to various places in different countries. Although, this process is rather complicated, development of freight transport model need to somehow represent the practical transport and logistics process.

McFadden et al. (1985) analysed freight demand using a multinomial probit. Jiang et al. (1999) modelled freight demand in France by using a disaggregate nested logit, but did not include attributes of transport services, such as cost and time, among the explanatory variables, given the lack of data regarding these features.

Tavasszy (2006) summaries the development of freight modelling over during last four decades (as shown in Table 2). It was found that the more recent models, the more integrative treatment of various decisions and the more detail of behavioural content of models.

Table 2. Summary of freight modelling techniques (Tavasszy, 2006)

<b>Decision problem</b>	<b>Typical modelling challenges</b>	<b>Typical techniques employed</b>	
Production and consumption	Trip generation and facility location Freight/economy linkage consumption patterns	Use-Transport Land Interaction Model [LUTI] (1970s) and Spatial Computable General Equilibrium Model [SCGE] (1990s)	Trip generation models, I/O (1970s)
Trade	International trade value to volume conversion		Gravity models, synthetic O/D models (1970s) Agent based simulation models (1990s)
Logistics services	Inventory location supply chain management considerations	Logistics choice models (1990s)	
Transportation services	Choice of mode intermodal transport light goods vehicles	Simple trip conversion factors (1970s) Discrete choice models (1990s)	Multimodal networks (1980s)
Network and routing	Routing and congestion tour planning city access	Network assignment (1980s) Simulation (1990s)	

For the freight trips and networks, there are some research has been done on multimodal network assignment for freight. In Thailand freight transport models were also developed based on the multimodal network assignment (see Jaensirisak et al., 2010). The models were used by the Ministry of Transport to study the impacts of freight transport policies and infrastructures on modal shift. The models have two main parts. One is used to forecast freight volume in the future, and the other one is used to represent the mode choice decisions of freight operators. The freight volume forecasting model is based on linear model which includes freight volume as a dependent variable and socio-economic variables (e.g. GPP, population, consumption rate) as dependent variables. The mode choice model is usually based on logit model and nested logit model. More recently, mixed logit and probit modes are used as well.

For this study, a national freight transport model was developed. The model was used to analyse impacts of transport infrastructures and policies on modal shift. Framework of the model development is shown in Figure 1. Main features of the model include:

- The model can explain freight transport in macro level, and mode and route choice decision;
- The model can forecast freight volume and movement on transport network;
- The results of the model can be used for transport infrastructure planning.

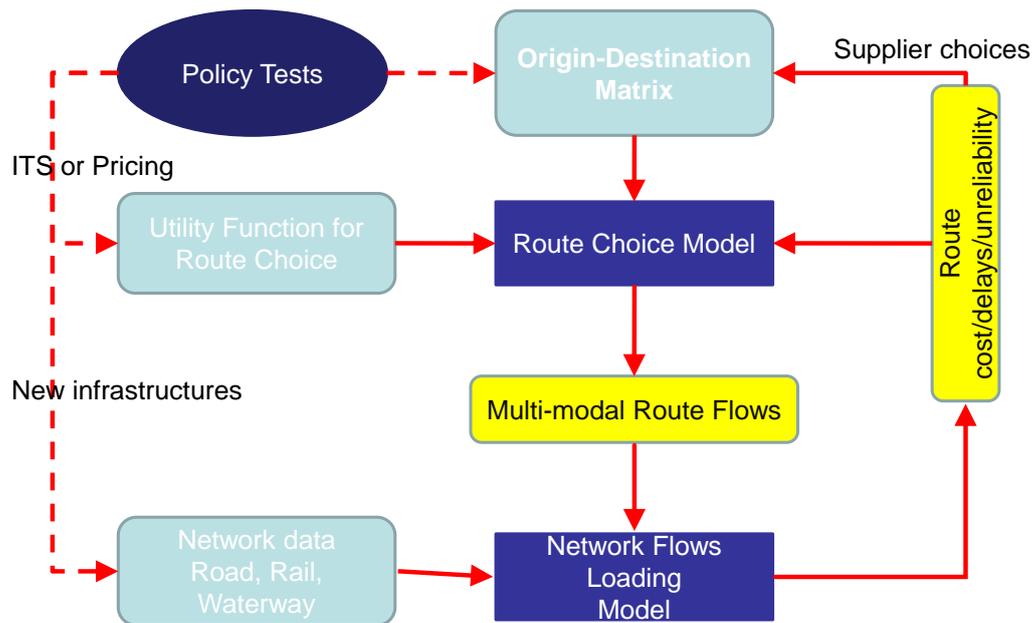


Figure 1. Framework of freight model development

The national freight transport model for Thailand was developed based on 4-steps model concept.

1. Generation model. The whole area of Thailand was the study area. It is divided into 76 zones (provinces). Input-Output analysis was applied to study structure of production and consumption of the country, in order to estimate the flow of production and consumption. Production/Consumption Matrix then was converted to O-D Freight Matrix. This was based on survey data, including type of goods, characteristics of transport, vehicle types, weight of transport per vehicle, and proportion of empty vehicle.
2. Distribution model. The Production/Consumption Matrix (from the generation model) was converted to origin-destination (O-D) Freight Matrix by Gravity Model. Survey data was needed, including type of goods, characteristics of transport, vehicle types, weight of transport per vehicle, and proportion of empty vehicle.
3. Mode and route choice model. The mode and route choice model was developed from Revealed Preference (RP) and Stated Preference (SP) data. This data was collected from freight operators.
4. Network model. The network model was developed for multi-modal networks, including road, rail and water (as shown in Figure 2). This is also included lift on-lift off points between road and rail, and between road and water. (In Thailand, there is no connection between rail and water transport.)

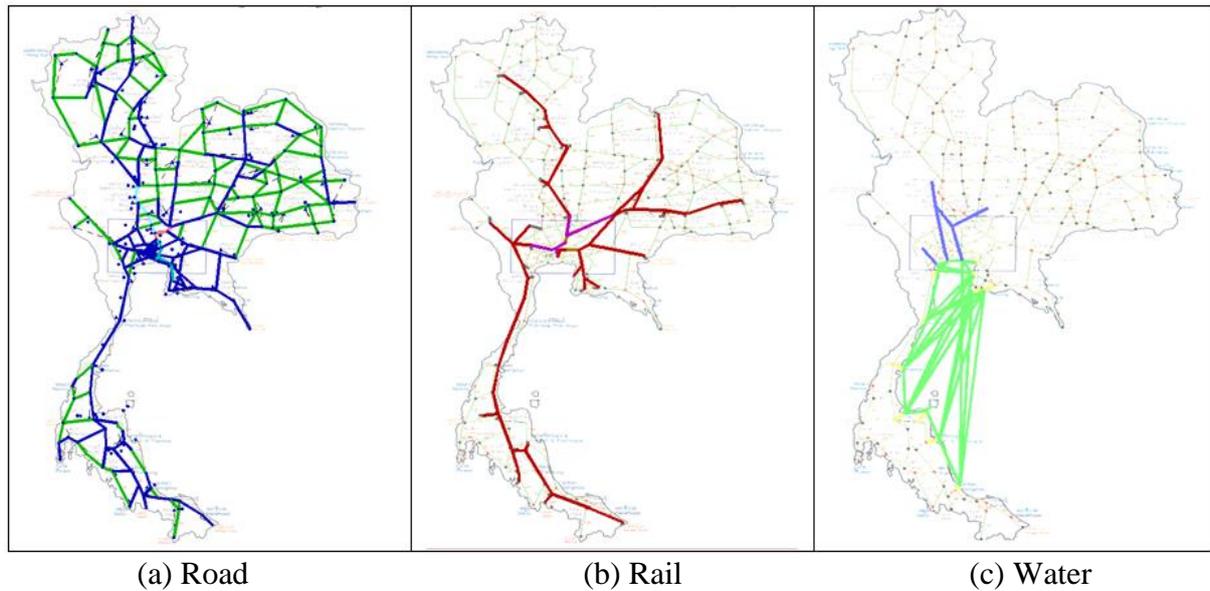


Figure 2. Transport network in the national freight transport model

Figure 3 shows the concept of multi-modal route choice model. Between an origin and a destination, there are several routes. Some routes may use one transport mode e.g. truck. There are several links on the roads. Some roads may have toll. Multimodal may also be used. This needs interchange between modes e.g. truck to rail. At each interchange, there is fee for lift on and lift off, and delay time.

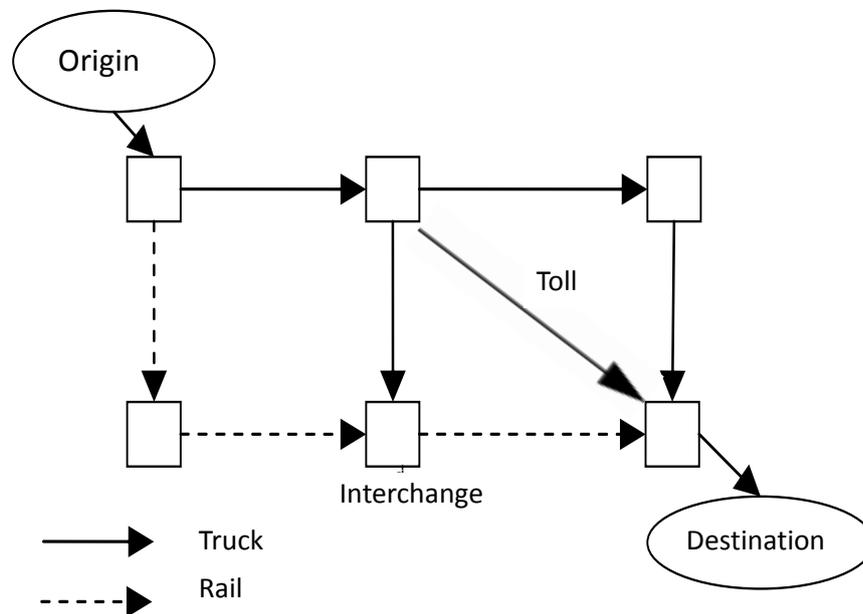


Figure 3. Concept of multi-modal route choice model

Selection of transport route is based on perceived utilities of the routes. Route with the highest utility will be selected by operators. Each link and interchange node has specific utility. This is depended mainly on cost, time and reliability (Reli), as shown in Eq. 1.

$$U_l = ASC_l + \beta_o (Cost_l) + \beta_t (Time_l (v_l)) + \beta_r (Reli_l) \tag{1}$$

Where

- ASC is an alternative specific constant of link l
- $\beta$  is coefficient of each factor
- Cost is transport cost in Baht/Ton
- Time is transport time in hours
- Reli is reliability of transport to deliver goods on time. (This is in the unit of % e.g. 90% means 90% of delivery are on time.)

Coefficients of parameters in Eq. 1 (shown in Table 3) were based on utility function in Logit Model, which was developed from Revealed Preference (RP) and Stated Preference (SP) data.

Table 3. Coefficients of parameters

Parameters	Coefficient
Cost ( $\beta_c$ )	-0.1194
Transport time ( $\beta_t$ )	-0.2351
Reli (%) ( $\beta_r$ )	0.2264
Number of observations	1,927
Rho Square	0.1250

Transport time (Time<sub>l</sub>) on each link is depended on speed on the link and delay at interchange nodes, as shown in Eq. 2.

$$Time_l = a_l + b_l \left( \frac{v_l}{c_l} \right)^n \tag{2}$$

Where

- Time<sub>l</sub> is transport time on link l
- $v_l$  is freight volume on link l
- a, b, c, n are specific coefficients which are related to nodes' and road's types and characteristics

Utility of each route (U<sub>p</sub>) is combination of links' utilities, as shown in Eq. 3.

$$U_p = \sum_{\forall l} \delta_{l,p} U_l \tag{3}$$

Total freight volume between origin r and destination s is q<sub>rs</sub>. Freight volume (F<sub>p</sub>) for each possible route is calculated from Probit Stochastic User Equilibrium (SUE) Assignment, as shown in Eq. 4. Between each origin (O) and destination (D), there are various routes (as the example in Figure 3). Utility of each route is the sum of utilities of several links, which is depended on time, cost and reliability of the links (as shown in Eq. 1). Route which has the highest utility would be chosen.

$$F_p = q_{rs} \Pr(U_p \geq U_{p'} | \forall p' \in \Pi_{rs}) \quad (4)$$

This method can deal with mode and route choice at the same time, and is suitable for representation of multi-modal freight transport.

Model calibration process is shown in Figure 4. Freight volume estimated from the model on each link was compared to the volume from Average Annual Daily Traffic (AADT) data, and calculated Z value from Eq. 5. The OD matrix was adjusted to minimise Z. However, the adjustment was allowed not more than 20% of the original OD matrix.

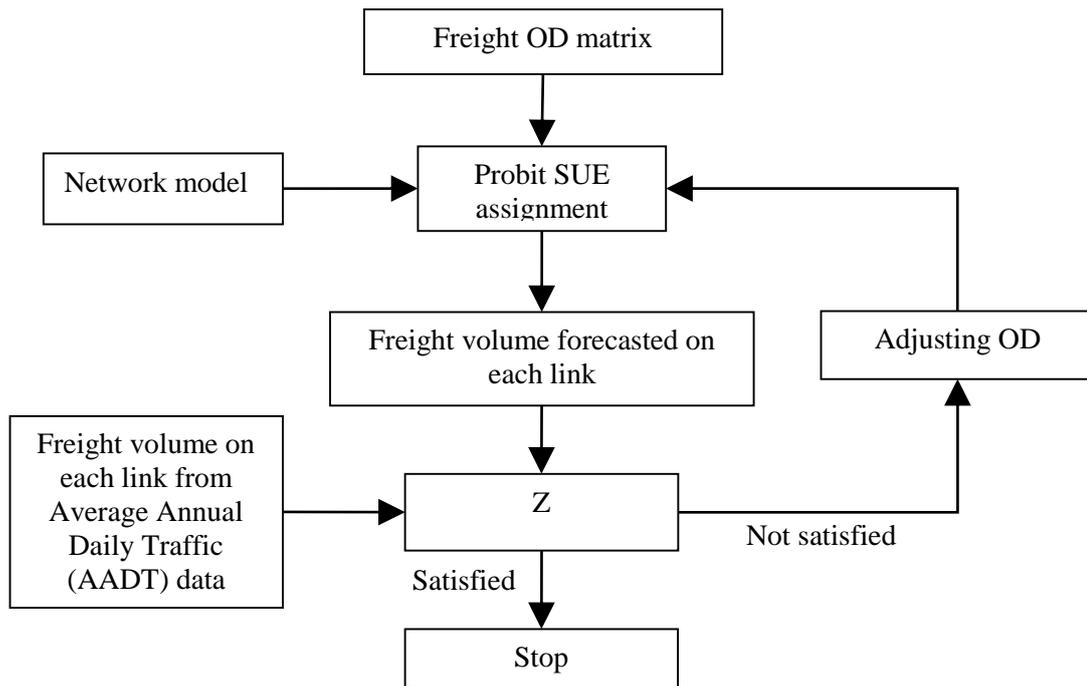


Figure 4. Model calibration process

$$Z = \min_l \cdot (v_l^{AADT} - v_l^{forecast})^2 \quad (5)$$

Where

$v_l^{AADT}$  is freight volume on link l from Average Annual Daily Traffic (AADT) data

$v_l^{forecast}$  is freight volume on link l from forecasting by the model

The model calibration result is shown in Figure 5. Freight volume on each link from forecasting by the model was compared to the volume from Average Annual Daily Traffic (AADT) data. The equality line shows  $R^2 = 0.9759$ , which means the model can represent 98% of the real situation.

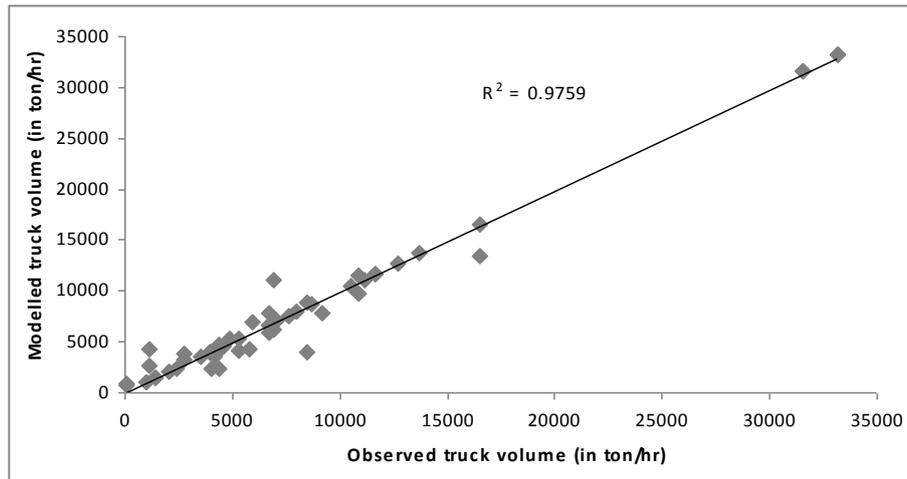


Figure 5. Model calibration result

#### 4. IMPACTS OF TRANSPORT INFRASTRUCTURE DEVELOPMENT ON MODAL SHIFT

##### 4.1 Analysis of the base case

The freight transport model (explained in Section 3) was first used to analysis the base case, which was the do-nothing case. This analysis was based on the case if there was no transport infrastructure development for the next 20 years.

The base year was 2013. The study found that if there is no improvement of alternative mode of freight transport, freight volume on road transport would increase significantly (as shown in Figure 6), particularly between Bangkok and Laem Chabang Port, which are the main origins and destinations of the country, and the surrounding area, which there are a lot of industrial parks. This shows that for the doing nothing case road network cannot cope with the transport demand in the future. Transport cost would significantly increase, as well as other transport problems – congestion, pollution, and accident.

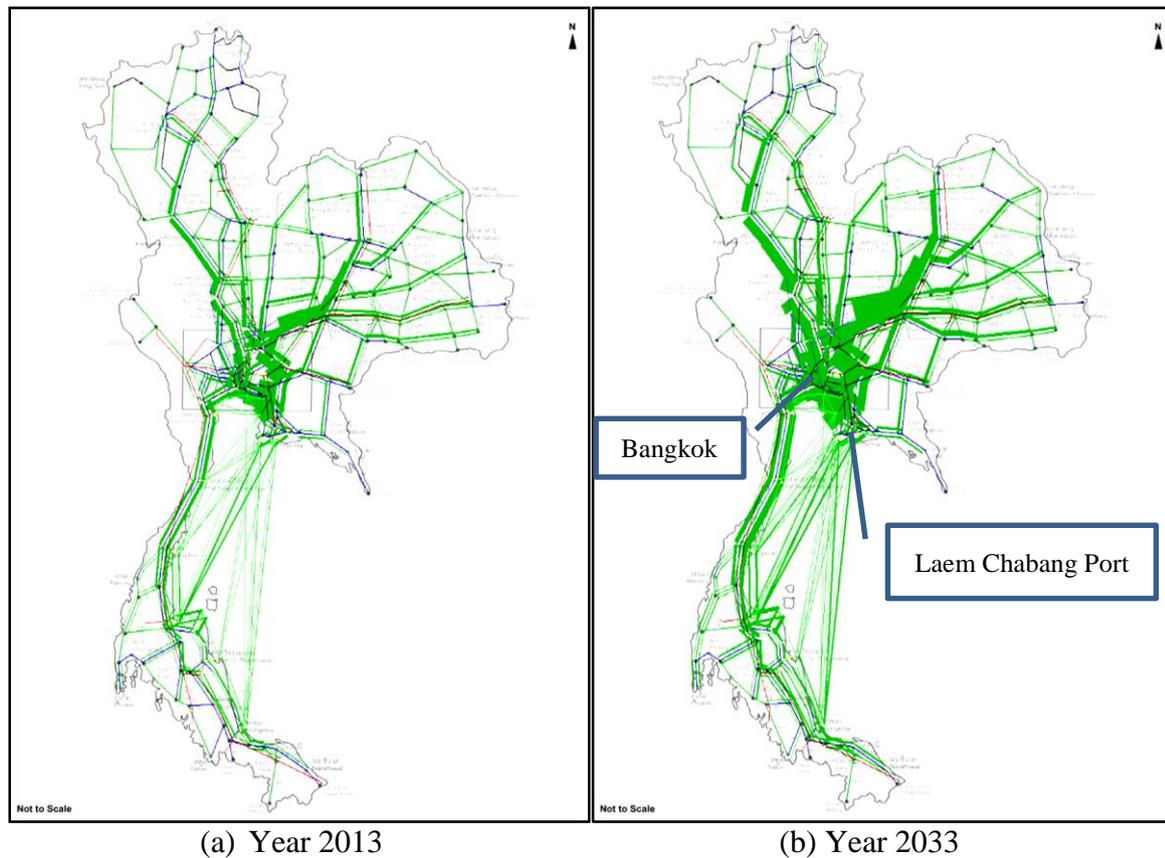


Figure 6. Freight volume on the network in Thailand for the base case for the years 2013 and 2033.

Table 4 presents mode share of freight of freight transport in Thailand for the base case in 2013. This presents in terms of both Tons and Ton-kms. It can see that road transport dominates almost of all freight transport in Thailand.

Table 4. Modal share of freight transport in Thailand for the base case in 2013

Transport modes	Mode share in terms of Tons	Mode share in terms of Ton-kms.
Road	81.9%	92.2%
Rail	2.3%	4.1%
Inland water	9.1%	1.8%
Coastal water	6.7%	1.9%

#### 4.2 Transport infrastructure development

In order to shift freight transport from road to rail and water, the government of Thailand proposed a major project investment plan in the national transport strategy for Thailand (2015-2023). This plan includes transport infrastructure projects for every freight transport modes. These projects include:

- Motorway expansion – five routes starting from Bangkok to five directions around 100-200 kilometres;
- Railway improvement including:

- Upgrading all existing single rail track to double tracks about 4,000 kilometres, which could increase average freight train from 32 kilometres per hour to 60 kilometres per hour;
- Expanding railway network – two new routes are proposed in total about 700 kilometres;
- Improving main interchanges between truck and rail which is aimed to reduce 50% of interchange time (between road and rail).
- Water transport improvement is aimed to reduce 50% of interchange time (between road and water transport) and 30% reduction of freight service cost. The improvement includes:
  - Improvement of inland ports in the central of Thailand;
  - Improvement of costal ports in the Gulf of Thailand.

Based on the above transport project plan, this study sets up scenarios to test the impacts of transport infrastructure and pricing policy on modal shift. The scenarios include:

- Scenario 1 – Motorway expansion: five routes starting from Bangkok to five directions around 100-200 kilometres. This is mainly to serve industrial parks which are mostly located within 200 kilometres around Bangkok.
- Scenario 2 – Railway improvement: upgrading all existing single rail track to double tracks which could increase average freight train from 32 kilometres per hour to 60 kilometres per hour.
- Scenario 3 – 30% Reduction of freight rail service cost
- Scenario 4 – Water transport improvement: reduce 50% of interchange time (between road and water transport) and 30% reduction of freight service cost.
- Scenario 5 – 30% Increase of road freight service cost
- Scenario 6 – Combination of Scenarios 1-5 including all projects

#### 4.3 Results of modal shift

The freight transport model (explained in Section 3) was applied to test the six scenarios. When the transport infrastructures were developed; transport cost, time and reliability of transport routes and modes between origins and destinations would be changed. Thus, freight volume would be changed to the highest utility routes or modes. For each scenario, transport cost, time and reliability of transport routes and modes are changed differently. For example, for Scenario 2 rail tracks are upgraded to double tracks, time and reliability of rail transport would be reduced (higher utility). There will some shift from transport by road to rail where origins and destinations are served by rail system. This effect is similar for other scenarios. The model was used to evaluate the effect by estimating freight volume (Tons) for each mode for each scenario. Then freight volume (Tons) was multiplied by distance of transport (Kilometres) to get Tons-kms of freight transport.

The impacts of transport infrastructure and pricing policy on modal shift are presented in Tables 5 and 6. The results show that:

- In the next 20 years, for the base case (do-nothing) modal share is hardly changed (comparing the base case between 2013 and 2033).
- The improvement of road service level (Scenario 1) will led to increase of road transport share. This increase is not high because the motorway expansion is only 100-200 kilometres around Bangkok.

- Improvement of rail network (Scenario 2) and 30% reduction of freight rail service cost (Scenario 3) could encourage significantly modal shift to rail (more than twice of the base year), particularly by reducing the service cost.
- Water transport improvement (Scenario 4) both inland and costal shipping could increase water transport share about 40%, compared to the base case.
- The 30% increase of road freight service cost (Scenario 5) without improvement of other alternatives could push some road transport to rail and water transport.
- Combination all projects (Scenarios 6) could reduce road transport significantly, and rail and water transport also increase significantly.

The results show that transport infrastructure development with pricing policy (reducing service cost of alternatives and increasing service cost of road transport) could achieve significantly modal shift from road to alternatives. For the integrated projects (Scenario 6), modal share in terms of Tons of road transport reduces from 82% to 74%, while mode share of rail transport increases from 2% to 5%, and mode share of water transport increases from 16% to 21%. Considering mode share in terms of distance of transport (Tons-kms), road transport reduces from 92% to 86%, while mode share of rail transport increases from 4% to 9%, and mode share of water transport increases from 4% to 5%.

These show that mode share of rail and water transport could be double if the transport infrastructures are developed. However, road transport share is still rather high. This is because rail and waterway networks cover only some part of the country. While road network is more than 200,000 kilometres, double track rail network is only about 5,000 kilometres with average speed of freight train 60 kilometres per hour. Inland water way network is about 200 kilometres in the north of Bangkok. Coastal shipping is only in the south of Thailand.

Table 5. Modal share (in terms of Tons) of freight transport in Thailand for the base case in 2013 and 2033 for each scenario

Transport modes	Base year 2013		Year 2033					
	Base case	Base case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Road	81.9%	81.5%	82.2%	80.1%	79.1%	74.4%	77.9%	73.8%
Rail	2.3%	2.3%	2.7%	3.9%	5.3%	2.8%	4.6%	4.9%
Inland water	9.1%	9.0%	8.4%	8.9%	8.7%	12.7%	9.7%	11.8%
Coastal water	6.7%	7.2%	6.7%	7.1%	6.9%	10.1%	7.7%	9.4%

Table 6. Modal share (in terms of Ton-kms.) of freight transport in Thailand for the base case in 2013 and 2033 for each scenario

Transport modes	Base year 2013		Year 2033					
	Base case	Base case	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Road	92.2%	92.0%	91.7%	89.4%	87.1%	89.0%	87.6%	85.8%
Rail	4.1%	4.1%	4.8%	6.9%	9.3%	5.3%	8.3%	9.1%
Inland water	1.8%	1.8%	1.6%	1.7%	1.7%	2.7%	1.9%	2.4%
Coastal water	1.9%	2.0%	1.9%	2.0%	1.9%	3.0%	2.2%	2.8%

## 5. CONCLUSIONS

This paper has presented the impacts of transport infrastructure development on freight modal share. A national freight transport model was developed and used to evaluate the impacts. Scenarios tested were based on the government's infrastructure plan, as well as, pricing policy (not in the government plan). The infrastructure projects include motorway expansion, and rail and water transport improvement.

The study found that integration of transport infrastructure development (by improving service of rail and water transport) with pricing policy (reducing service cost of the alternatives and increasing service cost of road transport) could achieve significantly modal shift from road to the alternatives. However, road transport share is still rather high. This is because rail and waterway networks cover only some part of the country.

In order to achieve higher modal shift, rail network should be significantly expanded. Freight rail speed needs to be increased. Inland water way has potentially been expanded to the north of Thailand. Connecting hubs of multi-modal interchange (between road and rail, between road and inland water port, and between road and coastal ports) are the key issue of modal shift. Moreover, pricing policy needs to be set up appropriately to encourage the modal shift and also to reflect externality costs.

Policy recommendation can be summarised as follows:

- Expansion of road (and expressway) network should be done with development and improvement of rail infrastructures and services. Road and rail networks and services need to be integrated (smooth transfer and low cost) in order to support multi-modal transport. More importantly road (particularly motorway) improvement should be carefully designed not to compete with rail.
- Reduction of rail freight service cost should be considered (subsidy from the government).
- Increase of road freight service cost (such as charging for road use or increasing fuel prices) should be careful. Although it helps to change from road to alternative transport modes, rail and water transport cannot provide door-to-door service. Road transport is still important in multi-modal transport. Increasing road transport cost will affect overall cost of transport services.

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