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IMPACT OF TRANSPORT INFRASTRUCTURE DEVELOPMENT ON SUGAR TRANSPORTATION MODAL SHIFT IN NORTHEASTERN THAILAND

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ABSTRACT: This study presents the current situation of the land transport of sugar products in Northeastern Thailand. Data collections, field surveys and individual interviews with sugar producers, transporters, warehouse operators, exporters and marketing teams were conducted. It was revealed that most sugar product is currently transported via the road transport because the rail transport system commonly suffers from delays, unreliability, and results in dirty, damaged and lost goods. In addition, there is no direct route for rail transport connecting warehouses near the seaports. Freight transport models were developed to estimate the modal shift of sugar transport between road and rail systems according to the transport infrastructure development plans. It was found that rail infrastructure development would potentially influence sugar product transport systems to shift freight transport from the road system to the rail system. Furthermore, the development of motorways will decrease the amount of sugar product transported by the rail system.

Keywords: Modal shift, Sugar transport, Freight transport model, Infrastructure development plans

1. INTRODUCTION

Global sugar production has recently decreased (by approximately 1.4% in 2015), while the global sugar consumption has continued to increase (by approximately 2.4%). If this trend of sugar production and consumption continues, a shortage of sugar products could be expected in the near future, and the prices of sugar products could significantly increase. The main reason for this shortage is due to large amounts of the global sugar cane supply being used to produce ethanol for renewable energy [1].

Sugar production, one of the most important agricultural industries, greatly stimulates the economic expansion of the country, from 2014-2015, Thailand was ranked 5th in the world for sugar production. 10.2 million tons were produced, which amounted to 6% of the global sugar production. Although sugar production in Thailand increased from 2009 to 2013, it decreased from 2014 to 2015 by approximately 1.1 million tons, which corresponded with the global trend. In 2014, the number of exported sugar products from Thailand totaled approximately 6.7 million tons (17.4% of the total amount of all exported agricultural freights). Thailand was accordingly ranked 2nd, with Brazil ranked 1st in the world. Based on the total sugar production in Thailand, approximately 70% was exported and the remaining 30% was consumed domestically. In addition, the total income earned from the total exported sugar products was 89,240 million baht (8.7% of the total income from all exported agricultural products) [2].

In Thailand, the percentage of total logistics costs compared to the Gross Domestic Product was 14.3%, and approximately half of that consisted of transport-related costs [3]. One of the most important strategies of Thailand’s transport infrastructure development plan is a modal shift from a road transport system to more efficient and effective transport systems (such as rail and water). Thus, there are several transport infrastructure plans for the development of intercity rail systems, such as double track projects, high-speed rail system projects, etc. [3].

The key objectives of this paper are to develop freight transport models for predicting and analyzing sugar transportation in the northeastern region of Thailand, to assess the influences of the transport infrastructure development plans on the modal shift of sugar transports, and to recommend appropriate policies, plans and projects related to the Thailand transport infrastructure development, aiming to reduce the transport and logistics costs efficiently.

2. METHODOLOGY

The research methodology is illustrated in Fig. 1, including six main steps. The details of each step can be explained as follows.

2.1 Literature Review, Related Studies, and Reports

Research studies, reports, publications and other literature related to freight transport and modeling, Thailand’s transport infrastructure development plans, and sugar production, consumption and exports were reviewed comprehensively.

2.2 Data Collections

Primary and secondary data of sugar production and consumption were collected. Several means of data collections ranging from field surveys (e.g., characteristics of road and rail networks and their related facilities, seaport conditions, operation and problems, existing truck and rail transport, etc.) to formal interviews (e.g., sugar producers, forwarders and exporters, truck operators, warehouse operators and others, etc.) were conducted.

2.3 Analysis of Sugar Transport and Export Trends, Potential Problems, and Barriers

From the data collections, sugar transport and export trends, potential problems, and barriers were systematically analyzed.

2.4 Development of Freight Transport Models

The four-step national freight transport models for Thailand and specifically the northeastern region were developed. These models include me) Freight generation model; ii) Freight distribution model; iii) Modal and route choice model, and iv) Network assignment model. More details will be discussed in section 4.

2.5 Analysis and Assessment of Selected Scenarios

The developed models were employed to forecast freight demand and transport patterns and to analyze the modal shift from road to rail transport systems as a result of the Thailand transport infrastructure development plans.

Five scenarios were established for the analysis and assessment, including: Scenario 1 - no transport infrastructure developments (base case); Scenario 2 - road network and motorway development; Scenario 3 - rail network improvement; Scenario 4 (a combination of scenarios 2 and 3); and Scenario 5 (a combination of scenarios 2 and 3, excluding motorway expansion). More details will be discussed in section 5.

2.6 Recommendation for Appropriate Plans, Policies, and Projects

After a suitable analysis and assessment, the appropriate plans, policies, and projects to resolve the current sugar transport and export problems and barriers in Northeastern Thailand are suggested.

3. CURRENT CONDITION OF THE STUDY AREA

There are 50 sugar production factories in Thailand. These sugar factories normally require sugar cane planting areas of approximately 10 million Rai (1 rai = 1,600 square meters). 19 factories (38%) are located in Northeastern Thailand, as shown in Fig. 2. These factories require the sugarcane planting areas of 4.3 million Rai (43%), spanning 20 provinces in the region. Such a planting area is capable of harvesting 44.9 million tons of sugar canes (43.6%) and approximately 5.0 million tons of sugar products (45%) [4].

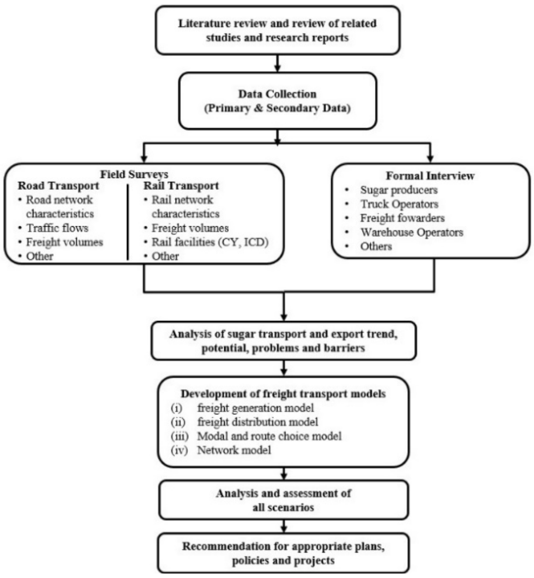

Fig. 1 Methodology

Fig. 2 Sugar factories located in the study area

It should be noted that 70% of the total sugar products in Northeastern Thailand are normally exported overseas (Asia 87.2%, Africa 10.7%, Oceania 8.1%, European Union 0.3%, USA 0.03%), and the remaining 30% is consumed domestically [4].

Most of the sugar products were transported to the shipping seaports via the road system. Typical transport routes for road networks are illustrated in Fig. 3. National Highway No. 2, 12, 22, 201, 304, and Motorway No. 7 are the main roads being used to transport sugar products from the production factories to the export destinations, which include the Bangkok port and the Laem Chabang port. The common types of trucks being adapted to transport sugar products are truck and trailer units (29%), tractor and semi-trailer units (29%), 10-wheeler trucks (20%) and others (22%) [5].

Although there are some operational problems in a road transport system (such as traffic congestion, road accidents, no rest areas for trucks, steep grades, sharp curves, etc.), most sugar products are currently transported via the road transport due to the rail transport service system commonly suffering from long travel times, delays, unreliability and often resulting in dirty, damaged and lost goods. In addition, there are no direct routes for rail transport connecting warehouses near the seaports [5].

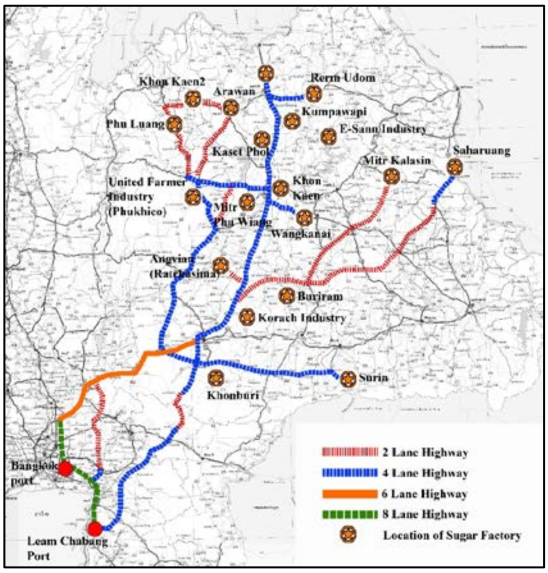

Fig. 3 Sugar transport routes to the destination seaports in the northeastern region of Thailand

4. FREIGHT TRANSPORT MODEL

Various studies have been extensively conducted on modeling freight transport, e.g., from [6] to [11]. In Thailand, several freight transport models were developed by using the multimodal network assignment, see e.g., [12]. The models were used in various transport projects to evaluate the impact of freight transport policies and infrastructures on modal shift [13].

In this study, a national freight transport model was developed based on the studies of [12], [14] and [15]. See [14] for details. The framework of the model development is illustrated in Fig. 4. This model can be applied to determine freight transport at a macro level, as well as modal and route choice decisions. The model can also be adapted to predict freight demand and its shipment on the transportation network. The model is potentially capable of analyzing the transport infrastructure planning.

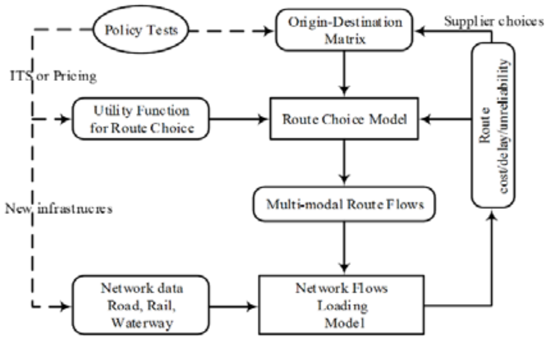

Fig. 4 Framework of the freight transport model

The national freight transport model for Thailand was developed based on the four-step model concept.

1) Generation model. The entire area of Thailand was divided into 102 zones (77 provinces, 10 major railway junctions, and 15 major ports). Input-Output analysis was applied to study the structure of production and consumption of the country and to forecast the freight flow of production and consumption in every zone (called Production-Consumption or PC Matrix).

2) Distribution model. The PC Matrix was then used to estimate the Origin-Destination or OD Freight Matrix, using the Gravity Model.

3) Modal and route choice models. The modal and route choice models were developed using the Revealed Preference (RP) and Stated Preference (SP) techniques.

4) Network assignment model. The network assignment model was developed for multi-modal networks, including road and rail transport systems as shown in Fig. 5.

The selection of transport routes is based on perceived utilities of the routes. The route with the highest utility will be selected by operators. Each link (*a*) and interchange node has a specific utility (*U*) of a transport mode (*m*). This depends mainly on cost and time, as shown in Eq. (1).

$$U_{m,a} = ASC_{m,a} + \beta_{C_{m,a}}\left(Cost_{m,a}\right) + \beta_{T_{m,a}}\left(Time_{m,a}\right) + Charge_{m,a} \quad (1)$$

where *ASC* is the alternative specific constant (ASC) of the transport mode *m* on a link *a*; β is the coefficient of each factor; *Cost* is the transport cost in kilometers travelled; *Time* is the transport time in hours; and *Charge* is the toll for using the road network or a lift on/off fee for a road and rail interchange. Note that the coefficients of the parameters in Eq. (1) were based on the utility function in the mode choice model, which was developed from the RP and SP data. The data was collected from different transport modes (i.e., road and rail) and different types of freight (sugar and other products). In addition, the value of the ASC is altered from the OD pair because the proportions of the transport modes by OD pairs are different.

Let U_k be a total utility of each route which is a combination of the links' utilities. The route utility can be formulated as in Eq. (2).

$$U_k = \sum_{\forall m} \sum_{\forall a} \delta_{a,k} U_{m,a} \quad (2)$$

where $\delta_{a,k}$ is a link-route incident variable. It is 1 when the link *a* is on the route *k* and 0 otherwise.

Let the total freight volume between origin *r* and destination *s* be q_{rs}. The freight volume (F_k) for each possible route *k* can be calculated from the Probit Stochastic User Equilibrium (SUE) Assignment [16]. Since there are various routes, the utility of each route is the sum of the utilities of several links, which depends on time, cost and charge of the links (i.e., Eq. 1). A route with the highest utility would be chosen and can be formulated as shown in Eq. 3.

$$F_k = q_{rs} \Pr\left(U_k \geq U_{k'} \middle| \forall k' \in \Pi_{rs}\right) \quad (3)$$

where $\Pr(.)$ is a probability function; and Π_{rs} is a set of possible routes between OD pair *rs*. This method can address the mode and route choice at the same time, and it is suitable for the representation of multi-modal freight transport in this study. The model calibration was conducted by comparing the freight flows calculated from the models to the Average Annual Daily Traffic (AADT) data [17]. The results in Fig. 6 show that the value of R^2 is 0.96, which is desirable.

5. INFLUENCES OF THE TRANSPORT INFRASTRUCTURE DEVELOPMENT PLANS ON MODAL SHIFT

The freight transport model was developed to analyze the base case in the year 2014. In this study, the target (future) year was set in 2030 regarding the full implementation of the transport infrastructure development plans.

Regarding the base case in 2030, Fig. 7 shows that the freight volume on the road network would increase significantly. The volumes are also high on the roads, particularly between the Bangkok Port and the Laem Chabang Port, which are the main origins and destinations of the country, as well as the surrounding areas, which consist of many industrial parks. These results imply that for the base case the road network cannot cope with the freight transport demand in the future. Transportation costs would significantly increase and cause transportation-related problems such as congestion, accidents, pollution, climate change, etc.

To shift freight transport from road to rail and water, the Thai government proposed a major project investment plan in the national transport strategy for Thailand (2015-2022) [3]. This plan includes transport infrastructure projects for every mode of freight transport. The projects include:

- Motorway expansion – five routes starting from Bangkok in five directions (approximately 100-200 kilometers for each direction);
- Railway improvements, including:
  - Upgrading all existing single rail track to double tracks (approximately 4,000 kilometers of tracks), which could increase the average freight train from 30 to 60 kph;
  - Expanding the railway network – two new routes are proposed, totaling approximately 700 kilometers;
  - Improving main interchanges between truck and rail, which is aimed to reduce 50% of the interchange time (between road and rail).
- Water transportation improvement is aimed to reduce 50% of the interchange time (between road and water transport) and cause a 50% reduction in freight service cost.

Based on the above transport projects, this study sets up five scenarios to determine the influences of transport infrastructure development (specifically on road and rail networks) on the sugar transportation modal shift in Northeastern Thailand. The scenarios are:

- Scenario 1: no development;
- Scenario 2: road network and motorway development. This improvement includes lane expansions on the current road network (Road No. 12, No. 22, No. 23, No. 201, etc.) and motorway construction (Bang Pa-In – Nakhon Ratchasima) as shown in Fig. 8;
- Scenario 3: rail network development. Upgrading all existing single rail tracks to a double track meter gauge (Kang Koi – Thanon Chira Junction – Khon Kaen – Nong Khai, Thanon Chira Junction – Ubon Ratchathani) and a standard gauge (Bangkok, Map Taput – Kangkoi – Nakhon Ratchasima – Nong Khai) as illustrated in Fig. 9;
- Scenario 4: a combination of Scenarios 2 and 3;
- Scenario 5: a combination of Scenarios 2 and 3

without motorway construction.

The freight transport model was applied to analyze the five scenarios. When the transport infrastructure developments were implemented, the transport costs, times and charges of transport routes and modes between origins and destinations were altered. It was found that the amount of sugar products to be transported was 5.5 million tons in 2014 and 8.3 million tons in 2030, which was a 1.5 times increase from 2014 to 2030. The analysis and assessment results of each scenario are discussed as follows:

The first scenario assumed no transport infrastructure development in 2030. Tables 1 and 2 show that the amount of sugar products transported by road and railway systems were 8.27 (99.1%) and 0.08 (0.9%) million tons, respectively.

The second scenario found that as a result of the road network and motorway developments the amount of sugar products transported by road and rail systems were 8.31 (99.6%) and 0.03 (0.4%) million tons, respectively. Compared to the first scenario, the sugar products transported by the road system will increase by 0.56%, whereas those transported by rail system will decrease.

The third scenario revealed that due to the rail network development, the amount of sugar products transported by road and rail systems were 7.71 (92.4%) and 0.63 (7.6%) million tons, respectively. Compared to the first scenario, the sugar products transported by the road system will decrease by 6.65%, whereas those transported by the rail system will increase. The amount of sugar transport was significantly shifted from road to rail transportation.

The fourth scenario showed that with the integration of both road and motorway network developments (Scenario 2) and the railway network development (Scenario 3) the amount of sugar products transported by road and rail systems became 7.89 (94.6%) and 0.45 (5.4%) million tons, respectively. Compared to the first scenario, the sugar products transported by the road system will slightly decrease (4.5%), while those transported by railway system will increase. The amount of sugar transport was slightly shifted from road to rail transport. It should also be noted that in terms of the modal shift performance from the road to rail systems, the fourth scenario was better than the first scenario but worse than the third scenario.

- The fifth scenario found that with the combination of both road network and rail network development, with the exception of the motorway construction, the amount of sugar products transported by the road and rail systems will be 7.86 (94.1%) and 0.49 (5.9%) million tons, respectively. Compared to the first scenario, the sugar products transported by the road system will slightly decrease (4.9%), while those transported by the rail system will increase. The amount of sugar transport was shifted slightly from road to rail transport. The fifth scenario was slightly better than the fourth scenario but worse than the third scenario.

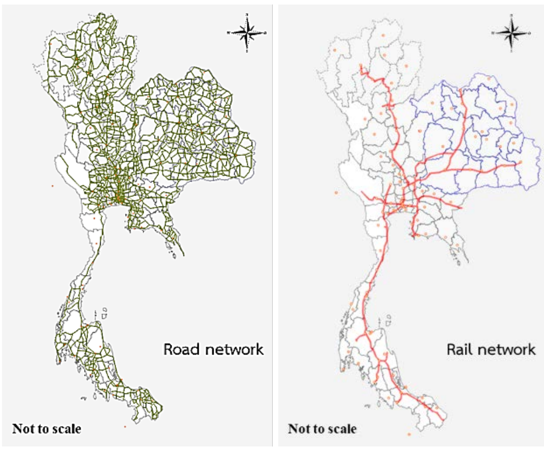

Fig. 5 Transport networks in the national freight transport model

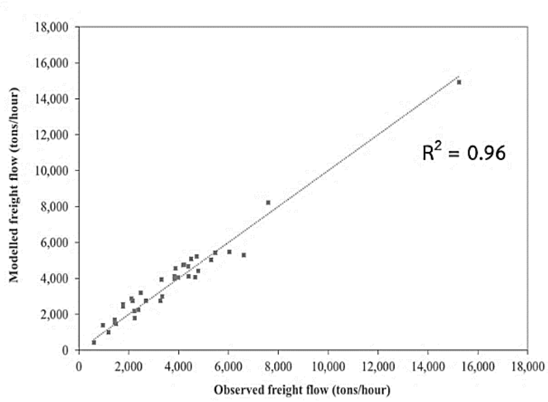

Fig. 6 Result of model calibration

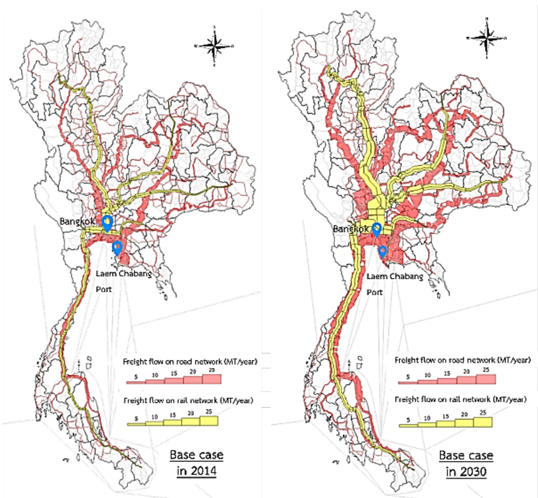

Fig. 7 Freight volume on road and rail networks for the base case in 2014 and 2030

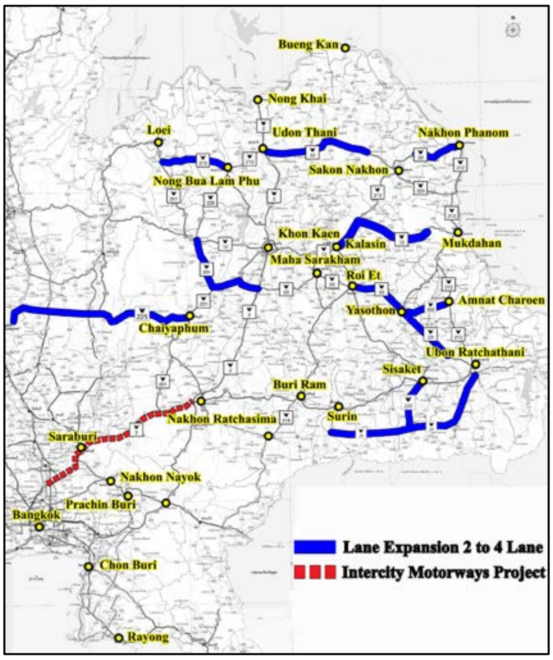

Fig. 8 Road network improvements

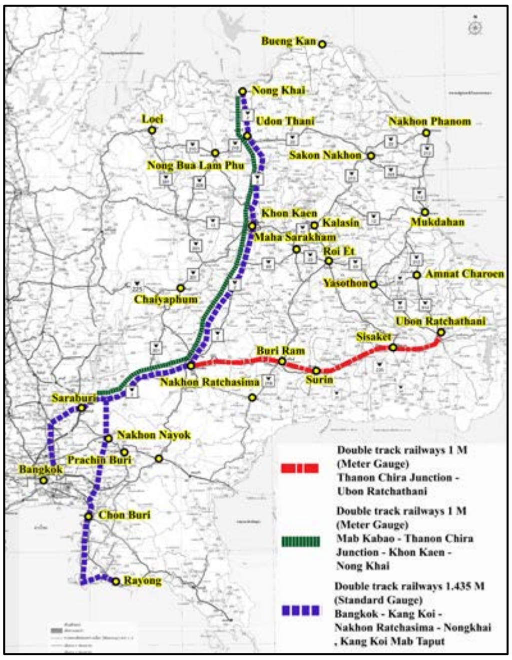

Fig. 9 Railway network improvements

Table 1 The volume of sugar transport in Northeastern Thailand

Mode of Transport	Base case in 2014	Volume of sugar transport in 2030 (million tons/year)				
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Road	5.402	8.265	8.312	7.711	7.892	7.855
Rail	0.055	0.077	0.031	0.632	0.451	0.488
Total	5.457	8.343	8.343	8.343	8.343	8.343

Table 2. The mode shares of sugar products transported by road and rail networks

Mode of Transport	Base case in 2014	Mode shares by road and rail network (Percentage change compared to Scenario 1)				
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Road	98.99%	99.07%	99.63% (+0.56%)	92.42% (-6.65%)	94.60% (-4.47%)	94.15% (-4.92%)
Rail	1.01%	0.93%	0.37% (-0.56%)	7.58% (+6.65%)	5.40% (+4.47%)	5.85% (+4.92%)

6. CONCLUSIONS AND RECOMMENDATIONS

This research study was conducted to examine the current situation of land transport of sugar products in Northeastern Thailand. Comprehensive data collections, field surveys, and individual interviews with sugar producers, sugar transport operators, warehouse operators, exporters and marketing teams at sugar factories and a sugar producers group were recently conducted. The study also surveyed the existing national road and rail transport infrastructure systems. As a result, it was revealed that most sugar products are currently transported via the road transport since the rail transport service system commonly suffers from delays and unreliability and often results in dirty, damaged and lost goods. In addition, there are no direct routes for rail transport connecting warehouses near the seaports.

Freight transport models were developed in order to predict the quantity of freight transport among all zones in the country as well as to estimate the modal shift of sugar transport between road and rail networks according to the Thailand transport infrastructure development plans. Five scenarios were selected and analyzed, including the first scenario of no transport infrastructure development, the second scenario of road network and motorway development, the third scenario of rail network development, the fourth scenario of all transport (i.e., road and rail) infrastructure development and the fifth scenario of all transport infrastructure development with the exception of the motorway. The results found that in the first scenario almost all sugar products (99%) were transported via the road system. With the road network improvement, the second scenario showed that the sugar products will be transported more via the road system then by rail transport. In contrast, the sugar transport was reasonably shifted from road to rail transport under the third scenario (rail system improvement). The integration of road and rail system developments (the fourth scenario) showed that the sugar transport would favor rail transport over road transport compared to the base case, but at a slightly lower percentage than the third scenario. A greater percentage of a modal shift (from the road to rail transport) was found when the motorway construction plan was excluded (the fifth scenario). However, the modal shift was less than that under the third scenario.

From the study, it can be seen that the rail infrastructure system development would potentially influence sugar product transportation systems to shift freight transport from a road system to a rail system. Furthermore, the development of motorways will slightly decrease the amount of sugar product transported by the rail system.

Recommendations for the proposed plans, policies and projects can be summarized as follows:

- The Thai government should support and accelerate transport infrastructure development, particularly the rail system to compete with the road system.
- The rail infrastructure development should be planned and implemented to furnish its services covering all important areas not only in the short-term (urgent) period (2-5 years) but also the medium period (5-10 years) and long-term period (11-20 years).
- Freight transferring and connecting terminals such as Container Yard (CY) and Inland Container Depot (ICD) should be planned and implemented to facilitate the multimodal freight transport.
- The development of multimodal freight transport systems (such as road, motorway, and rail transport modes) should be analyzed, planned, designed and implemented in a systematic and integrated manner to avoid the conflicting objectives of each modal development.
- Special attention must be made in the improvement and maintenance of the existing freight transport infrastructure systems (for both road and railway systems) for their operational efficiency and safety.

7. ACKNOWLEDGMENT

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