A DEVELOPMENT OF MODE CHOICE MODELS FOR MODAL SHIFT POTENTIAL TOWARDS INTERMODAL TRANSPORTATION: A CASE STUDY OF VIENTIANE–BOTEN RAILWAY

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Abstract

In this paper, the modal shift potential of travelers and freight on the Kunming-Bangkok route has been investigated by considering the behavioral aspects of long-distance travel. Due to the necessity for transportation infrastructure, the railway mode will be added to the various transport mode options in the region, shortening the seamless movement of travelers and freight from Kunming to Bangkok. In order to investigate long-distance travel (LDT) behavior, a Mode Split Model has been employed for analyzing the mode choice and modal shift of travellers, based on the development of new transportation infrastructure. The factors considered in the Mode Split Model are total cost, travel and transportation time, transfer time, distribution time, and frequency of service. The results show that the crucial factors for selecting transportation mode are transfer time and distribution time in the case of travelers in the area of the Vientiane–Boten railway. Based on the crucial factors, 45 – 55 percent of all modes will shift to the railway mode. However, the important factors for selecting transportation mode are total cost and travel time in the case of travelers not in the Vientiane–Boten railway area. Private vehicles would be selected for this case. Besides the total cost and transportation time, frequency of service is also a crucial factor for LSP in selecting the transportation mode, where there is a 30-40 percent mode shift from truck mode to railway mode.

Keywords: Vientiane–Boten railway; mode shift; modal split model; binary logit model; decision making factor

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1. INTRODUCTION

Land transportation is the primary mode of transportation in the Lao People's Democratic Republic (Lao PDR). This country is located in the heart of the Greater Mekong region, which is a landlocked country. There are 3 transportation modes in Lao PDR. However, due to its geographical location, the majority of freight uses road transportation, constituting 80 percent of total freight (ton-km). This is followed by river transport (18 percent) and air transport (2 percent) (Vanthana Nolintha, 2019). Overall international trade between China and other Southeast Asia countries, namely Thailand, Singapore, and Malaysia, totaled 40.4 million tons in 2016, less than 2 million tons of which, were transported by road via Lao PDR as trade transit, equating to 5 percent of the overall trade. The remaining 95 percent of trade was transported by sea. Meanwhile, bilateral trade between China and Lao PDR totaled 3.25 million tons in 2016, of which 1.2 million tons were transported by road, equating to 37 percent of total trade volume. The remaining 2.05 million tons (63 percent) were transported by sea (World Bank, 2020). Currently, the rail services in Lao PDR have been almost non-existent. At present, 3.5 kilometers of railway exists from Thanaleng to Nongkhai Province, in Thailand, as a short section of the railway route in Lao PDR. Based on the trade volume mentioned, improvement of Lao PDR's transportation infrastructure is required for capturing both the remaining share of the bilateral trade between China and Lao PDR and a small portion of maritime trade between China and other Southeast Asia countries. Due to the lack of transportation infrastructure, the Chinese government has initiated railway infrastructure in Lao PDR that will offer a cheaper mode of freight transportation. The transportation cost of cargo by utilizing the railway mode can reduce the costs of transportation by 30 to 50 percent compared to the cost of transportation by road.

The Chinese government has rapidly developed transport infrastructure under its Belt and Road Initiative (BRI) strategy. The BRI strategy is part of China's economic development strategy, which aims to expand China’s trade and cultural influence towards countries in both western and eastern regions, including ASEAN. The BRI strategy's development consists of two main components: (i) Silk Road Economic Belt and (ii) Maritime Silk Road. The Silk Road Economic Belt is a land transportation network connecting China through Central Asia, Iran, Turkey, and Europe. The Maritime Silk Road is a transportation route by sea, which begins in the South China Sea, through the Malacca Strait, the Indian Ocean, and the Red Sea, extending into the Mediterranean Sea (Alden & Barber, 2015). Due to the BRI strategy, more than 6000 trains made the journey from China to Europe in 2018, an increase of 72 percent compared to 2017. China has sent more than 11,000 freight trains to

Europe and back since the BRI strategy was announced in 2013. Railway networks have been constructed under the BRI strategy for connecting 48 Chinese cities with 42 cities in Europe through Asia (Florian Frese, 2019). A large amount of railway infrastructure has been constructed under the BRI strategy. The China – Laos railway (Vientiane–Boten railway) is a project under the Silk Road Economic Belt sub-strategy of the BRI.

The Vientiane–Boten railway has been developed as an addition to the transportation infrastructure, enhancing the transportation network in Lao PDR. Moreover, this railway will form an economic corridor between the two countries of China and Lao PDR. The Vientiane–Boten railway route comprises 427 kilometers of track originating in Boten, Luang Namtha Province at the China-Laos border and terminating at the destination of Vientiane Province, Lao PDR. This railway project, expected to be completed in 2021, aims to transport both passengers and freight. The frequency of the railway service will include 4 trains per day conveying passengers and 14 trains each day for freight transportation. In the near future, the Vientiane–Boten railway will be a new transportation mode for passengers and freight. This project is designed to support trade, investment, and tourism, benefiting both Lao PDR and South China's Guangxi Zhuang Autonomous Region. Moreover, this will eventually attract travelers and Logistics Service Providers (LSPs), especially regarding transportation time, which can be greatly reduced compared with the road and sea transport modes. This paper investigates the modal shift potential of travelers and freight on the Kunming-Bangkok Highways (R3A), AH2, AH8, AH9, AH10, AH12, AH13, and AH18 by considering behavioral aspects of long-distance travel.

In this paper, the analysis of mode shift is presented using the Mode Split Model. In order to find the effect of the Vientiane–Boten railway, which is provided as a novel choice of transportation mode for travelers and Logistics Service Providers (LSP) from Luang Prabang – Vientiane, Lao PDR. The remainder of this paper is organized as follows; Section 2 provides the background, general characteristics of the railway corridor, and an overview of the Vientiane–Boten railway. The methodology is described in Section 3, covering data collection, the influencing variables for each transportation mode, experimental design, and the modeling approach used for analysis. The results of the research and discussion are then illustrated in Section 4, followed by conclusions in Section 5.

2. VIENTIANE–BOTEN RAILWAY

The Vientiane–Boten Railway (Lao-China Railway) will connect Lao PDR to the Belt and Road Initiative (BRI). The World Bank (2020) reported that “the Lao-China

Railway, which will connect the Lao People's Democratic Republic (Lao PDR) to the entire network of the Belt and Road Initiative (BRI), has the potential to transform Lao PDR from a landlocked to a land-linked economy" (World Bank, 2020, p. 11); at present, Lao PDR is a landlocked country. The 427 kilometers of railway will connect Lao PDR's capital city (Vientiane) to Boten at the northern border. Boten city is a border city, close to China. The Boten station will connect with the railway network under the BRI at Kunming, China, with a railway link of 595 kilometer distance. The travel time of the railway route from Vientiane to Boten is expected to take less than four hours. Significantly the travel time on the railway is fourteen-fifteen hours less than the travel time by private vehicle as the current travel time from Vientiane to Boten by road is eighteen hours. Based on the 2020 World Bank report on "From Landlocked to Land-Linked: Unlocking the Potential of Lao-China Rail Connectivity" report, if the construction of the Vientiane - Boten Railway is well completed in 2021, the Vientiane - Boten Railway will facilitate both passengers and freight. The advantage of the Vientiane - Boten Railway is as follows:

> "Without considering border clearance times, it will take approximately another four hours from Boten to Kunming. The railway will also make it possible to travel between Vientiane and Vang Vieng in about an hour, less than the current four hours by car. Assuming an efficient border process for passengers and cargo, the Vientiane-Boten Railway could provide Lao PDR with a land link to global and regional supply chains, which could make the country more attractive to investors, create new jobs, and accelerate economic growth. However, this would require policymakers to implement reforms to improve the country's business and trade environment and facilitate well-targeted complementary infrastructure investments".
>
> (World Bank, 2020, p. 9)

2.1 General Characteristics of the Railway Corridor

The Vientiane - Boten railway is a part of the Kunming-Singapore multi-country rail network (or "Pan-Asia Railway"). The Kunming-Singapore multi-country rail network is an anchor investment by the Chinese government's Belt and Road initiative strategy (BRI) (Wu, 2016). The multi-country Kunming Singapore rail link was adopted at the 1995 ASEAN summit. The rail network has been proposed to be the backbone of the transportation infrastructure network for the China-Indochina Economic corridor, one of six defined economic main corridors for the BRI strategy. The Vientiane - Boten railway will be part of the central rail link in the Southeast Asia railway network, a direct route from Kunming to Singapore via Vientiane, Lao PDR, and Bangkok, Thailand, as

shown in Figure 1. The Vientiane - Boten railway has been constructed as a standard gauge (1435 mm) consisting of a distance of 427 kilometers. The Vientiane - Boten railway route passes through many provinces of Lao PDR, beginning at Boten city, Luang Namtha Province, Lao PDR and continuing to Vientiane province, Lao PDR (Derudder et al., 2018).

Passenger trains will be designed to run at a normal speed of 160 km/hr, with a maximum speed of 200 km/hr, while freight trains will be designed to run at a speed of 120 km/hr. Ten railway stations are planned in Lao PDR that will handle both freight and passenger operations. In addition, there are twenty-one passing stations, where trains can pass each other in opposite directions or faster trains can overtake slower freight trains. According to the Boten-Vientiane Railway Feasibility Study in 2016 by the China Railway Eryuan Engineering Group Co., Ltd., the railway is anticipated to "run two passenger train pairs per day by 2025, which will increase to five train pairs per day by 2030. Moreover, the railway is expected to carry about 10 million tons of cargo by 2025 and 16 million tons by 2030" (World Bank, 2020, p. 19).

2.2 Freight Demand for Railway Services

The Vientiane-Boten railway runs through diverse economic regions with varying production and tourism potential. It passes through the capital of Vientiane and the four provinces of Luang Namtha, Oudomxay, Luang Prabang, and Vientiane. The condition of the road network that connects the railway to the five northern provinces is fair and covers about one-third of the country's population. The major agricultural commodities are paddy, banana, maize, starchy roots, and tea. These are produced in the northern region, including in provinces along the railway route. Moreover, the provinces connected by the railway also have considerable tourism potential. International tourists in provinces along the railway account for about half of all foreign visitors to Lao PDR. The graph in Figure 2 presents the number of international visitors and domestic tourists in the provinces of Lao PDR. Four out of ten domestic tourists in the country visit provinces along the railway corridor, including the capital of Vientiane.

In 2016, about 70 percent of China's import volume from Lao PDR was transported by maritime mode (about 2 million tons), while 30 percent was transported by road mode (0.8 million tons). The products transported by road consisted of wood (53 percent), minerals (22.4 percent), and agricultural products (15.2 percent). China's imports and exports to Lao PDR in 2016 are shown in Figure 3. Almost all of China's agricultural imports from Lao PDR were conveyed by road. Other products, mainly wood, minerals, and fertilizer, were conveyed by sea. China's sea-based imports from Lao PDR are mainly carried to provinces

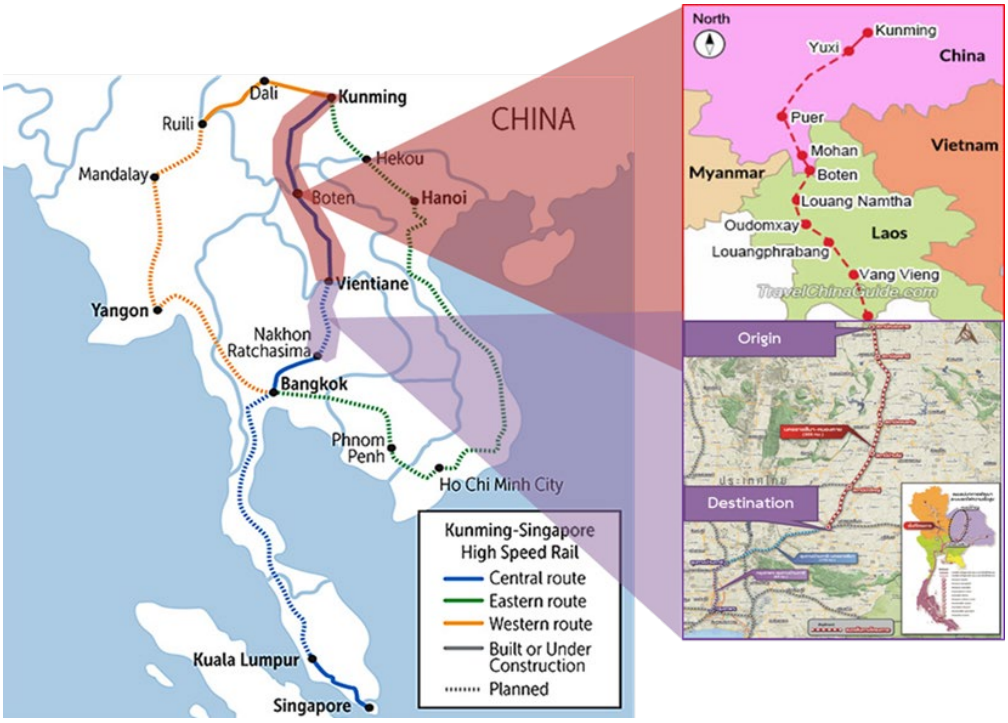
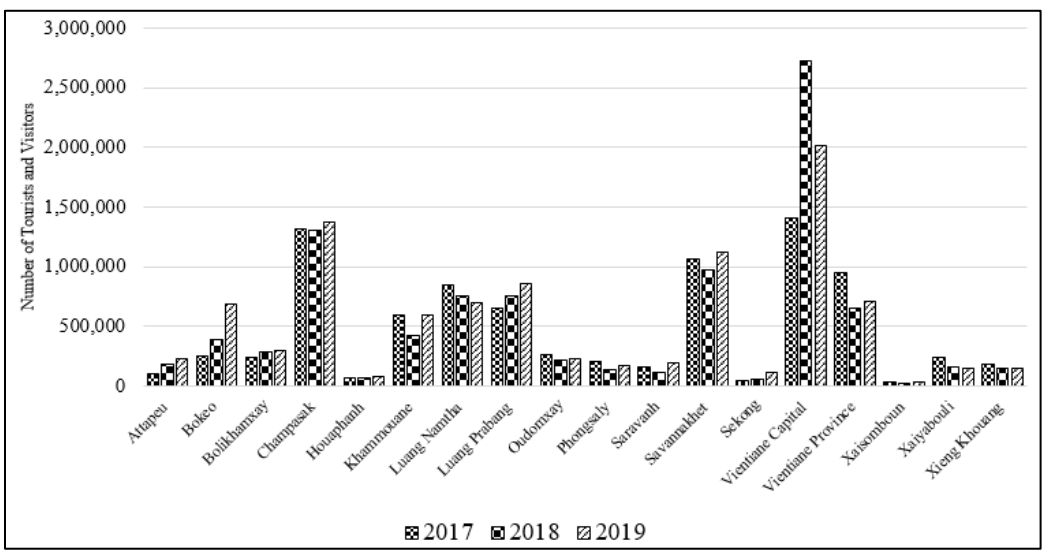
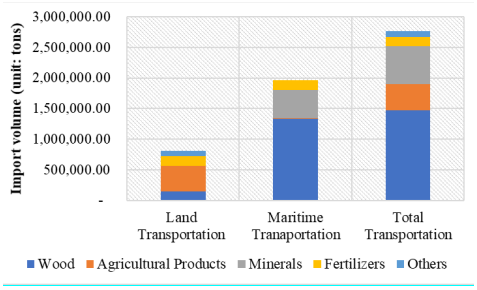


Figure 1 Kunming -Singapore High Speed Rail Route Map

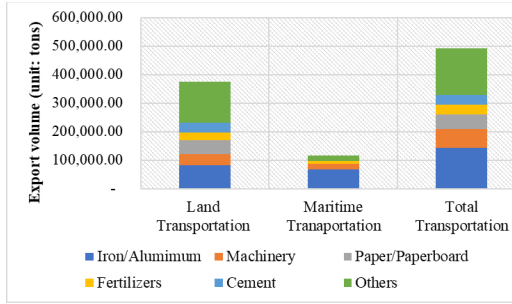


Source: Ministry of Information, Culture, and Tourism, Tourism Development Department, 2019

Figure 2. Number of visitors and domestic tourists by province, 2017- 2019



China's imports product from Lao PDR, 2016



China's exports product to Lao PDR, 2016

Source: China Customs Data 2016.

Figure 3 Import and Export Volume of China and Lao PDR, 2016

outside of Yunnan. 76 percent of China's exports to Lao PDR were conveyed by road mode, although the overall volume was only 0.49 million tons, and 23 percent (0.11 million tons) was shipped from China to Lao PDR by maritime mode, originating primarily in provinces outside of Yunnan. China's export products consist of iron, steel, machinery, paper, paperboard, fertilizer, and cement.

3. RESEARCH METHODOLOGY

Based on the development of transportation infrastructure in Lao PDR, road networks have been emphasized as the connection for each province in Lao PDR; the major road network consists of the R3A, AH2, AH8, AH9, AH10, AH12, AH13, and AH18 highways. Although these highways cover all major areas of Lao PDR, other transportation modes will be selected when the destination province has an airport. Thus, regarding travel behavior and freight in Thailand and Lao PDR, it has been found that the choice of transportation mode is currently focused on road modes such as private vehicles, buses, and trucks.

In order to investigate long-distance travel (LDT) behavior, a Mode Split Model has been employed for analyzing the mode choice and modal shift based on the development of transportation infrastructure. The Mode Split Model is the trip matrix (O-D matrix) obtained from the trip distribution in the 4-step transportation engineering model, segmented into the number of matrices representing each mode. The Mode Split Model can interpret the proportion of all possible vehicles from origin to destination. Firstly, data are obtained using a survey targeting both travelers and LSP under the situation and constraints of various transportation modes in the study area. Other factors which may affect the decision regarding the choice of transportation mode are also considered, consisting of travel time, travel cost, loading and unloading process, speed, certainty, and

convenience of transportation mode. In this paper, the utility function has been used. The traveler will associate some value with the utility of each transportation mode. If the utility of one transportation mode is higher than the other, then that mode is selected. However, there is also disutility in transportation. In this case, the disutility is the travel cost. There are 2 parts in the Utility Function: Determinant Component and Random Component. These can be represented using the following equations:

$$u_{in} = v_{in} + \varepsilon_{in} \quad (1)$$

Where

u_{in} is the utility for decision-maker *n* with choice *i;*

v_{in} is the proportion of utility, that is certainly measurable for decision-maker *n* with the choice *i;*

ε_{in} is the proportion of utility, that is certainly unmeasurable for decision-maker *n* with the choice *i*.

The utility function is based on an assumption about the distribution of variables that cannot be measured independently. The distribution of variables can be defined by many methods. The Gumbel distribution is the distribution of the variable in this analysis. Due to the Gumbel Distribution, the Logit model is employed and can be easily extended to multiple modes. The equation for this probability can be presented as:

$$P_n(i) = \frac{e^{v_{in}}}{\sum_{j \in c_m} e^{v_{jn}}} \quad (2)$$

Where

v_{in} is the utility value of choice *i* of traveler *n*;

c_m is the number of all choices;

j is choice *j* such as railway, truck, airplane, or private car;

$P_n(i)$ is the probability of decision-maker *n* selecting choice *i*.

In this study, three models are defined to develop the mode choice model, as follows:

1) The mode choice model for citizens and tourists where the areas passed by are on the Vientiane–Boten Railway route.
2) The mode choice model for citizens and tourists where the areas passed by are not on the Vientiane–Boten Railway route.
3) The mode choice model for freight transportation.

There are 3 main factors that affect the mode choice: (1) travel time, (2) travel cost, and (3) transfer time, as well as the pattern of changing mode. The data of each factor has been obtained from in-depth interviews with LSPs in Laos, LSPs in Nongkhai, Thailand, and the Ministry of Public Works and Transport of Laos. The data from the in-depth interviews was then considered for making the scenarios for the survey questionnaire. Table 1 displays the description of each factor. A Fractional Factorial Experiment design was used in this study. If the correlation coefficient of two variables is zero, it indicates that there is no linear relationship between the variables. The experimental design

Table 1 The Description of Factors for Mode Choice

The factors for mode choice	Level	Truck	Airplane	Rail
Transportation time	High	25 hr	1.5 hr	4 hr
	Medium	20 hr	1 hr 15 min	3 hr 30 min
	Low	15 hr	1 hr.	3 hr
Unloading and transfer time	High	-	2 hr	2 hr
	Medium	-	1 hr 30 min	1 hr 30 min
	Low	-	30 min	30 min
Delay time	High	2 hr	2 hr	2 hr
	Medium	1 hr 30 min	1 hr 30 min	1 hr 30 min
	Low	30 min	30 min	30 min
Frequency	High	24 trips/day	6 trips/day	30 trips/day
	Medium	18 trips/day	4 trips/day	25 trips/day
	Low	12 trips/day	2 trips/day	20 trips/day
Transportation cost (weight of freight is equal to 100 kg.)	High	200 baht/trip	500 baht/trip	90 baht/trip
	Medium	150 baht/trip	400 baht/trip	60 baht/trip
	Low	100 baht/trip	300 baht/trip	30 baht/trip
Unloading and transfer cost	High	-	75 baht/trip	75 baht/trip
	Medium	-	50 baht/trip	50 baht/trip
	Low	-	25 baht/trip	25 baht/trip

Note: Level (high, medium, and low) in each factor is defined based on the report of Ministry of Public Works and Transport of Lao PDR for railway mode, and the survey questionnaire for truck and airplane modes.

consists of 27 treatment combinations.

In this paper, the data have been collected by calculating the sample size with a Stated Preference (SP) technique. The sample was divided into 2 groups, consisting of travelers, and logistics service providers (LSPs). Firstly, the data of travelers was collected, obtaining a sample of 500 respondents, of which 135 were travelling citizens, and 365 were tourists. Secondly, the data of LSPs was also collected from a sample of 500 respondents. The data were collected by using a questionnaire, providing detailed information about the travel behavior of the travelers including socio-demographic variables and daily activity plans. In more detail, the dataset consisted of travel time, transport mode, and activity type (e.g., home, work, leisure, education, and other). In addition, the data collected from the respondents' included information on the individual respondents and their household characteristics, daily activities, and trip characteristics. The applied interview process was

designed to cover most of the individual and household characteristics, the daily activity, and trip characteristics. The interview method was structured, with questions regarding aspects of transport appearing in the daily activity process of the respondents, why these elements were important, and how each aspect affected the respondent's mode choice. Binary Logit Models were then developed to examine the relationships between a modal shift to the Vientiane–Boten Railway, and the socio-demographic, commuting, and other motivation factors. In this study, the Vientiane–Boten Railway was the focus of comparison with the route from Luang Prabang Station to Vientiane station. The choice of transportation mode consisted of private car, airplane, and public transport for passengers, while in the case of freight, the alternative mode was via truck. The total cost was a focus in the development of the mode choice model, while travel time and transfer time were generic attributes. The hypothesis in this study was: Travelers and LSPs think that the value of money and time spent travelling is the same for each vehicle type and consists of many parameters as follows:

ASC_Truck = Alternative Specific Constant of truck choice
ASC_Passengercar = Alternative Specific Constant of private vehicle choice
ASC_Airplane = Alternative Specific Constant of airplane choice
ASC_Rail = Alternative Specific Constant of railway choice
ASC_Public = Alternative Specific Constant of double-track railway choice
B_Cost = Total cost coefficient (unit: baht)
B_Time = Travel time of passengers and freight coefficient (unit: hours)
B_H&D = Transfer time, accessibility, and distribution time coefficient (unit: hours)

Table 2 The analysis of coefficient and p-value of the development model

Parameter	The areas passed by are on the Vientiane–Boten Railway route		The areas passed by are not on the Vientiane–Boten Railway route	
	Coefficient	p-value	Coefficient	p-value
ASC_Passengercar	0	-	0	-
ASC_Rail	0.0054	0.0040	-0.9380	0.0001
ASC_Airplane	-0.7580	0.0010	-2.1960	0.0014
ASC_Public	-0.8870	0.0021	-2.0420	0.0020
B_Cost	-0.0009	0.0003	-0.0013	0.0004
B_Time	-0.0202	0.0005	-0.0344	0.0078
B_H&D	-0.9880	0.0001	-0.2680	0.0063
Adjusted Rho-Squared	0.332		0.381	

Table 3 The Analysis of Coefficient and P-Value of the Development Model (freight transportation)

Parameter	Coefficient	p-value
ASC_Passengercar	0	-
ASC_Rail	-2.5870	0.0032
ASC_Airplane	-0.3350	0.0000
ASC_Public	-0.0026	0.0000
B_Cost	-0.0592	0.0241
B_Time	-0.6132	0.0325
B_H&D	0	-
Adjusted Rho-Squared	0.263	

4. RESULTS

Various transportation modes in Lao PDR are considered in this study. Lao PDR is currently a landlocked country, since all the borders of this country connect to the land of neighboring countries, with no sea border. Although Lao PDR is a landlocked country, the location of the country is still significant in terms of its transportation network. Lao PDR is at the center of the ASEAN countries, such that it can form land links with and between Thailand, Vietnam, and China. Based on these reasons, the Chinese Government has made the decision to invest in transportation infrastructure, including the Vientiane–Boten railway. This railway infrastructure is being constructed as a new transportation mode along the route from the capital Vientiane and the small town of Boten on the border with China. Therefore, an expected mode shift exists from the current transportation modes for both travelers (private vehicle, bus, and airplane) and freight (truck, and airplane) to the new transportation mode, in this case the railway mode; this mode shift was investigated by applying a Mode Split Model.

The factors considered in the Mode Split Model were the total cost, travel time, and transportation time, transfer time, and distribution time. The results show that the important factors for selecting a travel and transportation mode under the future situation of travelers in the area of the Vientiane–Boten railway are handling time and distribution time. Significantly, 45 – 55 percent of all transportation modes shifted to the railway mode. However, the important factors for selecting travel and transportation mode under the future situation of travelers who are not in the Vientiane–Boten railway area were total cost and travel time; private vehicles were selected in this case. The total cost, transportation time, and frequency of service were found to be important factors for LSPs in selecting transportation mode; there

Table 4 The Proportion (Percentage) of Mode Choice (Citizens and Tourists)

Case	Private Vehicle	Vientiane–Boten Railway	Airplane	Public transport
The areas passed by are on the Vientiane–Boten Railway route	35.25	53.11	2.75	7.89
The areas passed by are not on the Vientiane–Boten Railway route	56.98	24.04	2.67	16.31

Table 5 The Proportion (Percentage) of Mode Choice (Freight Transportation)

Case	Truck	Vientiane–Boten Railway	Airplane
Logistics service providers	53.23	37.04	9.74

was a mode shift of 30-40 percent from truck mode to railway mode. Table 4 and Table 5 present the analysis of the modal split model separated between citizens and tourists, and freight transportation.

5. CONCLUSIONS

This paper presents an analysis of the mode shift for transportation through Lao PDR, using a Mode Split Model to find the effect of the addition of the Vientiane–Boten railway, which is a new choice of transportation mode for travelers and Logistics Service Providers (LSPs) who would like to travel or transport freight from Luang Prabang to Vientiane in Lao PDR. The factors that affect travel behavior and mode choice are the focus of this study. The findings show that, in general, the Vientiane–Boten railway will affect the travel mode choice, with travelers shifting from other modes of public transport to the railway mode. Based on the results of the Mode Split Model, 53 percent of tourists and other travelers in the area of the Vientiane–Boten railway are more likely to select the railway mode due to reduced travel time and cost. On the other hand, regarding tourists and travelers not in the area of the Vientiane–Boten railway, only around 24 percent of them are more likely to select railway mode, with a mode shift from road to railway. The findings of this study could potentially be helpful for LDT providers that operate public transport for passengers. According to the results, shifts in the mode of travel will be increased due to the availability of various travel modes. Therefore, public transport for connecting between the railway mode and other modes should be provided.

Regarding the tourism industry, some visitors will change their current travel mode, switching from the current mode of private car or airplane to the railway mode, as the travel time and cost of the railway mode is much

lower than travelling by private vehicle. Even though the travel time for the airplane mode is much lower than for railway mode, the frequency of service and the travel cost will also be considered. Due to the comparison of travel time and cost of each travel mode, the Vientiane–Boten railway will be selected by most visitors. Moreover, visitors can travel along the route of the Vientiane–Boten railway easily. Lao PDR will earn considerable income from an increase in demand for passenger rail traffic. Regarding Logistics Service Providers (LSPs), there are many reasons affecting the decision to select transportation mode; these consist of transportation time, transfer time, probability and duration of potential delays, frequency of service, transportation cost, and transfer cost. Therefore, some LSPs will still select the truck mode for freight transportation.

ACKNOWLEDGMENTS

This research was supported by Thailand Science Research and Innovation: TSRI in 2020 (Contract No. RDG62T0130)

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