การศึกษารูปแบบทางเลือกในการขนส่งน้ำมันระหว่างประเทศเปรียบเทียบระหว่างทางรถไฟกับทางถนน กรณีศึกษา เส้นทางจากคลังน้ำมันที่อำเภอบ้านไผ่จังหวัดขอนแก่น ถึงสถานีรถไฟท่านาแล้ง สาธารณรัฐประชาธิปไตยประชาชนลาว

A Comparative Study of Oil Transportation Modal Choice between Intermodal Rail and Road: A Case Study of Freight Route between Ban Phai Tank Farm Khon Kaen Province to Railway Yard at Thanaleng the Laos People's Democratic Republic.

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บทคัดย่อ

งานวิจัยนี้ มีวัตถุประสงค์เพื่อศึกษาปัจจัยที่มีผลต่อการพิจารณาการตัดสินใจเลือกรูปแบบการขนส่งน้ำมันระหว่างทางถนนกับทางราง และเพื่อประเมินทางเลือกรูปแบบในการขนส่งที่สอดคล้องกับความต้องการของผู้ที่มีส่วนเกี่ยวข้องได้ดีที่สุด จากการศึกษาถึงปัจจัยต่าง ๆ พบว่า ปัจจัยด้านเวลา ค่าใช้จ่าย ความยืดหยุ่น ความปลอดภัย และความน่าเชื่อถือ มีความสำคัญต่อการพิจารณาการเลือกรูปแบบการขนส่งน้ำมันระหว่างทางถนนกับทางราง โดยนักวิจัยได้ทำการรวบรวมข้อมูล และสัมภาษณ์ผู้มีส่วนเกี่ยวข้องถึงน้ำหนักความสำคัญของแต่ละปัจจัย บนเส้นทางขนส่งน้ำมันจากคลังน้ำมันที่อำเภอบ้านไผ่จังหวัดขอนแก่น ถึงสถานีรถไฟท่านาแล้ง สาธารณรัฐประชาธิปไตยประชาชนลาว เพื่อเป็นข้อมูลนำเข้าในการวิเคราะห์การตัดสินใจแบบพหุเกณฑ์ โดยวิธีกระบวนวิเคราะห์ตามลำดับชั้น โดยพบว่า ปัจจัยด้าน เวลาและค่าใช้จ่าย มีน้ำหนักความสำคัญมากกว่าความยืดหยุ่น ความปลอดภัย และความน่าเชื่อถือในรูปแบบการขนส่งน้ำมัน และเมื่อรวมค่าคะแนนถ่วงน้ำหนักรวมทุกปัจจัยแล้ว พบว่าการขนส่งน้ำมันทางรางมีค่าคะแนนถ่วงน้ำหนักรวมสูงกว่าทางถนน คิดเป็นคะแนน 0.63 และ 0.37 ตามลำดับ

คำสำคัญ: การวิเคราะห์การตัดสินใจแบบพหุเกณฑ์ กระบวนการวิเคราะห์ตามลำดับชั้น การขนส่งน้ำมัน การขนส่งสินค้าทางราง

Abstract

This research aims at studying influencing factors on the modal choice decision between road and intermodal rail modes for oil transportation between Ban Phai Tank Farm Khon Kaen Province to Railway Yard at Thanaleng the Laos People's Democratic Republic, that best suits stakeholders' needs. According to the interviews with stakeholders, it is found that among five influencing factors including time, cost, flexibility, safety, and reliability, time and cost outweigh the other factors. In addition, the input information on each influencing factors are collected to determine the weighted score of each mode which are used as the input for multi-criteria decision analysis technique called analytic hierarchy process. The results show that the intermodal rail is more preferred to the road with the total sum weighted score of 0.63 and 0.37, respectively.

Keywords: Multi-criteria Decision Analysis, Analytic Hierarchy Process Transportation, Oil Transportation, Intermodal Rail Freight

1. Introduction

Transporting oil from Thailand to most destinations in the Laos People's Democratic Republic (Laos PDR) is carried out by truck through Thai-Laos friendship bridge, the only existing land transportation link between Thailand and Laos PDR. The Thai-Laos Friendship Bridge is one of the promotion of Thai-Laos border trade, which is in line with the development guidelines of Thailand Logistics (2006-2010) which has been approved by the Development Committee National Economy and Society on April 17, 2006 and one of the strategic agenda is to raise the level of excellence in trade facilitation processes (Trade facilitation) by reducing processing and transportation time and cost of the operators in the transport of import – export goods (Suproongroj, 2010).

Although, the bridge consists of both road and rail link. The current rail service operated between Nong Khai and Thanaleng through the bridge since March 2009 is only available for passengers but not for freight. Since transporting oil by truck is less attractive in comparison to rail in terms of traffic congestion, traffic accidents, energy consumption and environmental friendliness, this research is aims at studying the comparative modal choice of oil transportation between rail and road. The freight route between Ban Phai Tank Farm in Khon Kaen province to railway yard at Thanaleng in the Laos PDR is considered as a case study.

2. Relevant theories and method

This research is to compare and assess the capability of rail and road transportation services. This part discusses the research process guidelines and procedures using analytic hierarchy process methods to evaluate delivery options for oil. Including the analysis of factors that affect the modal choice of transportation, consisting of.

2.1 Rail Freight Transportation

Research related to rail transport generated some interests particularly in the late eighties but went into a dormant phase thereafter. With the increasing interests in rail transport especially in the developed world (to avert ever-increasing road congestion), rail research interests have been revived. Laos and Thailand have launched a freight train service across the Laos-Thai Friendship Bridge between Laos capital Vientiane and Nong Khai province to facilitate import and export businesses (Saruchera, 2017).

2.2 Oil Transportation by Mode

Transportation is an essential part of the oil and gas industry. However, due to the hazardous nature of transported products, crude oil require special handling and increased safety regulations. Therefore, cargo security, delivery speed, and proper transportation equipment play a crucial role in the oil supply chain (PLS, 2020)

Modes of the most popular ways of transporting crude oil across the world includes

- Road

The easiest and most popular transportation mode for oil industry is trucking. With road transportation, shipments can be scheduled at any time and delivered to any place. This advantage makes trucking more beneficial than other transportation modes. Also, it transports smaller amounts of oil, meaning that the extent of damage in case of fire due to cracks or leaks is relatively small (PLS, 2020). However, it is considered the most expensive and inefficient means of crude oil transportation. This method is typically utilized only when wellhead locations are not accessible by pipeline or rail networks, or for short distances during final-mile segments of the movement (Wetzel, 2019).

- Rail

. Rail transportation makes oil containers less prone to damage compared to other shipping modes. This method doesn't have enough flexibility to move oil at any point. But, when combined with other modes, rail can be extremely beneficial for a fast and cost-effective way to move oil long distance (PLS, 2020).

- Pipelines

This transportation method suggests that oil is gathered and then transported directly to the site or plant via a pipeline network. Despite pipeline shipping being a hot topic of discussions between industry experts, it is a fast and reliable way to distribute oil. New technology helps advance the safety of this mode, and pipelines have sensors for monitoring important indicators like temperature, pressure, etc. Pipeline transportation has its disadvantages. Firstly, it limits areas and destinations to be shipped to in accordance with infrastructure development. Additionally, pipelines move enormous amounts of oil, so when an accident happens, the damage is very serious and it's often hard to liquidate the consequences (PLS, 2020).

2.3 Freight Transportation Mode Share in Thailand

According to Ministry of Transport (MOT) statistics reported by Sathapongpakdee (2019), mode share of Thailand domestic freight transportation is as shown in Figure 1.

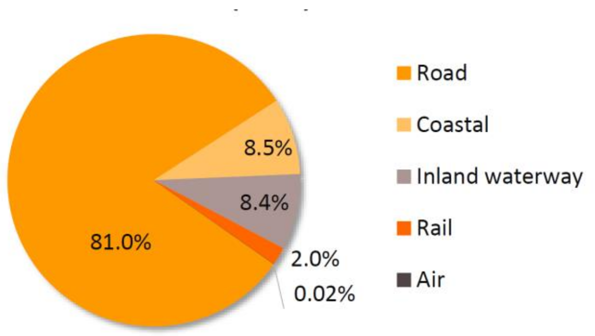

Figure 1 Mode Share of Thailand Domestic Freight Transportation (Source: MOT in Sathapongpakdee, 2019)

This implies that oil transport relies predominantly on road transport where the fossil fuel and ore accounts for approximately 22.7 percent share of road freight transportation as of 2015 (MOT in Sathapongpakdee, 2019)

2.3 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP), introduced by Thomas Saaty (1980), is an effective tool for dealing with complex decision making, and aid the decision maker to set priorities and make the best decision. By reducing complex decisions to a series of pairwise comparisons, and then synthesizing the results, the AHP helps to capture both subjective and objective aspects of a decision. In addition, the AHP incorporates a useful technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision-making process. The AHP considers a set of evaluation criteria, and a set of alternative options among which the best decision is to be made. The AHP generates a weight for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria. The higher the weight, the more important the corresponding criterion. Next, for a fixed criterion, the AHP assigns a score to each option according to the decision maker's pairwise comparisons of the options based on that criterion. The higher the score, the better the performance of the option with respect to the considered criterion (Mocenni, 2017). The pairwise comparisons are collected into a pairwise comparison matrix which represent ratios between weights can be expressed in the following form (Brunelli, 2015):

$$\mathbf{A} = (w_i/w_j)_{n \times n} = \begin{pmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{pmatrix} \quad [1]$$

One crucial step in the AHP is the derivation of a priority vector for each pairwise comparison matrix which needs to be complied with the relaxed assumption that A single decision maker is perfectly rational and can precisely express his preferences on all pairs of independent alternatives and criteria using positive real numbers. The most popular method to estimate a priority vector is that proposed by Saaty (1980) himself, according to which the priority vector should be the principal eigenvector of A. In linear algebra it is often called the Perron-Frobenius eigenvector, from the homonymic theorem (Horn and Johnson, 1985). The method stems from the following observation. Taking a matrix A whose entries are exactly obtained as ratios between weights and multiplying it by w one obtains (Brunelli, 2015):

$$\mathbf{Aw} = \begin{pmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{pmatrix} \begin{pmatrix} w_1 \\ \vdots \\ w_n \end{pmatrix} = \begin{pmatrix} nw_1 \\ \vdots \\ nw_n \end{pmatrix} = n\mathbf{w}. \quad [2]$$

From linear algebra, it is known that a formulation of the kind Aw = nw implies that n and w are an eigenvalue and an eigenvector of A, respectively. Saaty proposed to extend this result to all pairwise comparison matrices by replacing n with the more generic maximum eigenvalue of A. That is, vector w can be obtained from any pairwise comparison matrix A as the solution of the following equation system (Brunelli, 2015).

$$\begin{cases} \mathbf{Aw} = \lambda_{\max}\mathbf{w} \\ \mathbf{w}^T\mathbf{1} = 1 \end{cases} \quad [3]$$

where λ_{max} is the maximum eigenvalue of A, and 1 = $(1, .. , 1)^T$. Another widely used method to estimate the priority vector is the geometric mean method, proposed by Crawford and Williams (1985). According to this method each component of w is obtained as the geometric mean of the elements on the respective row divided by a normalization term so that the components of w eventually add up to 1 as follows (Brunelli, 2015):

$$w_i = \left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}} \Bigg/ \sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}} \quad [4]$$

Finally, the AHP combines the criteria weights and the options scores, thus determining a global score for each option, and a consequent ranking. The global score for a given option is a weighted sum of the scores it obtained with respect to all the criteria (Mocenni, 2017).

The AHP can be implemented in three simple consecutive steps (Mocenni, 2017):
1) Computing the vector of criteria weights.
2) Computing the matrix of option scores.
3) Ranking the options.

When many pairwise comparisons are performed, some inconsistencies may typically arise. The AHP incorporates an effective technique for checking the consistency of the evaluations made by the decision maker when building each of the pairwise comparison matrices involved in the process (Mocenni, 2017). According to the result that given a pairwise comparison matrix A, its maximum eigenvalue, λ_{max}, is equal to n if and only if the matrix is consistent (and greater than n otherwise), Saaty (1977) proposed the Consistency Index (Brunelli, 2015):

$$CI(\mathbf{A}) = \frac{\lambda_{\max} - n}{n-1} \quad [5]$$

However, numerical studies showed that the expected value of CI of a random matrix of size n + 1 is, on average, greater than the expected value of CI of a random matrix of order n. Consequently, CI is not fair in comparing matrices of different orders and needs to be rescaled. The Consistency Ratio, CR, is the rescaled version of CI. Given a matrix of order n, CR can be obtained dividing CI by a real number RI_n (Random Index) which is nothing else but an estimation of the average CI obtained from a large enough set of randomly generated matrices of size n. Hence (Brunelli, 2015):

$$CR(\mathbf{A}) = \frac{CI(\mathbf{A})}{RI_n} \quad [6]$$

Estimated values for RI_n are reported in Table 1. Note that the generation of random matrices requires the definition of a bounded scale where the entries take values, for instance the interval [1/9, 9]. According to Saaty (1980) in practice one should accept matrices with values CR ≤ 0.1 and reject values greater than 0.1. A value of CR = 0.1 means that the judgments are 10% as inconsistent as if they had been given randomly (Brunelli, 2015).

Table 1 Values of RI_n

n	3	4	5	6	7	8	9	10
RI_n	0.5247	0.8816	1.1086	1.2479	1.3417	1.4057	1.4499	1.4854

(Source: Brunelli, 2015).

2.3 Related research

Suproongroj (2010) studies the comparison of Thai-Laos Logistics Systems between using 1st Thai-Laos Friendship Bridge and Nongkhai-Tanalang Railway, By studying the logistics costs of the products with the highest import and export in the fiscal year 2007-2008 at Nong Khai Customs House. The top two imported products are coatings and automobile assembly cables. While the top two export products are oil and cars, which are analyzed in terms of distance, duration and logistics costs. The considered logistics costs consist of transport costs and packaging costs only. The results show that the road transport distance is close to the distance by rail transport. The duration of the rail transport is greater than that of the road transport. While the cost of rail transportation is less than the cost of road transportation. Logistics costs of coatings electrical, automobile and motor vehicle wiring for road transportation is higher than the cost of rail transportation of 26, 20, 11 and 31 percent, respectively. The use of road transportation will take less time while at a higher cost. On the contrary, the use of rail transportation will take more time while the cost is lower. Therefore, this research considers the effects of the use of road transportation and rail transportation in terms of time and logistics costs. The use of road transportation systems will increase the cost but will cause a rapid response. However, based on the tendency of fuel price increases, the logistics costs of road transport may increase. Therefore, in the future, rail transportation may be a good logistics system. Good in the trade process between Thailand and Laos.

Bepat (2016) investigates and compares the brokered transport costs of road and rail transport for the independent timber growers of NCT Forestry Co-operative Limited in Kwa-Zulu-Natal. Reliability, flexibility, visibility, rates and total transport time were evaluated for each mode of transport. The impact of the carbon emissions is also considered and the option of performance based standard vehicles investigated. During the period 2000 to 2003, rail was the dominant mode of transport. However from 2004 onwards, due to the diminishing service levels and the high tariff structures of rail transport, road became the preferred mode of transport. The results of the survey conducted for the purposes of this study showed that although road transport outperformed rail transport, rail transport scored significantly higher than road transport as a cost-effective mode of transportation. Rail transport was shown to be a far less carbon intensive mode of transport than road transport, while there were substantial cost savings and benefits from performance based standard vehicles.

Forkenbrock (2001) estimates external costs for four representative types of freight trains. For each type of freight train, the estimation covers three general types of external costs which are compared with the private costs experienced by railroad companies. The general types of external costs include: accidents (fatalities, injuries, and property damage); emissions (air pollution and greenhouse gases); and noise. Resulting private and external costs are compared with those of freight trucking. Rail external costs are 0.24 cent to 0.25 cent (US) per ton-mile, well less than the 1.11 cent for freight trucking, but external costs for rail generally constitute a larger amount relative to private costs, 9.3-22.6%, than is the case for trucking, 13.2%.

3. Methods and Results

According to the interviews with forty samples of stakeholders who are mainly entrepreneurs and operators of trucking industries in Laos P.D.R., it is found there are five influencing factors, that the respondents consider important to their modal choice decisions on oil transportation along the study route, which include time, cost, flexibility, safety, and reliability.

3.1 Weight

The respondents are asked to determine the comparison weight between each pair of those five influencing factors in the pairwise comparison matrix form as shown in Table 2.

Table 2 Pairwise Comparison Matrix of Weight

Factors	Time	Cost	Flexibility	Safety	Reliability
Time	1.00	1.00	1.29	1.29	1.29
Cost	1.00	1.00	1.29	1.29	1.29
Flexibility	0.78	0.78	1.00	1.00	1.00
Safety	0.78	0.78	1.00	1.00	1.00
Reliability	0.78	0.78	1.00	1.00	1.00
Total	4.33	4.33	5.57	5.57	5.57

Hence, the priority vector is determined from the pairwise comparison matrix as shown in Table 3 using the geometric mean method.

Table 3 Priority Vector of Weight

Factors	Weight
Transportation Time	0.23
Transportation Cost	0.23
Flexibility	0.18
Safety	0.18
Reliability	0.18

The eigenvector of weight can be determined by matrix multiplication between pairwise comparison matrix of weight in Table 2 and priority vector of weight in Table 3 as shown in Table 4.

Table 4 Eigenvector of Weight

Factors	Eigenvalue
Transportation Time	1.1566
Transportation Cost	1.1566
Flexibility	0.8593
Safety	0.8593
Reliability	0.8593

3.2 Score

Among the four influencing factors, the researcher determines the score value of each factors which are classified into direct and indirect factors. The former is defined as quantitative factors including transportation time and cost. Both factors have negative effects on the decision choices i.e. the higher the value, the less attractive the choice. The latter is defined as qualitative factors that need to be evaluated based on the relative score of 1 to 9 by the respondents. These factors include flexibility safety and reliability. All these factors have positive effects on the decision choices i.e. the higher the value, the more attractive the choice. The resultant vectors of the influencing factor values of intermodal rail and road are as shown in **Table 5**.

It is noticed that oil transported by intermodal rail is found to be not only faster but also cheaper than transported by road. In addition, the respondents' perception on flexibility and safety of intermodal rail transport is superior to that of road transport. While the perception on reliability found to be the same. All influencing factor values are compared between the competitive modes in the form of pairwise comparison matrices as shown in **Tables 6, 7, 8, 9 and 10,** respectively.

Table 5 The resultant vectors of the influencing factor values of intermodal rail and road

Factors (Unit)	Effects	Weight	Rail*	Road
Transportation Time (Hour/Trip) Full-load	Negative (-)	0.23077	9	11
Transportation Cost (Baht/Trip) Full-load	Negative (-)-	0.23077	12,000	30,000
Flexibility (Score of 1-9)	Positive (+)	0.17949	9	3
Safety (Score of 1-9)	Positive (+)+	0.17949	9	5
Reliability (Score of 1-9)	Positive (+)+	0.17949	7	7

Note: Intermodal Rail

Table 6 Pairwise Comparison Matrix of Transportation Time between Intermodal Rail and Road

Transportation Time	Road	Intermodal Rail
Road	1.00	1.22
Intermodal Rail	0.82	1.00
	1.82	2.22

Table 7 Pairwise Comparison Matrix of Transportation Cost between Intermodal Rail and Road

Transportation Cost	Road	Intermodal Rail
Road	1.00	2.50
Intermodal Rail	0.40	1.00
	1.40	3.50

Table 8 Pairwise Comparison Matrix of Flexibility between Intermodal Rail and Road

Flexibility	Road	Intermodal Rail
Road	1.00	0.33
Intermodal Rail	3.00	1.00
	4.00	1.33

Table 9 Pairwise Comparison Matrix of Safety between Intermodal Rail and Road

Safety	Road	Intermodal Rail
Road	1.00	0.56
Intermodal Rail	1.80	1.00
	2.80	1.56

Table 10 Pairwise Comparison Matrix of Reliability between Intermodal Rail and Road

Reliability	Road	Intermodal Rail
Road	1.00	1.00
Intermodal Rail	1.00	1.00
	2.00	2.00

The normalized score of influencing factors are derived based on pairwise comparison matrix of transportation time and cost, flexibility, safety and reliability between intermodal rail and road as shown in Table 11.

Table 11 Normalized Score of Influencing Factors

Factors	Weight	Intermodal Rail	Road
Transportation Time	0.23	0.55	0.45
Transportation Cost	0.23	0.71	0.29
Flexibility	0.18	0.75	0.25
Safety	0.18	0.64	0.36
Reliability	0.18	0.50	0.50

The weighted sum of the normalized scores of every influencing factor results in the total score of intermodal rail and road which are 0.63 and 0.37, respectively.

4. Conclusions and Recommendations

This research is aims at studying the comparative modal choice of oil transportation between rail and road. By interviewing with the forty sample respondents who are entrepreneurs and operators of trucking industries in Laos P.D.R., it is found that among five influencing factors including time, cost, flexibility, safety, and reliability, time and cost outweigh the other factors. By collecting all the input data of influencing factors including quantitative data of transportation time and cost and qualitative data of respondents' perception on flexibility, safety, and reliability of intermodal rail and road transportation on the freight route between Ban Phai Tank Farm Khon Kaen Province to Railway Yard at Thanaleng the Laos People's Democratic Republic. It is found that oil transported by intermodal rail is found to be not only faster but also cheaper than transported by road. In addition, the respondents' perception on flexibility and safety of intermodal rail transport is superior to that of road transport. While the perception on reliability found to be the same. The data collected are input into the Multi-criteria Decision Analysis technique called Analytic Hierarchy Process (AHP) to determine which oil transportation modes are more preferable to the respondents and the overall weighted score indicates that intermodal rail is superior to road with the score of 0.63 and 0.37, respectively.

The result from this research is expected to be an initial indicator of how respondents who are stakeholders of the project response to the preference of each transportation model. It is recommended that the further research should incorporate the more extensive survey on a larger scale of sample sizes to develop a fully comprehensive utility models that is useful for predicting the modal share of oil transportation for planning and developing appropriate intermodal rail facilities along the corridor in the future.

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Reference

[1] Suproongroj, M. T. (2010). Comparison Study of Thai-Laos Logistics Systems Between Using 1st Thai-Laos Friendship Bridge and Nongkhai-Tanalang Railway. Department of Industrial Engineering, Faculty of Engineering, Thammasat University. Degree of Master of Engineering in Industrial Engineering.

[2] Saruchera, F. (2017) Rail freight transportation concerns of developing economies: A Namibian perspective, Journal of Transport and Supply Chain Management, Vol. 11.

[3] PLS Logistics Services (2020) Best Transportation Methods for Oil and Gas Shipping https://www.plslogistics.com/blog/4-transportation-methods-oil-and-gas-shipping/ [Accessed on 22 June 2020]

[4] Wetzel, B. (2019). Oil in Motion: Visibility into Crude Oil Transportation. Breakthrough https://www.breakthroughfuel.com/blog/oil-in-motion-visibility-into-crude-oil-transportation/ [Accessed on 22 June 2020]

[5] Sathapongpakdee, P. (2019) Thailand Industry Outlook 2019. Road Freight Transportation Service, Krungsri Research, August 2019.

[6] Saaty, T.L. (1980) The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation McGraw-Hill, New York.

[7] Mocenni, C. (2017) The Analytic Hierarchy Process https://www3.diism.unisi.it/~mocenni/Note_AHP.pdf [Accessed on 22 June 2020]

[8] Brunelli, M. (2015). Introduction to the Analytic Hierarchy Process. SpringerBriefs in Operations Research. P. 83. 978-3-319-12502-2 (electronic).

[9] Horn, R.A. and Johnson, C.R. (1985) Matrix Analysis. Cambridge University Press.

[10] Crawford, G. and Williams, C. (1985) A note on the analysis of subjective judgment matrices. Journal of Mathematical Psychology 29(4), 387–405.

[11] Saaty, T.L. (1977) A scaling method for priorities in hierarchical structures. Journal of Mathematical Psychology 15(3), 234–281.

[12] Suproongroj, T. (2010) Study Comparison of Thai-Laos Logistics Systems Between Using 1st Thai-Laos Friendship Bridge and Nongkhai-Tanalang Railway,

[13] Bepat, M. (2016) A Comparison of Road and Rail Transport for the Benefit of the Independent Timber Growers of Natal Cooperative Timbers. Master of Commerce. University of South Africa. February 2016.

[14] Forkenbrock, D. J. (2001) Comparison of external costs of rail and truck freight transportation. Transportation Research Part A, 35, pp. 321-337.

[15] เอกชัย ศิริกิจพาณิชย์กูล (2562) เอกสารประกอบการสอนวิชา 01208543 Rail freight Management.