LOCATION SELECTION OF LOGISTICS CENTER: A CASE STUDY OF GREATER MEKONG SUBREGION ECONOMIC CORRIDORS IN NORTHEASTERN THAILAND

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Abstract

The Greater Mekong Subregion (GMS) Economic Corridors have recently become an essential key component of trade in Southeast Asia. As one of the member countries in regional cooperation, Thailand can use these corridors as a tool to boost the nation's economy with respect to cross-border trade. As a large volume of freight is regularly transported and stored, logistics centers are heavily involved in these activities. In this study, an integrated methodology using both AHP and TOPSIS was proposed and utilized for the selection of a suitable location. The Northeastern zone of Thailand was chosen as a case study for the site of a logistics center as two major corridors of the GMS pass through this area. Initially, there were eight alternative Northeastern provinces considered with regard to ten determining criteria. Subsequently, AHP was employed to construct weightings for each of the criteria, and TOPSIS was utilized to rank the provinces from the most to least appropriate alternatives for the location of the logistics center. The outcomes show that Nakhon Ratchasima is the best location within Northeastern Thailand.

Keywords: Logistics center, GMS Economic Corridors, Northeastern Thailand, AHP, TOPSIS

1. INTRODUCTION

Considered as one part of international trade, cross-border trade is an important element of Thailand's regional economy. The value of this trade is represented by the imports and exports with Thailand's four neighboring countries as shown in Figure 1 (data from 2015 to 2017). Malaysia is Thailand's largest trade partner in Southeast Asia, with which import and export values have gradually risen, while values relating to other neighbors continue to fluctuate slightly. Logistics systems

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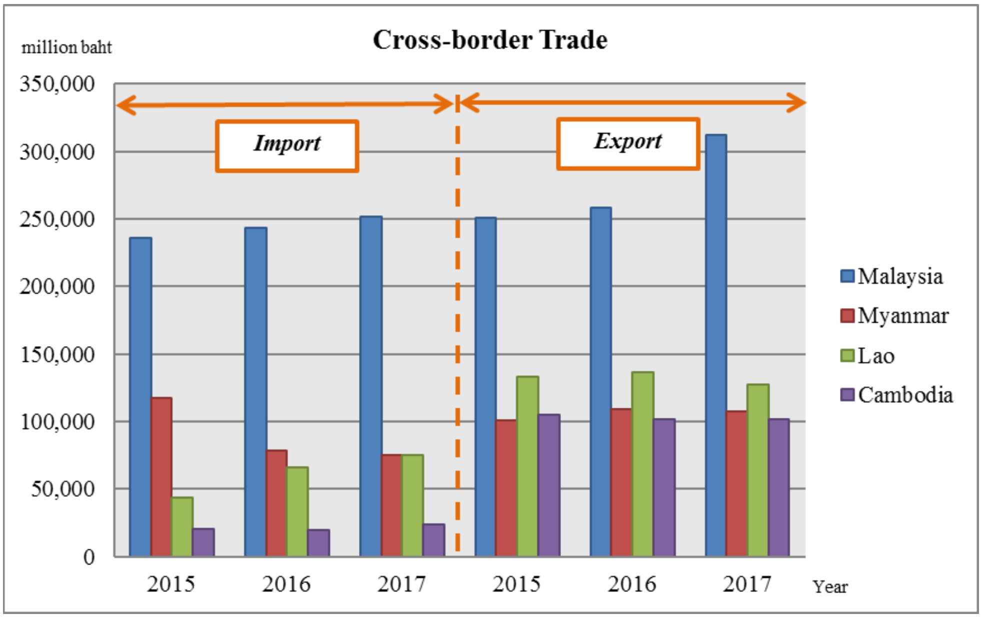

Figure 1: Cross-border trade for Thailand from 2015 to 2017 (Foreign Trade, 2017)

are a crucial reason for the huge volume of freight between Thailand and Malaysia. Padang Besar cargo terminal (situated at the border) and road and rail transport across the border, are major factors clearly supporting trade between the two territories. Unfortunately, the logistics components and infrastructure of Thailand's other regions have been slowly instituted. Consequently, the freight values of imports and exports with Myanmar, Lao, and Cambodia, are all below 150,000 million baht, which is very low in comparison to those with Malaysia.

In order to promote cross-border trade in other areas of Thailand, (i.e. Northern, Western, Northeastern and Eastern) economic corridor development has been initiated in the Greater Mekong Subregion (or GMS - defined as region of the Mekong River basin in Southeast Asia) and is the main focus of this study. The GMS currently plays a major role in fulfilling logistics systems by linking member nations. More specifically, an economic corridor is defined as the area of investment along transport routes, where numerous economic activities explicitly appear. In accordance with ADB (2018), the GMS member countries (Cambodia, China, Laos, Myanmar, Thailand and Vietnam) have created economic corridors connecting the subregion with major markets; nodal points within these economic corridors serve as centers for enterprise development. Thus, economic corridors are an expansion of key transport corridors, enhancing economic activities and benefits, and over the long term helping the subregion to meet its potential as a land bridge serving China, Southeast Asia, South Asia, and East Asia through continued construction and development. To expand Thailand's trade across the GMS, two other countries – China, in particular its Southern region, and Vietnam, should be also included.

By reinforcement of operations, such as consolidation, storage, and distribution, in order to promote GMS commerce, the need for a logistics center must be taken into account. Obviously, it has emerged as an important element of logistics infrastructure in several supply chains (Pham, Ma, & Yeo, 2017). In other words, it serves as a logistical interconnection point within a logistics network, with a primary function as an interface between local and long-distance goods transport (Winkler & Seebacher, 2011). Such logistics centers typically deal with distribution, storage, transportation, consolidation, handling, customs clearance, imports, exports, transit processes, infrastructural services, insurance, and banking (Önden, Acar, & Eldemir, 2016). With regard to the location of the logistics center, Thailand's Northeastern region was selected for the case study due to the following reasons. First, this region contains special economic zones (SEZs), areas for various freight services in the provinces of Nong Khai, Nakhon Phanom, and Mukdahan, more than other regions. Second, the size of the available labor force is much greater in this region. Third, a double track system railway improvement as well as new railway networks are under construction. Fourth, this region can act as a center for both the North-South (extension) and East-West Economic Corridors of the GMS. Nonetheless, no studies have yet considered which of the Northeastern provinces through which the GMS Economic Corridors pass, is most appropriate for use as a logistics center. Therefore, the objective of this study is to investigate the most attractive provincial location for a logistics center in Northeastern Thailand, along the GMS Economic Corridors, based upon a multi-criteria decision making (MCDM) methodology. A combined MCDM method using both AHP and TOPSIS was engaged as a tool to choose the best location for the logistics center. AHP (Analytical Hierarchy Process) is a technique to construct criteria weightings conducted through ratio scale, ranging from one to nine, and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is applied to rank pre-determined alternatives from best to worst. Accordingly, this method can identify the best out of all possible locations.

2. LITERATURE REVIEW

2.1 Logistics Center

At present, a variety of demands from customers has emerged in the international market, representing the exchange of numerous goods and services across territories, and this has rapidly increased. In response, firms have utilized many management tools with relation to product quality, fast movement of physical and non-physical goods, quick information flow, and appropriate storage of goods. Among them, management of logistics has been recognized as one of the essential tools. Islam, Meier, Aditjandra, Zunder, and Pace (2013) point out that logistics is associated distinctively with the integration of information, transportation, inventory, warehousing, material handling, and packaging, and recently added security. While a huge volume of goods is moved and stored all the time, a logistics center is necessary to serve those activities. Hence, the necessity for logistics centers has emerged from the needs of the market economy and its principle to cooperate with foreign countries (Grabara, Dima, & Okwiet, 2012). According to Notteboom (2009), logistics centers act as intermodal transport hubs in either local or international nodes, connecting systems and providing several valuable collection, logistics, and further distribution activities, while transferring freight from one node to another. Logistics centers are also described as regions situated within the official institutions concerned with logistics and transport organizations, and are in possession of active links to all kinds of modes of transport, the possibilities to perform activities, for instance storage, maintenance and repair, loading and unloading, handling, weighing, load splitting, and packing, and are low-cost, fast, secure, transfer areas for moving equipment between transport modes (Zarah & Yazgan, 2016).

2.2 Location Selection by MCDM Methods

A location problem relates to determining the proper placement of an infrastructural component (e.g. ground, site, facility) when considering area (Żak & Węgliński, 2014). Several mathematical techniques (such as linear programming, heuristics and so on) are applied to solve location decisions associated directly with their objectives. With different criteria and alternatives, the site of a logistics center is acknowledged as one of the MCDM conditions in this study. To deal with this, an MCDM method is utilized as a considerable tool to obtain the optimum outcome. The ultimate goal of the MCDM method is to investigate a number of alternatives in light of the many criteria and conflicting objectives (Voogd, 1983). Up to now, there are several MCDM techniques used to make a decision on the location selection. For example, Żak and Węgliński (2014) used ELECTRE to rank the regions in Poland from the most to least appropriate for locating a logistics center based on the related criteria of technology, infrastructure, economy, society, and environment, respectively. Bagočius, Zavadskas, and Turskis (2013) used WASPAS to raise the ranking accuracy for selecting a deep-water seaport in the Klaipeda area, the major transport corridor between Eastern and Western

Europe, to satisfy economic needs. To select the most appropriate location for the nautical tourism port in the Croatian Northern Adriatic, Kovačić (2010) undertook PROMETHEE with GAIA to search for the most suitable location along the specified boundary. In addition to these single study examples, combined studies are also existing. For instance, Yang and Chen (2016) investigated global logistics hub port assessment criteria, and then compared the competitiveness of three major international hub ports in Northeast Asia by using a hybrid AHP-Grey method. In order to choose the most attractive freight village in Istanbul, AHP and PROMETHEE were combined as the decision analysis methodology (Yildirim & Önder, 2014). Sayareh and Alizmini (2014) engaged a decision analysis model by integrating TOPSIS and AHP. TOPSIS was used to provide weightings for the most dominant decision-making criteria, while an analysis of the most optimized container seaport in the Persian Gulf was conducted by AHP. Moreover, the technique of fuzzy set is extensively recognized in MCDM. To make a decision for the best location of an offshore wind power station for China, Wu, Zhang, Yuan, Geng, and Zhang (2016) used ELECTRE in the intuitionistic fuzzy environment. Regarding sustainable energy for vehicle driving in China, Guo and Zhao (2015) adopted fuzzy TOPSIS to explore the optimal locations for electric vehicle charging stations. In the study of Chou, Hsu, and Chen (2008), fuzzy AHP was employed to choose the best locations for international tourist hotels in Taiwan based on 21 criteria. Also, studies with MCDM and other methods have appeared in numerous decision problems. In the research of Erdoğan and Kaya (2016), interval type-2 fuzzy AHP (generating weights of criteria) was combined with interval type-2 fuzzy TOPSIS (ranking alternatives) for determining the most attractive location alternative for a nuclear power plant. In accordance with the importance of electricity for both public and private sectors in Bangladesh, Kabir and Sumi (2014) constructed a fuzzy AHP-PROMETHEE method to select the most appropriate power substation location. Kayikci (2010) employed fuzzy AHP and ANN in the decision-making process for selecting the most suitable location for an intermodal freight logistics center.

3. METHODOLOGY

3.1 Determination of Criteria

Based principally on Żak and Węgliński (2014), the criteria were slightly adapted and modified. The first group used was transport infrastructure with two criteria. Highway was picked up as the first criterion because 80% of freight conveyance in Thailand depends on this mode of transport (National Economic and Social Development Board, 2014), while rail transport, which is gradually being transformed into double tracks across the country, has been promoted by the Thai government (National Economic and Social Development Board, 2017). Economic development was taken as the next group, where GPP per capita was selected as the respective criterion. If this shows a higher number, signifying a good economy, investors may choose to invest in that province. Later, land price and construction cost are commonly related to investment cost, but the latter is often neglected. In general, most construction companies assess buildings as the same cost in any region. Regarding the price of land, there is a minimum to maximum range. In this study, the maximum price is considered, as the lowest price has little significance. In order to serve a variety of logistics activities, the number of logistics service providers plays a major role; thus, it should be taken into account. Subsequently, SEZ is included in the investment attractiveness. SEZ explicitly enables investors to have a great privilege of tax incentives, to access infrastructure and facilities and to benefit from a large labor force. With reference to logistics attractiveness, the GPP of transport and storage reflects the operational level of logistics. The greater the GPP shown, the higher the degree of the logistics. Labor is then presented as one of the criteria of social attractiveness. It has an important impact on driving the logistics sector. In the aspects of the environment friendliness, pollution is required to be eliminated by the nearby communities. Ultimately, accidents in road transport should be taken into consideration with a huge loss. Obviously, these lead to loss of lives, vehicles, property, and goods.

3.2 Selected Alternatives

Focused only on Northeastern Thailand, two economic corridors of the GMS pass through various provinces. The NSEC (North-South Economic Corridor) has two routes, with the first route passing through Nong Khai, Udon Thani, Khon Kaen and Nakhon Ratchasima, and the second route passing through Nakhon Ratchasima, Khon Kaen, Udon Thani, Sakon Nakhon, and Nakhon Phanom. Regarding the EWEC (East-West Economic Corridor), this route passes through Khon Kaen, Kalasin, and Mukdahan. Consequently, eight out of the 20 Northeastern provinces were selected as potential alternatives for the development of a logistics center. Screening for alternatives is demonstrated in Figure 2.

3.3 Purposive Experts

In reference to the experts involved in the pairwise comparison of criteria, there is no definite principle or procedure to determine the appropriate number of experts. This therefore depends on the availability of experts. For example, three experts were selected from universities in Turkey who previously published many papers in the nuclear power plant location selection (Erdoğan & Kaya, 2016). Wang, Jung, Yeo, and Chou (2014) contacted 11 experts to join an MCMD problem

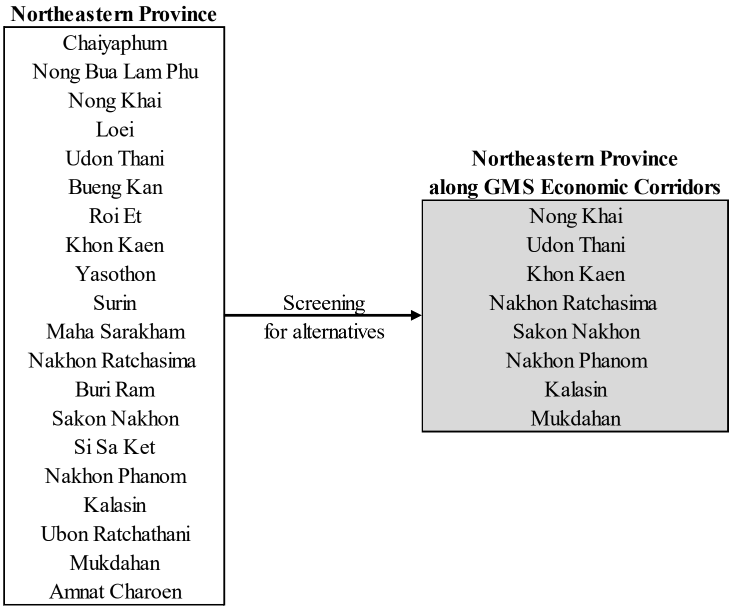

Figure 2: Screening of Northeastern provinces as alternatives for the development of a logistics center

for the selection of a cruise port and call location in East Asia. Roh, Jang, and Han (2013) asked 25 participants in their work on a multi – criteria location problem to select the best location for a humanitarian relief warehouse. In this study, 10 experts in the field of logistics were ultimately invited to contribute their perspectives.

3.4 Questionnaire Design

One of the most important determinants in an MCDM problem is the weightings of the criteria; a questionnaire must be designed as a tool to collect data before these weightings are generated. Therefore, the questionnaire utilized the structure as follows:

Definition: Logistics center

This section provided an introductory meaning of logistics center, along with an outline of its activities related to transport and storage.

Section 1: General data of the expert (respondent)

This section contained three questions, comprising gender, occupation type, and experience.

Section 2: Perspectives for each pair of criteria

AHP was first stated as a tool for the computation of each criterion weighting. Ishizaka and Nemery (2013) note that the number of comparisons is calculated by the following formula:

$$(n^2 - n) / 2$$

where n is the number of criteria. Thus, an expert uses his knowledge and experience to compare 45 pairs of criteria, $(10^2 - 10) / 2$, based on their degree of importance. The degrees of importance are ranged from one to nine as follows:

1 = One alternative is equally important to another.
3 = One alternative is moderately more important than another.
5 = One alternative is strongly more important than another.
7 = One alternative is very strong more important than another.
9 = One alternative is extremely more important than another.
2, 4, 6, 8 – intermediately more important.

3.5 The Integrated AHP-TOPSIS Method

With its extensive application, an integrated method between AHP and TOPSIS was proposed. The trend of MCDM methodology use is to combine two or more methods to make up for shortcomings in any particular single method (Velasquez & Hester, 2013). Generally, AHP uses pairwise comparison matrices with ratio scales (one to nine) to determine weightings for each criterion; it can also calculate a consistency ratio, for which reliability is obtained. The AHP procedure is presented as follows (Karim & Karmaker, 2016):

Step 1: Construct the structural hierarchy.

Step 2: Construct the pairwise comparison matrix.

Assuming n attributes, the pairwise comparison of attribute i with attribute j yields a square matrix A_{nxn} where a_{ij} denotes the comparative importance of attribute i with respect to attribute j. In the matrix, $a_{ij} = 1$ when $i = j$ and $a_{ji} = 1/a_{ij}$

$$A_{n\times n} = \begin{array}{c} \text{Attribute} \\ 1 \\ 2 \\ 3 \\ \cdots \\ \cdots \\ n \end{array} \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & \cdots & a_{3n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & r_{n3} & \cdots & \cdots & a_{nn} \end{bmatrix}$$

Step 3: Construct a normalized decision matrix.

$$c_{ij} = a_{ij} \Big/ \sum_{J=1}^{n} a_{ij}$$

$$i = 1,2,3,\ldots\ldots,n,\ j = 1,2,3,\ldots\ldots,n$$

Step 4: Construct the weighted, normalized decision matrix.

$$w_i = \sum_{J=1}^{n} c_{ij} / n, i = 1,2,3,\ldots\ldots,n$$

$$W = \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ w_n \end{bmatrix}$$

Step 5: Calculate an eigenvector and row matrix.

$$E = N^{th} rootvalue / \sum N^{th} rootvalue$$

$$Rowmatrix = \sum_{j=1}^{n} a_{ij} * e_{j1}$$

Step 6: Calculate the maximum eigenvalue, λ_{max}.

$$\lambda_{\max} = Rowmatrix / E$$

Step 7: Calculate the consistency index and consistency ratio.

$$CI = (\lambda_{\max} - n)/(n-1)$$

$$CR = CI / RI$$

where n and RI denote the order of the matrix and randomly generated consistency index respectively

Later, TOPSIS is engaged for ranking from the most to least appropriate alternatives. The fundamental idea of TOPSIS is that the best solution is the one which has the shortest distance to the ideal solution and the furthest distance from the anti-ideal solution (Hwang & Yoon, 1981; Lai, Liu, & Hwang, 1994). The computing process for TOPSIS (Chang, Liao, Tseng, & Liao, 2015) is described in the following steps:

Step 1: Construct the standardized appraisal matrix.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

where i indicates the alternatives, j denotes the selection criteria, and x_{ij} refers to the i alternative under the j criterion to be assessed.

Step 2: Construct the weighted standardized appraisal matrix.

Weights of the selection criteria, $w = (w_1, w_2, \ldots, w_n)$, multiplied by the standardized appraisal matrix, may be expressed as:

$$v = \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ v_{m1} & v_{m2} & \cdots & v_{nm} \end{bmatrix} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \cdots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \cdots & w_n r_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ w_1 r_{m1} & w_2 r_{m2} & \cdots & w_n r_{mn} \end{bmatrix}$$

Step 3: Identify the positive ideal solution and negative ideal solution.

$$A^* = \{v_1^*, v_2^*, \ldots, v_j^*, \ldots, v_n^*\} = \left\{\left(\max_i v_{ij} | j \in J\right) | i = 1, \ldots, m\right\},$$

$$A^- = \{v_1^-, v_2^-, \ldots, v_j^-, \ldots, v_n^-\} = \left\{\left(\min_i v_{ij} | j \in J\right) | i = 1, \ldots, m\right\}.$$

Step 4: Calculate the Euclidean distance between the positive ideal solution (S_i^*) and negative ideal solution (S_i^-) for each alternative.

$$S_i^* = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_i^*\right)^2}, i = 1, \ldots, m,$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_i^-\right)^2}, i = 1, \ldots, m.$$

Step 5: Calculate the relative closeness to the positive ideal solution for each alternative.

$$C_i^* = \frac{S_i^-}{S_i^* + S_i^-}$$

An alternative A_i is closer to A^* and farther from A^- as C_i^* approaches 1.

Step 6: Rank the preference order by C_i^*.

According to C_i^*, larger index values indicate better performance of the respective alternative.

Overall, the procedure of location selection is shown in Figure 3, criteria were first obtained from the literature review. Subsequently, opinions on the criteria were gathered from each expert, with a total of 10. The AHP was then employed to determine the weightings for each criterion. Eventually, TOPSIS was conducted to rank the eight pre-determined provincial logistics centers (the alternatives along the GMS Economic corridors) from most to least attractive.

4. RESULTS AND DISCUSSION

4.1 Weights of Criteria

All judgements on the 45 criteria pairs, based upon the fundamental 1-9 scale, were gathered from 10 experts. According to their opinions, the average weightings of all criteria were determined using the means from the AHP, including their rank, and were tabulated as shown in Table 1. It is obvious that GPP per capita is the most important criteria, followed by highway, SEZ, labor, GPP transport and storage, railway, logistics service provider, land price, accidents during transport, and pollution, respectively.

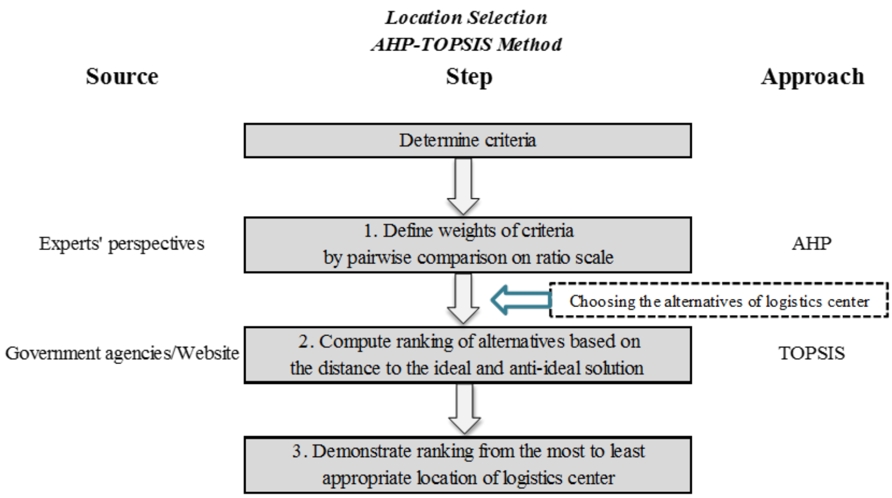

Figure 3: The procedure for location selection

Table 1: Average weighting from all experts for each criterion

Expert	Criterion									
	1	2	3	4	5	6	7	8	9	10
Expert 1	0.150	0.046	0.229	0.039	0.069	0.119	0.099	0.193	0.022	0.034
Expert 2	0.193	0.212	0.143	0.054	0.036	0.093	0.131	0.083	0.022	0.033
Expert 3	0.098	0.094	0.244	0.036	0.054	0.074	0.166	0.183	0.020	0.030
Expert 4	0.126	0.035	0.243	0.111	0.056	0.109	0.195	0.074	0.025	0.027
Expert 5	0.142	0.061	0.098	0.036	0.132	0.199	0.060	0.221	0.026	0.026
Expert 6	0.068	0.052	0.264	0.030	0.113	0.161	0.167	0.095	0.023	0.027
Expert 7	0.225	0.052	0.207	0.051	0.065	0.082	0.164	0.108	0.020	0.027
Expert 8	0.139	0.100	0.077	0.035	0.161	0.228	0.059	0.147	0.021	0.031
Expert 9	0.236	0.212	0.063	0.028	0.083	0.169	0.059	0.105	0.020	0.026
Expert 10	0.188	0.079	0.051	0.076	0.108	0.247	0.046	0.159	0.022	0.023
Average	**0.157**	**0.094**	**0.162**	**0.050**	**0.088**	**0.148**	**0.115**	**0.137**	**0.022**	**0.028**
Rank	**2**	**6**	**1**	**8**	**7**	**3**	**5**	**4**	**10**	**9**

Remark (criteria): 1 is Highway; 2 is Railway; 3 is GPP per capita; 4 is Land price; 5 is Logistics service provider; 6 is SEZ; 7 is GPP transport and storage; 8 is Labor; 9 is Pollution; 10 is Accident during transport.

4.2 Rank of Alternatives

The data of the alternatives for different criteria were collected as shown in Table 2. However, they have different units (e.g. km./km.^{2}, km.^{2}, baht and so on). To solve this problem, the technique of normalization was used for adjusting the different units to use the same

Table 2: Weightings of criteria and values of alternatives

	Criterion									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Weight	0.157	0.094	0.162	0.050	0.088	0.148	0.115	0.137	0.022	0.028
NK	0.12	0.01	84,465	45,000	288	473.67	2,188	218,787	2	56
UT	0.09	0.01	85,359	180,000	678	-	3,150	605,392	7	236
KK	0.09	0.01	112,038	200,000	2,581	-	4,551	925,266	13	221
NR	0.08	0.02	105,618	30,000	784	-	6,135	1,302,017	19	487
SN	0.10	-	64,759	62,000	535	-	1,145	382,333	3	187
NP	0.11	-	73,088	50,000	529	794.79	1,848	297,492	-	71
KS	0.11	-	57,798	33,500	2,942	-	921	391,206	3	129
MH	0.09	-	67,103	24,000	448	578.50	511	190,789	-	87

Remark: 1 – 10 (criteria) are same as Table 1; NK is Nong Khai; UT is Udon Thani; KK is Khon Kaen; NR is Nakhon Ratchasima; SN is Sakon Nakhon; NP is Nakhon Phanom; KS is Kalasin; MH is Mukdahan.

measurement as displayed in Table 3. Afterward, the weighted scores were employed to compare each alternative in relation to each criterion as demonstrated in Table 4. Next, the maximum and minimum values, associated with the objectives of the criteria, were selected as the positive and negative ideals as shown in Table 5.

The distance values to the positive and negative ideal solution for each alternative were then shown in Table 7, ultimately, the values of relative closeness to the ideal solution for each alternative, including the alternatives' rankings, were obtained. The higher the relative closeness to the ideal solution, the better the site. Consequently, Nakhon Ratchasima was determined to be the most attractive location for a logistics center in Northeastern Thailand.

Table 3: Normalized decision matrix

Alternative	Criterion									
	1	2	3	4	5	6	7	8	9	10
NK	0.442	0.507	0.359	0.143	0.069	0.434	0.246	0.119	0.082	0.088
UT	0.326	0.270	0.362	0.571	0.163	0.000	0.355	0.329	0.286	0.369
KK	0.319	0.514	0.476	0.634	0.622	0.000	0.512	0.503	0.530	0.346
NR	0.282	0.637	0.448	0.412	0.189	0.000	0.691	0.707	0.775	0.761
SN	0.348	0.000	0.275	0.197	0.129	0.000	0.129	0.208	0.122	0.292
NP	0.383	0.000	0.310	0.159	0.127	0.728	0.208	0.162	0.000	0.111
KS	0.376	0.000	0.245	0.106	0.709	0.000	0.104	0.212	0.122	0.202
MH	0.330	0.000	0.285	0.076	0.108	0.530	0.058	0.104	0.000	0.136

Remark: All abbreviations are same as Table 2.

Table 4: Weighted normalized decision matrix

Alternative	Criterion									
	1	2	3	4	5	6	7	8	9	10
NK	0.069	0.048	0.058	0.007	0.006	0.064	0.028	0.016	0.002	0.002
UT	0.051	0.025	0.059	0.029	0.014	0.000	0.041	0.045	0.006	0.010
KK	0.050	0.048	0.077	0.032	0.055	0.000	0.059	0.069	0.012	0.010
NR	0.044	0.060	0.073	0.021	0.017	0.000	0.079	0.097	0.017	0.021
SN	0.055	0.000	0.045	0.010	0.011	0.000	0.015	0.028	0.003	0.008
NP	0.060	0.000	0.050	0.008	0.011	0.108	0.024	0.022	0.000	0.003
KS	0.059	0.000	0.040	0.005	0.062	0.000	0.012	0.029	0.003	0.006
MH	0.052	0.000	0.046	0.004	0.009	0.078	0.007	0.014	0.000	0.004

Remark: All abbreviations are same as Table 2.

Table 5: Positive and negative ideal values

	Criterion									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Objective	Max	Max	Max	Min	Max	Max	Max	Max	Min	Min
A^*	0.069	0.060	0.077	0.004	0.062	0.108	0.079	0.097	0.000	0.002
A^-	0.044	0.000	0.040	0.032	0.006	0.000	0.007	0.014	0.017	0.021

Remark: All abbreviations are same as Table 1.

Table 6: Distance values to the positive ($\boldsymbol{S_i^*}$) and negative ($\boldsymbol{S_i^-}$) ideal solution

Alternative	$\boldsymbol{S_i^*}$	$\boldsymbol{S_i^-}$
Nong Khai	0.121	0.095
Udon Thani	0.144	0.059
Khon Kaen	0.120	0.110
Nakhon Ratchasima	0.124	0.131
Sakon Nakhon	0.167	0.036
Nakhon Phanom	0.125	0.116
Kalasin	0.161	0.069
Mukdahan	0.144	0.087

Table 7: Relative closeness to the ideal solution ($\boldsymbol{C_i^*}$)

Alternative	$\boldsymbol{C_i^*}$	Rank
Nong Khai	0.440	4
Udon Thani	0.291	7
Khon Kaen	0.478	3
Nakhon Ratchasima	0.514	1
Sakon Nakhon	0.176	8
Nakhon Phanom	0.482	2
Kalasin	0.301	6
Mukdahan	0.378	5

5. CONCLUSIONS AND RECOMMENDATIONS

In order to promote trade, investment, tourism, and transit corridors with neighboring countries and territories nearby, Thailand should efficiently utilize the GMS Economic Corridors as a project to stimulate the nation's economy. Particularly within the Northeastern region of Thailand two major corridors are held (i.e. NSEC and EWEC). Unfortunately, there is currently no strategic area to manipulate such logistics activity for receiving, consolidation, storage, and distribution of freight. Hence, a combined MCDM utilizing AHP and TOPSIS was proposed and utilized to identify a suitable location for a provincial logistics center.

In accordance with Table 2, which relates to the AHP, the weightings of GPP per capita (the most important criterion), highway, SEZ, and labor, are quite close, ranging from 0.137 to 0.162, while accidents during transport, and pollution, were among the least important values, at 0.028, and 0.022, respectively. Moreover, it is obvious that each province has different noticeable criteria. Nakhon Ratchasima has three criteria of note, including railways, for which this province has the highest density of 0.02 km. per $km.^2$; GPP transport and storage, as more services are produced regarding the transport and storage of goods with an amount of 6,135 million baht; and labor, with this province holding the largest labor force with a total of 1,302,017 available laborers. Nong Khai leads regarding the criterion of highway, with the highest density of 0.12 km. per $km.^2$; and accidents during transport, having the lowest number of only 56 accidents. Meanwhile, Mukdahan exhibits notable values regarding land price which is as low as 24,000 $bath/wa^2$ when comparing the highest land values in each province; this province also receives no complaints regarding pollution. Nakhon Phanom is the outstanding province for SEZ with a maximum trade area of 794.79 km^2 and no pollution complaints. Khon Kaen presents the greatest value of GPP per capita, with the total monetary value of all finished goods and services produced valued at 112,038 baht per person, generating the highest weighting in the region. Lastly, Kalasin has more logistics service providers (2,942) than the other provinces.

TOPSIS was then employed to rank the provinces using the different weightings of each criteria from the most to least attractive on the basis of the positive and negative ideal solution through a procedure of normalization. Thus, Nakhon Ratchasima (the highest $\boldsymbol{C_i^*}$ of 0.514) was found to be the most appropriate province for the location of a logistics center in the Northeastern region situated along the GMS Economic Corridors. According to the Development Plan of Nakhon Ratchasima, in the four years from 2018 to 2021 (Nakhon Ratchasima, 2016), the strong points of Nakhon Ratchasima as a potential site for a logistics center, are its potential to be a regional gateway for logistics, together with its potential for freight distribution, its action at the boundary of agricultural industry and technology, the outstanding capabilities of its industry sector on production and quality, low impacts of flooding problems, and high labor productivity. Overall, this indicates that Nakhon Ratchasima is situated in the geographical center for freight consolidation and distribution due to its location between multiple production and consumption areas.

Also, with the expansion of transport infrastructure e.g. a special highway and double track railway, Nakhon Ratchasima is viewed as a possible site for a dry port to serve logistics operations in the Northeastern provinces and neighboring nations (especially Laos). Leveque and Roso (2002) make clear that a dry port is an inland intermodal terminal directly linked to seaport(s) with means for high capacity transport, where exporters and importers can leave and pick up their containers as if directly to a seaport. In this case, the dry port may be in the midrange, with a distance of 310 kilometers from Laemchabang seaport. According to Roso, Woxenius, and Lumsden (2009), a midrange dry port serves as a consolidation point for different rail services, implying that administration and technical equipment specific for sea transport are only needed in one terminal. The high frequency achieved by consolidating flows together with the relatively short distance, facilitates loading of containers for one container vessel in dedicated trains; a dry port can be considered as a buffer relieving the seaport's stacking areas (Roso et al., 2009). Lately, the governor of Nakhon Ratchasima (Matichon, 2018) stated that "the province is the top choice for establishing the regional dry port due to the ongoing projects of dual track with high-speed railway with a purpose to support rail conveyance, leading to the center of Northeastern zone; recently, 700 out of 2,000 factories have shipped their export goods by truck via highways to Laemchabang and Map Ta Phut Port; in order to reduce logistics costs and road accidents, shifting from road to rail network, including a one-stop customs service, should be taken into account by linking the eastern seaports through a dry port at Nakhon Ratchasima; eventually, this will enable manufacturers to compete in the global market with low cost structure".

Although Nakhon Ratchasima shows the maximum value of $\boldsymbol{C_i^*}$ (0.154) as the most attractive location in this study, $\boldsymbol{C_i^*}$ values of the second (Nakhon Phanom), third (Khon Kaen) and fourth (Nong Khai) rank are rather close, with $\boldsymbol{C_i^*}$ values of 0.482, 0.478, and 0.440, respectively. Thus, these provinces represent effective alternatives if Nakhon Ratchasima is not chosen owing to any particular reason. Obviously, some of their criteria are of meaningful prominence. For example, Nakhon Phanom seems remarkable regarding the criterion of SEZ, corresponding to the SEZ establishment of Thailand's cross-border trade policy. This enables investors to gain tax and non-tax incentives, and the local unemployment rate may be reduced. The maximum GPP per capita (the highest weight of all criteria) belongs to Khon Kaen, resulting in a potential rise of goods demand and purchasing power. Nong Khai presents the ultimate ratio of highway distances per unit area among the eight provinces. This can mitigate the traffic congestion on truck transport, and in particular between territories (Thailand – Laos).

In terms of the limitations in this study, the hybrid AHP-TOPSIS method was only used to select the optimized location for a logistics center in the Northeastern region of Thailand, while other MCDM procedures were not included for consideration. The reason for this is to provide a purposeful comparison to obtain a reliable outcome. Additionally, 10 experts were identified in order to compare the importance of each pair of criteria. If different experts were invited to give their perspectives, the weightings of the criteria could be altered, potentially causing different outcomes. For future study, it is believed that new criteria may be taken into consideration after a dynamic change of economic, transport, labor, social, environmental, and technological matters, so these new factors should be added to be a part of the decision-making process. Besides this, the result of the location selection by the hybrid AHP-TOPSIS method in this research may be compared with other MCDM analyses, such as ELECTRE, PROMETHEE, ANP, VIKOR, MACBETH, or Grey Theory, or with other approaches such as fuzzy. Additionally, a sensitivity analysis could be used to examine alteration of the final results, when the weightings of the criteria are changed.

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