Site Selection of SEZ-based Freight Village: A Case Study of Border Provinces in Thailand

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Abstract

The cross-border trade seems to be one of the solid choices to stimulate Thailand's trade on account of the world economy's turmoil. In response, the Special Economic Zones (SEZs) situated in the selected provinces have been emerging as areas of offering certain incentives to a variety of businesses. With routine movement and storage of goods in SEZ, however, it is crucial to take a Freight Village into account. A Freight Village is typically defined as the hub of a specific area where all activities of goods are related to transport, logistics and distribution. Hence, site selection of Freight Village was examined in this study. Based upon Multi-criteria Decision Making (MCDM) of alternatives, the combined fuzzy AHP-PROMETHEE methodology was proposed. Fuzzy AHP was used to determine weights of five criteria along with 12 sub-criteria, while PROMETHEE was applied to rank eight border provinces from the best to worst site. A result shows that Songkhla is the most appropriate province to locate a Freight Village.

Keywords: Freight Village, Special Economic Zone (SEZ), Fuzzy Set, Fuzzy AHP, PROMETHEE

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การเลือกทำเลที่ตั้งสถานีสินค้าในพื้นที่เขตเศรษฐกิจพิเศษ: กรณีศึกษาจังหวัดชายแดนในประเทศไทย

ไกรสีห์ กำจรฤทธิ์*

บทคัดย่อ

การค้าชายแดนเป็นอีกทางเลือกหนึ่งที่เหมาะสมในการผลักดันการค้าระหว่างประเทศในภาวะที่เศรษฐกิจโลกมีความผันผวน ในการส่งเสริมการค้าชายแดนนั้น รัฐบาลไทยได้จัดตั้งเขตเศรษฐกิจพิเศษในจังหวัดที่ได้กำหนดไว้เพื่อให้สิทธิพิเศษต่างๆ สำหรับสร้างแรงจูงใจแก่ธุรกิจที่จะมาลงทุน เมื่อสินค้ามีการเคลื่อนย้ายและจัดเก็บต่อเนื่องในเขตเศรษฐกิจพิเศษ จำเป็นอย่างยิ่งที่จะต้องมีสถานีสินค้า (Freight Village) เพื่อเป็นศูนย์กลางของกิจกรรมที่เกี่ยวข้องกับการขนส่ง โลจิสติกส์ และการกระจายสินค้า ดังนั้นการเลือกทำเลที่ตั้งสถานีสินค้าจึงถูกนำมาพิจารณาในงานวิจัยนี้ เนื่องจากปัญหาดังกล่าวเกี่ยวข้องโดยตรงกับการตัดสินใจที่อยู่บนพื้นฐานหลากหลายเกณฑ์ จึงได้นำเสนอแนวทางการบูรณาการด้วยวิธี Fuzzy AHP และ PROMETHEE โดยที่ Fuzzy AHP นำมาใช้เพื่อกำหนดค่าน้ำหนักของ 5 เกณฑ์หลัก และ 12 เกณฑ์รอง ขณะที่ PROMETHEE ใช้สำหรับเรียงลำดับตำแหน่งความเหมาะสมของสถานีสินค้าที่ตั้งอยู่ในจังหวัดชายแดน 8 จังหวัดจากมากสุดไปน้อยสุด ผลลัพธ์แสดงให้เห็นว่าจังหวัดสงขลามีความเหมาะสมมากที่สุดที่จะเป็นสถานีสินค้า

คำสำคัญ: สถานีสินค้า, เขตเศรษฐกิจพิเศษ, ทฤษฎี Fuzzy, Fuzzy AHP, PROMETHEE

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1. Introduction

Broadly regarded as the most important factor of the world economy, global trade has apparently become the fundamental part of economic activity everywhere because it creates the intricate network of economic interactions that cover the whole world (Ortiz-Ospina, Beltekian, & Roser, 2018). Over 200 years, global trade has dramatically grown, particularly the exported goods. Ortiz-Ospina et al. (2018) commented, "Up to 1870, the sum of worldwide exports accounted for less than 10% of global output. Today, the value of exported goods around the world is close to 25%. This presents that over the last hundred years of economic growth, there has been more than proportional growth in global trade." With an uncertainty of various factors, nevertheless, the growth rate of global trade related to physical products, has been fluctuated over the last decade as illustrated in Figure 1. Obviously, trade growth in 2018 is weighed down by some factors, including new tariffs and retaliatory measures affecting widely-traded goods, weaker global economic growth, volatility in financial markets and tighter monetary conditions in developed countries; as a result, the consensus estimates have world GDP growth slowing from 2.9% in 2018 to 2.6% in both 2019 and 2020 (WTO, 2019).

Figure 1 World merchandise trade volume and real GDP growth, 2011-2020

Also, this leads to an unsteady trade on Thailand's export. For example, according to Tradingeconomics (2019), exports of Thailand declined 2.15% year-on-year to USD 21.41 billion in June 2019, less than market forecasts of a 5% decrease and following a 5.79% fall in the previous month. That was the fourth straight month of yearly drop in overseas sales, amid weakening global demand and ongoing trade tensions between USA and Beijing. Exports to China slumped 14.9%, while those to the

US fell 2.1%. During January to June period, exports declined 2.91% from a year earlier. Alternatively, cross-border trade may enhance economy of Thailand instead. To implicate in that trade, some benefits are, for instance lower transport cost because of being the regional center, cheap price of raw materials shipped from other neighboring nations, development of transport infrastructures from the agreement of Greater Mekong Subregion (GMS) Economic Corridors and free trade agreement in member countries of Southeast Asia. Later, in response, special economic zones (SEZs) have been eventually instituted in border provinces. SEZ is typically defined as the designated geographical areas within an economy, where business activity is subject to different rules, e.g. tariffs, quotas and duties, from those prevailing in the rest of the economy (OECD, 2017). Its purpose is basically to promote trade, attract investment and decrease an unemployment rate. Particularly, the government will provide the supporting measures with promotions for the development of infrastructure, including tax and non-tax incentives, setting up One Stop Service Center (OSS) and other facilitating measures. As a large of freight volume has been normally moved and stored, a freight village may be established on purpose to manipulate such logistics activity as transporting, warehousing and distributing. however, site selection of freight village in those SEZs has never been existed.

Thus, the objective of this study is to examine the best border province, holding SEZ, for establishment of freight village in Thailand. With regard to the conceptual framework, the integrated MCDM methodology is constructed as illustrated in Figure 2. By diminishing the fuzziness and vagueness of experts' opinions, fuzzy AHP (Analytic Hierarchy Process) is utilized to solve those obstacles and to create weights of criteria/sub-criteria. Next, alternatives with those weights are put into the procedure of PROMETHEE (Preference Ranking Organization Method for Enrichment of Evaluations). Finally, the rank of those alternatives is in sight. As a consequence, the first rank is the top choice of freight village site.

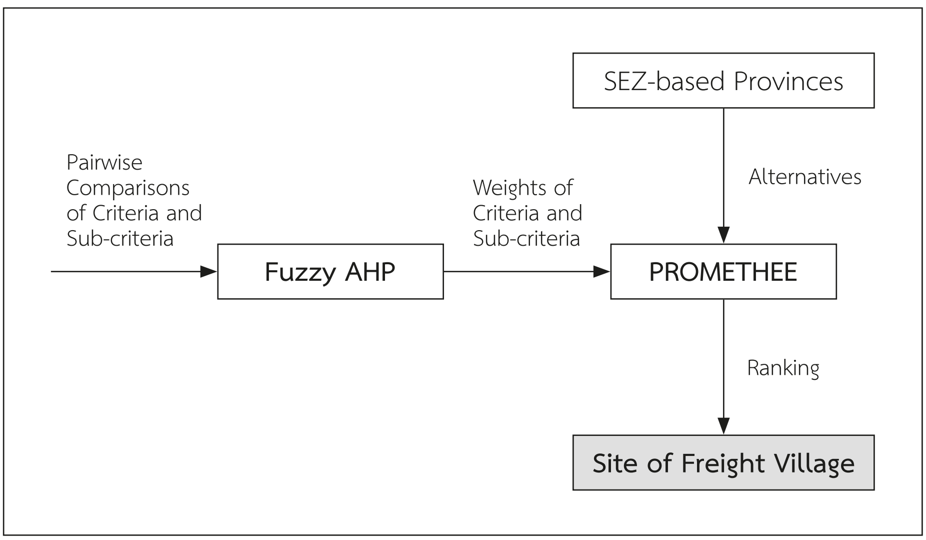

Figure 2 The conceptual framework of fuzzy AHP-PROMETHEE method

2. Literature Review

2.1 Freight Village

Commonly, the management of logistics and supply chain contribute value creation by means of place utility. At that place, a product can be added several values, for example moving, packing, final assembly, storing and so forth. By responding, a freight village is one of the crucial formats to fulfill those value-added activities. A freight village is an area of land that is devoted to a number of transport and logistics facilities, activities and services, which are not just co-located but also coordinated to encourage maximum synergy and efficiency (UNESCAP, 2009). In other words, freight villages are described as geographical groupings of independent companies which deal with freight transport and related accompanying service (Regmi & Hanaoka, 2013). In the same way, a freight village is defined as the hub of a specific area where all activities relating to transport, logistics and goods distribution – both for national and international transit – are carried out on a commercial basis by various operators (Ballis & Mavrotas, 2007). In general, those operators can be either owners or tenants of buildings and facilities (e.g. warehouses, break-bulk centers, storage areas, offices, car parks and others) which have been built that freight village (Baydar, Süral, & Çelik, 2017).

After all, a freight village is recognized as the logistical interconnection point within the logistics network that primarily function as an interface between local and long-distance goods transport (Winkler & Seebacher, 2011). This means that a freight village includes an intermodal terminal which facilitates an integration between different transport modes (e.g. road and railway) thus offering the choice and selection of the best possible cost and time effective transport chain for the shippers (Wagener, 2017). Otherwise, both shippers and customers are highly interested in freight villages, where they are offered those intermodal transport services, providing opportunities for cost reduction for their transport activities (Özceylan, Erbaş, Tolon, Kabak, & Durğut, 2016).

2.2 Multi-criteria Decision Making (MCDM) Method

People frequently face making decisions both in their professional and private lives (Ishizaka & Nemery, 2013). To cope with them, many MCDM methods have been created and emerged as the essential tools to assist decision makers in making their judgement. According to Sun (2010), those MCDM ones have rapidly developed and become the main disciplines of research to deal with complex decision problems. Basically, a MCDM method is defined as the evaluation of alternatives for the purpose of selection or ranking, using a number of qualitative and/or quantitative criteria that have different measurement units (Özcan, Çelebi, & Esnaf, 2011). Or else, it refers to finding the best opinion from all of the feasible alternatives in the presence of multiple, usually conflicting, decision criteria (Torfi, Farahani, & Rezapour, 2010). Overall, a MCDM method typically involves the multi-stage process, which is composed of defining objectives, choosing the criteria to measure the objectives, specifying alternatives, assigning weights to the criteria and finally applying the appropriate mathematical algorithm for ranking alternatives (Mosadeghi, Warnken, Tomlinson, & Mirfenderesk, 2015). With multiple MCDM methods, nevertheless, the integrated MCDM ones with respect to fuzzy AHP and/or PROMETHEE were reviewed in this study.

For example, Sun (2010) developed the evaluation model based on fuzzy AHP and fuzzy TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) to assist the industrial practitioners for performance evaluation in fuzzy environment where the vagueness and subjectivity were handled with the linguistic values parameterized by the triangular fuzzy numbers. Kaya and Kahraman (2011) manipulated the combined fuzzy MCDM model in the context of urban industrial planning. Weights of criteria were constructed by a procedure of fuzzy AHP, while fuzzy ELECTRE (ELimination Et Choix Traduisant la REalité or elimination and choice expressing reality) was applied to evaluate the environmental impact generated by six industrial districts, usefully predicting to shape an industrial structure of Istanbul metropolitan district in the future. Büyüközkan and Çifçi (2012) employed the hybrid model of fuzzy AHP and fuzzy TOPSIS to evaluate applicability of the electronic service quality framework in order to explain the complexity of aspects observed in the implementation of healthcare services over the internet. In accordance with conflicting factors dealt with the appropriate substation location selection problem in relation to the uncertain and imprecise information, therefore, Kabir and Sumi (2014) integrated MCDM approaches of fuzzy AHP and PROMETHEE to decide and choose the optimized power substation location. In order to evaluate the performance of cement companies through financial ratios, Rezaie, Ramiyani, Nazari-Shirkouhi, and Badizadeh (2014) utilized fuzzy AHP to identify weights of criteria by taking the subjective judgments of decision makers and then used VIKOR (Vlse Kriterijumska Optimizacija Kompromisno Resenje) to rank the firms. On the basis of construction projects selection and risk assessment, Taylan, Bafail, Abdulaal, and Kabli (2014) selected fuzzy AHP to construct weights for fuzzy linguistic variable of the construction projects overall risk and fuzzy TOPSIS for solving group decision making problems under the fuzzy environment. Vinodh, Prasanna, and Hari Prakash (2014) initiated an evaluation model related to the merger between fuzzy AHP and fuzzy TOPSIS to enable industry practitioners to perform performance evaluation. The purpose of it was to determine the best method for recycling plastics among various plastic recycling processes. Esfahanipour and Davari-Ardakani (2015) conducted method of fuzzy AHP to determine the relative importance of evaluation criteria, taking the vagueness and imprecision of human judgments into consideration, whereas PROMETHEE was employed to rank companies. Also, TOPSIS was undertaken to assess the validity of obtained ranking outcomes. With respect to the telecommunication business in India, the study of Kumar, Shankar, and Debnath (2015) presented the combined fuzzy AHP-DEA (Data Envelopment Analysis) approach. Fuzzy AHP was utilized to determine weights of the consumer’s preference as criteria, while DEA was carried out to identify the inefficient service providers in terms of efficiency. Based upon the pharmaceutical supply chain in relation to outsourcing risks, Mokrini, Kafa, Dafaoui, Mhamedi, and Berrado (2016) proposed a combined method for the risk assessment in order to measure level of risks associated with the outsourcing logistics. Thus, fuzzy AHP and PROMETHEE were integrated to evaluate risks and assign them to the predefined categories. With reference to the selection of 3D printers, ÇEtİNkaya, Kabak, and ÖZceylan (2017) conducted fuzzy AHP and PROMETHEE to prioritize criteria and rank those printers, respectively. Awasthi, Govindan, and Gold (2018) proposed the hybrid fuzzy AHP-VIKOR method-based framework for sustainable global supplier selection, taking sustainability risks from the sub-suppliers into consideration. Fuzzy AHP was designed to construct criteria weights for sustainable global supplier selection, while fuzzy VIKOR was used to rate supplier performances against the evaluation criteria. In the research of Ghobadi and Ahmadipari (2018), they combined methods of fuzzy AHP and PROMETHEE in the geographical information system environment to carry out the spatial site selection for the wind power plants in Lorestan Province of Iran. Regarding tourism industry, Butowski (2018) created the evaluation structure conducted for the assessment of European coastal and offshore areas for a sailing tourism. That structure was then performed by MCDM methods of AHP and PROMETHEE for determining the weights of criteria and evaluating the attractiveness of different destinations, respectively. With an increase of e-commerce systems on internet, accordingly, Ostovare and Shahraki (2019) examined the status of websites and e-services provided by five-star hotels. Criteria were carried out by fuzzy Delphi, and weights of them were obtained by Shannon entropy method, while PROMETHEE was manipulated to rank those websites. Ahmed, Tan, Solangi, and Ali (2020) used the integrated approach of Delphi, AHP and fuzzy VIKOR to select SEZ in Pakistan in relation to criteria of location, linkages, labor force, facilities, incentives, environmental sustainability and market orientation, respectively.

3. Materials and Methods

3.1 Determination of Criteria and Alternatives

Distinctly served as one of the most important factors in the procedure of MCDM methodology, a criterion is initially taken into consideration to determine the weight. In this study, criteria and sub-criteria were derived from National Economic and Social Development Board (2019), Yildirim and Önder (2014) and Özceylan et al. (2016). Transport infrastructure (i.e. highway, railway, airport and seaport) was the first criterion. Highway is the major transport of Thailand with proportion of 81.10% of all modes in relation to domestic carriage (National Economic and Social Development Board, 2017). Railway has been recently promoted as the modal shift, which its cost roughly stands at 0.95 baht per ton-kilometer, lower than that of highway at 2.12 (Transport and Traffic Policy and Planning, 2009). Airport and seaport are viewed as considerable gateways to link other territories. With the reduction of lead time, air transport is picked on account of a quick delivery of goods, while a ship can carry tons of freight. The next one was related to investment attractiveness. This persuades capitalists to invest in the particular area of trade promotion. In this case, it consists of rental cost, labor, border trade and site expansion. The rental cost is considered as one of the most concerned factors of investors with regard to the direct burden. The availability of labor is involved in a capacity of organization, so a number of laborers are chosen as a criterion. According to the free trade agreement of ASEAN nations, this encourages investors to move their production bases to SEZ. Therefore, a freight village can assist them to support activities of logistics, e.g. transport, inventory and warehousing. The site expansion of SEZ is also included due to an increase of freight volume in the future. Health was selected as the third criterion, particularly a number of hospitals to serve patients. The fourth one was utility, where electricity and water supply are utilized as energy and consuming source, respectively. Eventually, an environment was the last one. A complaint of pollution is acknowledged as the indicator of environmental friendliness in that area.

According to the 20 years national strategy between 2018 and 2037 in strategy II and the 12th national economic and social development plan from 2017 to 2021 in strategy IV (National Economic and Social Development Board, 2019), SEZ has clearly been emerged as an economic development tool which contributes prosperity to the region, improves income and quality of life, and solves the security problem. As a result, the government commenced an establishment of SEZs in 10 provinces. However, eight of them were chosen as alternatives of the potential freight village. The reason was that the rental cost has not been approved for two of them, yet. To sum up, the MCDM hierarchical structure, encompassing four levels of goal, criteria, sub-criteria and alternatives, can be depicted in Figure 3.

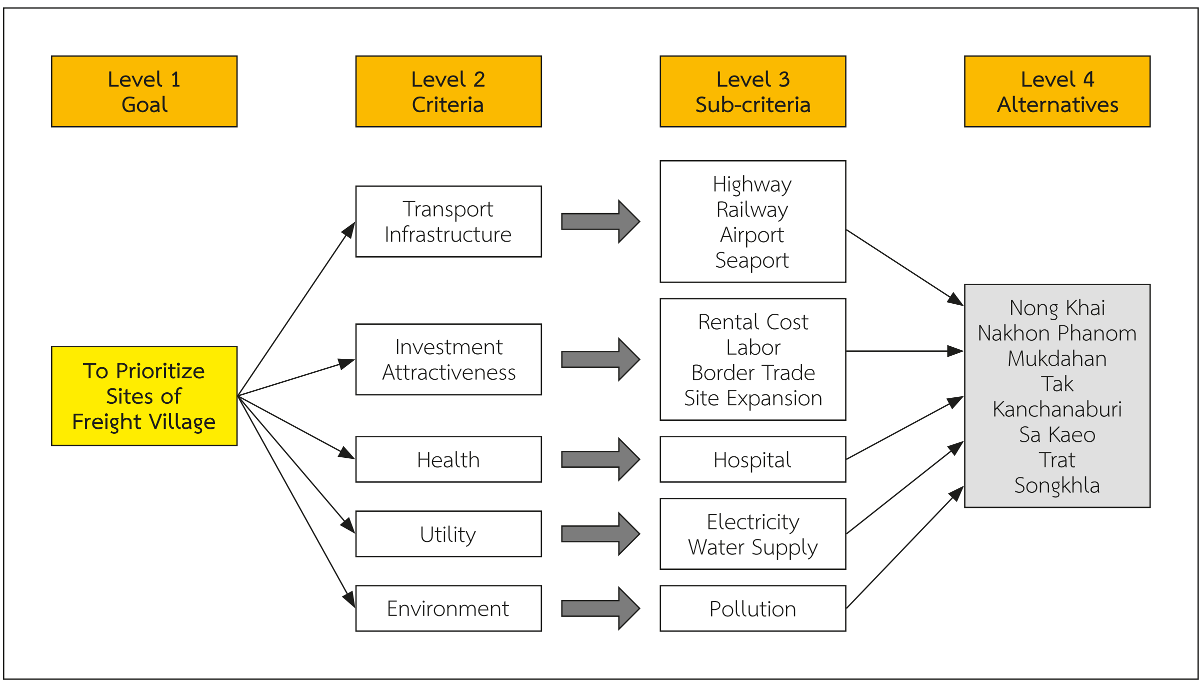

Figure 3 The MCDM hierarchical structure of freight village site

3.2 Fuzzy Set Theory

Fuzzy set theory has been used for the modeling decision-making process based on imprecise and vague information, particularly judgment of decision makers (Lima Junior, Osiro, & Carpinetti, 2014; Zadeh, 1965). Based on Büyüközkan and Çifçi (2012), a fuzzy set is defined by a membership function that maps elements to degrees of membership within a certain interval, which is usually [0, 1]. In general, qualitative aspects are represented by means of linguistic variables, which are expressed qualitatively by linguistic terms and quantitatively by a fuzzy set in the universe of discourse and respective membership function (Zadeh, 1973). The concepts of it, including its operations are described as follows (Kumar et al., 2015; Lima Junior et al., 2014; Zadeh, 1965; Zimmermann, 1991):

1) Definition of fuzzy set

A fuzzy set Ã in X is defined by: $\tilde{A} = \{x, u_A(x), x \in X$ (1)

in which $u_A(x)$: $X \longrightarrow [0, 1]$ is the membership function of Ã and $u_A(x)$ is the degree of pertinence of x in Ã. If $u_A(x)$ is equal to zero, x does not belong to the fuzzy set Ã. If $u_A(x)$ is equal to 1, x completely belongs to the fuzzy set Ã.

2) Definition of fuzzy numbers

A fuzzy number (represented by x) is a fuzzy set in which the membership function satisfies the conditions of normality; in other words, sup $\tilde{A}(X)_{x \in X}$ is determined in the way that $\tilde{A}(X)_{x \in X}$ has to be a normalized fuzzy set, so

$$\sup \tilde{A}(X)_{x \in X} = 1 \quad (2)$$

and of convexity, comprising $\tilde{D}$: fuzzy decision matrix, C_m: criteria, A_n: alternatives,

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_i \\ A_n \end{array} \begin{array}{c} \begin{matrix} C_1 & C_2 & C_j & C_m \end{matrix} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \tilde{x}_{1j} & \tilde{x}_{1m} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \tilde{x}_{nj} & \tilde{x}_{nm} \end{bmatrix} \end{array} \quad (3)$$

for all fuzzy numbers or $x_1, x_2 \in X$ and all fuzzy Eigen values or $\lambda \in [0, 1]$. The triangular fuzzy number (TFN) is generally used in decision making because of its intuitive membership function, weights of criteria or $\tilde{W} = [\tilde{w}_1 + \tilde{w}_2 + \ldots + \tilde{w}_m]$, given by

$$\mu_A(x) = \begin{cases} 0 & \text{for } x < l, \\ \dfrac{x-l}{m-l} & \text{for } l \le x \le m, \\ \dfrac{u-x}{u-m} & \text{for } m \le x \le u, \\ 0 & \text{for } x > u, \end{cases} \quad (4)$$

in which l, m and u are real numbers with $l < m < u$. Outside the interval [l, u], the pertinence degree is null, and m represents the point in which the pertinence degree is maximum.

3) Algebraic operations with fuzzy numbers

Given any real number K and two TFNs $\tilde{A} = (l_1, m_1, u_1)$ and $\tilde{B} = (l_2, m_2, u_2)$, the main algebraic operations are expressed as follows:

Addition of two TFNs

$$\tilde{A} \oplus \tilde{B} = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \qquad l_1 \geq 0, l_2 \geq 0 \tag{5}$$

Multiplication of two TFNs

$$\tilde{A} \otimes \tilde{B} = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2) \qquad l_1 \geq 0, l_2 \geq 0 \tag{6}$$

Subtraction of two TFNs

$$\tilde{A} \ominus \tilde{B} = (l_1 - l_2, m_1 - m_2, u_1 - u_2) \qquad l_1 \geq 0, l_2 \geq 0 \tag{7}$$

Division of two TFNs

$$\tilde{A} \oslash \tilde{B} = (l_1 \div l_2, m_1 \div m_2, u_1 \div u_2) \qquad l_1 \geq 0, l_2 \geq 0 \tag{8}$$

Inverse of a TFN

$$\tilde{A}^{-1} = (1 \div u_1, 1 \div m_1, 1 \div l_1) \qquad \geq 0 \tag{9}$$

Multiplication of a TFN by a constant

$$k \times \tilde{A} = (k \times l_1, k \times m_1, k \times u_1) \qquad l_1 \geq 0, k \geq 0 \tag{10}$$

Division of a TFN by a constant

$$\tilde{A} \div k = (l_1 \div k, m_1 \div k, u_1 \div k) \qquad l_1 \geq 0, k \geq 0 \tag{11}$$

3.3 Fuzzy AHP

Fuzzy AHP approach is applied in an uncertain environment to construct weights of criteria with the following steps (Patil & Kant, 2014).

Step 1: Define scale of relative importance used in the pairwise comparison matrix.

In this step, the TFNs, $\tilde{1}$ to $\tilde{9}$, are applied to improve the conventional nine-point scaling scheme. In order to take the imprecision of human qualitative assessments into consideration, the five TFNs (i.e. $\tilde{1}$, $\tilde{3}$, $\tilde{5}$, $\tilde{7}$, $\tilde{9}$) are defined with the corresponding membership function as depicted in Figure 4. Also, the fuzzy membership function, represented by scales, for linguistic values for criteria is tabulated in Table 1.

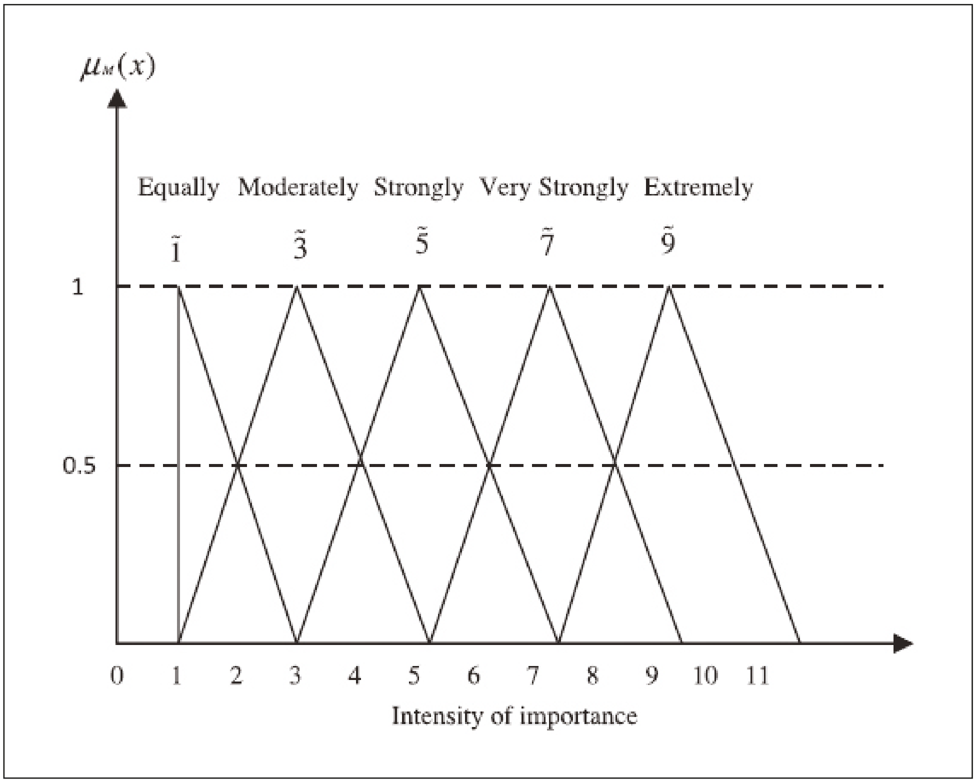

Figure 4 Fuzzy membership function of TFNs (Nepal, Yadav, & Murat, 2010)

Table 1 Scales of relative importance (Sirisawat & Kiatcharoenpol, 2018)

Fuzzy Number	Linguistic Variable	Triangular Fuzzy Numbers
$\tilde{1}$	Equal Importance	(1,1,1)
$\tilde{2}$	Equal to Moderate Importance	(1,2,3)
$\tilde{3}$	Moderate Importance	(2,3,4)
$\tilde{4}$	Moderate to Strong Importance	(3,4,5)
$\tilde{5}$	Strong Importance	(4,5,6)
$\tilde{6}$	Strong to Very Strong Importance	(5,6,7)
$\tilde{7}$	Very Strong Importance	(6,7,8)
$\tilde{8}$	Very Strong to Extreme Importance	(7,8,9)
$\tilde{9}$	Extreme Importance	(8,9,10)

Step 2: Construct the fuzzy comparison matrix.

Based on TFN, a decision maker decides on pairwise comparisons for the criteria. Then, a fuzzy comparison matrix Ã is constructed by arithmetic mean of pairwise comparisons.

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & .. & .. & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & .. & .. & \tilde{a}_{2n} \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ \tilde{a}_{n1} & \tilde{a}_{n2} & .. & .. & 1 \end{bmatrix} \tag{12}$$

While $\tilde{a}_{ij} = 1$, i is equal to j and $\tilde{a}_{ij} = (\tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9})$ or $\tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1}$ if i is not equal to j. When scoring is conducted for a pair, a reciprocal value is automatically assigned to the reverse comparison within the matrix. That is, if $\tilde{A}_{ij}$ is a matrix value assigned to the relationship of component i to component j, then $\tilde{A}_{ij}$ will be equal to $1/\tilde{A}_{ij}$.

Step 3: Convert the fuzzy comparison matrix into a crisp comparison matrix.

The α-cut is determined to incorporate a decision maker's confidence over his/her decision (Adamo, 1980). It will yield an interval set of values from a fuzzy number.

While α is fixed, the following α-cut comparison matrix can be obtained from a fuzzy comparison matrix, after setting the index of optimism, u, in order to estimate the degree of satisfaction

$$\tilde{A}^{\alpha} = \begin{bmatrix} 1 & \tilde{a}_{12}^{\alpha} & .. & .. & \tilde{a}_{1n}^{\alpha} \\ \tilde{a}_{21}^{\alpha} & 1 & .. & .. & \tilde{a}_{2n}^{\alpha} \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ \tilde{a}_{n1}^{\alpha} & \tilde{a}_{n2}^{\alpha} & .. & .. & 1 \end{bmatrix} \tag{13}$$

Degree of satisfaction for the judgment matrix is estimated by the index of optimism u determined by a decision maker. The larger value of index u indicates the highest degree of optimism. The index of optimism is a linear convex combination as defined in the following equation (Lee, Pham, & Zhang, 1999).

$$\tilde{a}_{ij}^{\alpha} = u\tilde{a}_{iju}^{\alpha} + (1 - u)\,\tilde{a}_{iju}^{\alpha} \qquad \text{where } 0 < u \leq 1 \tag{14}$$

The α-cut fuzzy comparison matrix converted into their crisp comparison matrix A by plugging the value of u in equation (14).

$$A = \begin{bmatrix} 1 & a_{12} & .. & .. & a_{1n} \\ a_{21} & 1 & .. & .. & a_{2n} \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ a_{n1} & a_{n2} & .. & .. & 1 \end{bmatrix} \tag{15}$$

Step 4: Check consistency

The consistency ratio (CR) for each of the matrix and overall inconsistency for the hierarchy are calculated in order to control the consequences of this method. When the crisp comparison matrix A is consistent, it means the fuzzy comparison matrix Ã is also consistent. The consistency can be checked as follows:

(I) Calculate the largest Eigen value (λ_{max}) of the matrix by using equation (16).

$$Aw = \lambda_{max} w \quad (16)$$

where w is principal Eigen vector of the matrix.

(II) The Consistency Ratio (CR) is used to estimate directly the consistency of pairwise comparisons. The CR is computed by using equation (17).

$$CR = CI \div RI \quad (17)$$

$$CI = (\lambda_{max} - n) \div (n - 1) \quad (18)$$

where CI is consistency index. RI is random index, which is displayed in Table 2, and n is matrix size.

Table 2 The random consistency index (RI)

Size (n)	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40

As a rule, only if the CR ≤ 0.10, the consistency of the matrix is viewed as acceptable, otherwise a decision maker is required to revise the original values in the pairwise comparison matrix.

Step 5: Calculate the weights of criteria

The weight of each criterion will be calculated by normalizing any of the rows or columns of matrix A.

3.4 PROMETHEE

PROMETHEE belongs to the family of outranking methods, which means that it is based on the pairwise comparisons of the alternatives (Ishizaka & Nemery, 2013). In accordance with Kabir and Sumi (2014), the deviation between the evaluations of two alternatives on a criterion is considered. For larger deviations, a decision maker allocates a larger preference to the best alternative or possibly no preference if the deviation is negligible. Thus, the larger the deviation the larger the preference will be. The details and computation of PROMETHEE I & II are briefly summarized as follows (Brans & Mareschal, 2005; Ishizaka, Nemery, & Lidouh, 2013):

1) Information within a criterion

For each criterion c_i, and for each ordered pair of alternatives, a decision maker shows his/her preference by means of a preference degree. The preference degree $P_i(a, b)$ indicates if an alternative a is preferred or not to b on the criterion c_i based on the difference between their evaluation $d_i(a, b)$. This preference degree is obtained using the preference function which may require different parameters such as the indifference threshold q_i and the preference threshold p_i. If the difference $d_i(a, b)$ between the score of alternative a and b on criterion c_i is higher than p_i, the alternative a is preferred over b. If $d_i(a, b) < q_i$, then alternative a and b are indifferent. The functions are exhibited as follows:

$P_i(a, b) = 0$ if $d_i(a, b) < q_i$ (alternative a is indifferent to b)
$P_i(a, b) = 1$ if $d_i(a, b) > q_i$ (alternative a is preferred to b)

Eventually, six types of preference function (i.e. Usual, U-shaped, V-shaped, level, V-shaped with indifference and Gaussian criterion) are involved.

2) Aggregated preference functions

In order to evaluate how much the alternative a is preferred to b over all criteria, the preference index $\pi(a, b)$ is calculated with a weighted sum of the preference degrees $P_i(a, b)$. The weights w_i represent the importance of each criterion in the decision:

$$\pi(a, b) = \sum_{i=1}^{n} P_i(a, b)\, w_i \qquad (19)$$

where, $P_i(a, b)$: preference degree on criterion i
w_i : weight of criterion i
n : the number of criteria

If $\pi(a, b) \approx 0$, this means a weak global preference or indifference of a over b; $\pi(a, b) \approx 1$, this means a strong global preference of a over b.

3) Outranking flows

As each alternative is compared with m - 1 other alternatives, two flows can be defined as follows:

$$\text{Positive flows: } \phi^{+}(a, b) = [1 \div (m - 1)] \sum_{x \in A} \pi(a, x) \qquad (20)$$

where, m : the number of alternatives
A : the set of the m alternatives

This score represents the global preference of alternative a in comparison to all the other alternatives. Indeed, this score has to be maximized.

Negative flows: $\phi^{-}(a, b) = [1 \div (m - 1)] \sum_{x \in A} \pi(a, x)$ (21)

where, m : the number of alternatives

A : the set of the m alternatives

This score represents the global weakness of alternative a in comparison to all the other alternatives. Indeed, this score has to be minimized.

4) Ranking

According to the positive and negative flows, PROMETHEE I partial ranking is defined as follows:

- a is preferred to b if $\phi^{+}(a) \geq \phi^{+}(b)$ and $\phi^{-}(a) < \phi^{-}(b)$, or $\phi^{+}(a) > \phi^{+}(b)$ and $\phi^{-}(a) \leq \phi^{-}(b)$
- a is indifferent to b if $\phi^{+}(a) = \phi^{+}(b)$ and $\phi^{-}(a) = \phi^{-}(b)$
- a is incomparable b, otherwise

However, those two flows are usually combined to obtain the net flows defined as follows:

$$\phi(a) = \phi^{+}(a) - \phi^{-}(a) \quad (22)$$

which leads to the complete ranking of PROMETHEE II. The higher the net flows, the better the rank of an alternative.

4. Numerical Illustration

4.1 Application of Fuzzy AHP

Primarily, eight experts in fields of logistics and supply chain were invited for making a decision on pairwise comparisons of 23 pairs associated with linguistic variables. Later, their opinions were expressed by fuzzy numbers (ranging from $\tilde{1}$ to $\tilde{9}$) and transformed as three numbers within parentheses of TFNs. After computation through the web-based fuzzy AHP (namely http://www.onlineoutput.com/fuzzy-ahp-software/), as a result, the average weights and ranks, with the average fuzzy numbers of criteria and sub-criteria are shown by matrices in Table 3-6. Also, the consistency ratios of them in those Tables were 0.077, 0.029, 0.080 and 0.000, respectively; thus, they were acceptable on account of being lower than 0.100. In addition, it is remarked that the abbreviation of criteria and sub-criteria is as follows – C1: transport infrastructure; C2: investment attractiveness; C3: Health; C4: utility; C5: environment (equivalent to C51: pollution); C11: highway; C12: railway; C13: airport; C14: seaport; C21: rental cost; C22: labor; C23: border trade; C24: site expansion; C41: electricity and C42: water supply, respectively.

Table 3 Average weights of criteria

Criterion	C1	C2	C3	C4	C5	Weight	Rank
C1	(1.000,1.000,1.000)	(0.125,0.219,0.500)	(5.000,6.864,8.000)	(5.000,6.479,8.000)	(3.000,5.448,7.000)	0.376	2
C2	(2.000,4.566,8.000)	(1.000,1.000,1.000)	(5.000,7.201,9.000)	(4.000,6.190,8.000)	(3.000,5.661,8.000)	0.436	1
C3	(0.125,0.146,0.200)	(0.111,0.139,0.200)	(1.000,1.000,1.000)	(0.200,0.586,3.000)	(0.333,0.841,3.000)	0.035	5
C4	(0.125,0.154,0.200)	(0.125,0.162,0.250)	(0.333,1.706,5.000)	(1.000,1.000,1.000)	(0.333,1.489,4.000)	0.110	3
C5	(0.143,0.184,0.333)	(0.125,0.177,0.333)	(0.333,1.189,3.003)	(0.250,0.672,3.003)	(1.000,1.000,1.000)	0.043	4

Table 4 Average weights of sub-criteria in relation to transport infrastructure

Criterion	C11	C12	C13	C14	Weight	Rank
C11	(1.000,1.000,1.000)	(1.000,3.105,6.000)	(1.000,3.776,7.000)	(1.000,3.776,7.000)	0.343	1
C12	(0.167,0.322,1.000)	(1.000,1.000,1.000)	(1.000,2.577,4.000)	(1.000,2.417,5.000)	0.277	2
C13	(0.143,0.265,1.000)	(0.250,0.388,1.000)	(1.000,1.000,1.000)	(0.333,0.841,3.000)	0.188	4
C14	(0.143,0.265,1.000)	(0.200,0.414,1.000)	(0.333,1.189,3.003)	(1.000,1.000,1.000)	0.192	3

Table 5 Average weights of sub-criteria in relation to investment attractiveness

Criterion	C21	C22	C23	C24	Weight	Rank
C21	(1.000,1.000,1.000)	(0.250,0.697,3.000)	(0.143,0.218,0.333)	(2.000,3.905,6.000)	0.271	3
C22	(0.333,1.435,4.000)	(1.000,1.000,1.000)	(0.200,0.310,0.500)	(1.000,3.337,6.000)	0.288	2
C23	(3.003,4.587,6.993)	(2.000,3.226,5.000)	(1.000,1.000,1.000)	(2.000,4.517,7.000)	0.425	1
C24	(0.167,0.256,0.500)	(0.167,0.300,1.000)	(0.143,0.221,0.500)	(1.000,1.000,1.000)	0.015	4

Table 6 Average weights of sub-criteria in relation to utility

Criterion	C41	C42	Weight	Rank
C41	(1.000,1.000,1.000)	(0.333,1.148,4.000)	0.512	1
C42	(0.250,0.871,3.003)	(1.000,1.000,1.000)	0.488	2

In summary, all sub-criteria with their weights (%) are finally ranked as demonstrated in Table 7. Clearly, the highest and lowest weight of sub-criteria are border trade and site expansion, respectively.

Table 7 Rank and weights of sub-criteria

Rank	Sub-criterion	Weight
2	Highway (C11)	12.90
5	Railway (C12)	10.40
7	Airport (C13)	7.10
6	Seaport (C14)	7.20
4	Rental Cost (C21)	11.80
3	Labor (C22)	12.60
1	Border Trade (C23)	18.50
12	Site Expansion (C24)	0.70
11	Hospital (31)	3.50
8	Electricity (C41)	5.60
9	Water Supply (C42)	5.40
10	Pollution (C51)	4.30

4.2 Application of PROMETHEE

After weights of 12 sub-criteria had been generated as appeared in Table 7, all data were prepared to compute the most appropriate site of freight village via PROMETHEE. The following preference parameters are firstly defined as exhibited in Table 8. First, min/max are the abbreviation of minimum/maximum value for the preference of sub-criterion. Second, weight in percentage is a measure how much it is important with regard to others. Third, the usual preference function (U) is utilized due to the aim of optimization, where the larger the value the better, or the smaller the better.

Table 8 The preference parameters

Sub-criterion	C11	C12	C13	C14	C21	C22	C23	C24	C31	C41	C42	C51
Min/Max	Max	Max	Max	Max	Min	Max	Max	Max	Max	Max	Max	Min
Weight	12.9	10.4	7.1	7.2	11.8	12.6	18.5	0.7	3.5	5.6	5.4	4.3
Preference function	U	U	U	U	U	U	U	U	U	U	U	U

Next, input data of eight alternatives along with 12 sub-criteria in different units (shown in Table 9) were collected from many sources as presented in Table 10. Also, it is noted that A1: Nong Khai; A2: Nakhon Phanom; A3: Mukdahan; A4: Tak; A5: Kanchanaburi; A6: Sa Kaeo; A7: Trat and A8: Songkhla.

Table 9 Criteria/Sub-criteria of freight village site with measurements

Criterion	Sub-criterion	Measurement (unit)	Source (year)
Transport Infrastructure	Highway	Distance per area (km./km.^{2})	Department of highway (2019)
	Railway	Distance per area (km./km.^{2})	Google map (2019)
	Airport	Weight of freight (ton)	Airports of thailand (2019)
	Seaport	Weight of freight (million tons)	Marine department (2017)
Investment Attractiveness	Rental Cost	Value (baht/rai)	NESDB (2018)
	Labor	A number of labors (no.)	National statistical office (2018)
	Border Trade	Value (million baht)	Department of foreign trade (2018)
	Site Expansion	5-point (point)	NESDB (2018)
Health	Hospital	A number of hospitals (no.)	National statistical office (2017)
Utility	Electricity	Usage (kilowatt-hr.)	National statistical office (2017)
	Water Supply	Usage (million m.^{3})	National statistical office (2017)
Environment	Pollution	A number of complaints (no.)	Pollution control department (2018)

Remark: NESDB stands for Office of the National Economic and Social Development Board.

Table 10 The input data for alternatives in each criterion

Alternative	Sub-criterion											
	C11	C12	C13	C14	C21	C22	C23	C24	C31	C41	C42	C51
A1	0.1248	0.0136	0	0.00	35,000	212,528	62,306.31	2	12	429,836,658	10.5	2
A2	0.1080	0.0000	0	0.00	140,000	290,987	85,218.32	3	14	417,871,842	10.3	2
A3	0.0931	0.0000	0	0.00	30,000	197,277	151,353.77	2	8	288,702,216	7.7	0
A4	0.0648	0.0000	0	0.00	250,000	254,423	77,961.70	5	12	606,941,316	16.0	3
A5	0.0644	0.0060	0	0.00	20,000	466,937	75,824.56	1	20	1,728,657,288	16.5	13
A6	0.1039	0.0101	0	0.00	225,000	310,569	91,814.65	2	11	768,079,468	9.7	2
A7	0.1511	0.0000	0	0.44	160,000	173,897	36,655.97	1	8	554,778,840	7.5	1
A8	0.0978	0.0200	8,440	11.80	300,000	884,176	649,726.64	2	29	3,437,547,347	63.6	17

Then, the above-mentioned data obtained from Table 8 and 10 were carried out by the procedure of PROMETHEE through software of Visual PROMETHEE. In terms of descriptive statistics, the maximum, minimum, average and S.D. (Standard Deviation), values of alternatives in each sub-criterion are demonstrated in Table 11.

Table 11 Descriptive statistics for alternatives in each sub-criterion

Sub-criterion	C11	C12	C13	C14	C21	C22	C23	C24	C31	C41	C42	C51
Minimum	0.0644	0.0000	0	0.00	20,000	173,897	36,655.97	1	8	288,702,216	7.50	0
Maximum	0.1511	0.0200	8,440	11.80	300,000	884,176	649,726.64	5	29	3,437,547,347	63.60	17
Average	0.1010	0.0062	1,055	1.48	145,000	348,849	153,857.74	2	14	1,029,051,872	17.73	5
S.D.	0.0271	0.0072	2,791	3.90	101,643	219,777	189,875.04	1	7	1,002,636,184	17.63	6

Based on ranking types, subsequently, PROMETHEE I and PROMETHEE II were used to provide partial and complete ranking, respectively, of alternatives. PROMETHEE I is commonly related to the computation of two preference flows, i.e. Phi+ (positive flow) and Phi- (negative flow), and allows for incomparability between alternatives when both Phi+ and Phi- give conflicting rankings (Brans & Mareschal, 2013; Kabir & Sumi, 2014). As illustrated in Figure 5, Phi+ is defined as a measure of strength, representing on the left-side bar with the best value at the top of the bar and the worst one at the bottom, but Phi- is defined as a measure of weakness, representing on the right-side bar with the best value at the top of the bar and the worst one at the bottom (Brans & Mareschal, 2013). Thus, a value of 1.0 is the best result on the left-side bar; on the other hand, a value of 0.0 is the best one on the right-side bar.

In regard to Figure 5, Songkhla is the best alternative of Phi+, followed by Sa Kaeo, Kanchanaburi, Nong Khai, Nakhon Phanom, Mukdahan, Tak and Trat, respectively. According to Phi-, rank of alternatives from the most to least attractive one is Songkhla, Sa Kaeo, Nakhon Phanom, Kanchanaburi, Nong Khai, Mukdahan, Tak and Trat, respectively. Thus, it is clear that Songkhla is preferred to all others, while Sa Kaeo comes second in positive and negative flow. Kanchanaburi (3rd order in Phi+, but 4th order in Phi-), Nong Khai (4th order in Phi+, but 5th order in Phi-) and Nakhon Phanom (5th order in Phi+, but 3rd order in Phi-) seem incomparable. Meanwhile, Mukdahan, Tak and Trat are at the same rank. In addition, unicriterion net flows, showing the difference between positive and negative flows, of alternatives in each criterion are displayed in Table 12.

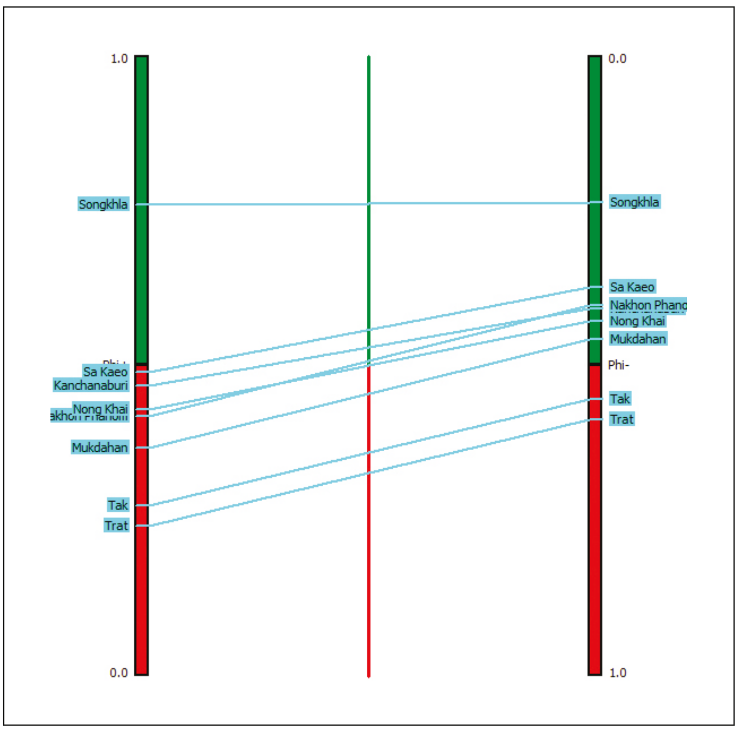

Figure 5 Chart of PROMETHEE I (Partial Ranking)

Table 12 Unicriterion net flows of alternatives in each sub-criterion

Alternative	Sub-criterion											
	C11	C12	C13	C14	C21	C22	C23	C24	C31	C41	C42	C51
A1	0.7143	0.7143	-0.1429	-0.1429	0.4286	-0.4286	-0.7143	0.0000	0.0000	-0.4286	0.1429	0.1429
A2	0.4286	-0.5714	-0.1429	-0.1429	0.1429	0.1429	0.1429	0.7143	0.4286	-0.7143	-0.1429	0.1429
A3	-0.4286	-0.5714	-0.1429	-0.1429	0.7143	-0.7143	0.7143	0.0000	-0.8571	-1.0000	-0.7143	1.0000
A4	-0.7143	-0.5714	-0.1429	-0.1429	-0.7143	-0.1429	-0.1429	1.0000	0.0000	0.1429	0.4286	-0.4286
A5	-1.0000	0.1429	-0.1429	-0.1429	1.0000	0.7143	-0.4286	-0.8571	0.7143	0.7143	0.7143	-0.7143
A6	0.1429	0.4286	-0.1429	-0.1429	-0.4286	0.4286	0.4286	0.0000	-0.4286	0.4286	-0.4286	0.1429
A7	-1.0000	-0.5714	-0.1429	-0.1429	-0.1429	-1.0000	-1.0000	-0.8571	-0.8571	-0.1429	-1.0000	0.7143
A8	-0.1429	1.0000	1.0000	1.0000	-1.0000	1.0000	1.0000	0.0000	1.0000	1.0000	1.0000	-1.0000

In aspects of PROMETHEE II, it is concerned with the net flows only and clearly leads to a complete ranking of the alternatives, and the incomparable status is not existed; those alternatives can thus be ordered from the best to the worst (Ishizaka & Nemery, 2013). In accordance with Figure 6 and Table 13, the highest value of the net flow (Phi) is Songkhla. It is obvious that Sa Kaeo, Kanchanaburi, Nakhon Phanom and Nong Khai (slightly above zero) are on the positive side (upper bar), while Mukdahan, Tak and Trat (the lowest value) are on the negative zone (lower bar).

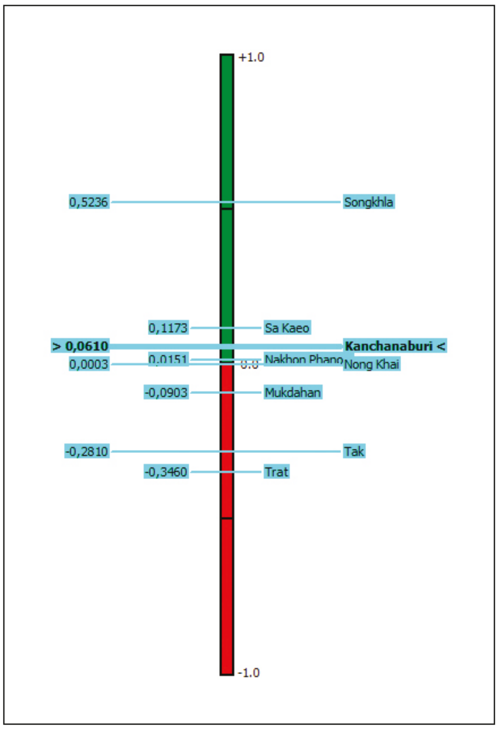

Figure 6 Chart of PROMETHEE II (Complete Ranking)

Table 13 Multicriteria Ph+, Ph- and Phi of alternatives

Alternative	Phi+	Phi-	Phi
Nong Khai	0.4287	0.4284	0.0003
Nakhon Phanom	0.4179	0.4027	0.0151
Mukdahan	0.3673	0.4576	-0.0903
Tak	0.2734	0.5544	-0.2810
Kanchanaburi	0.4687	0.4077	0.0610
Sa Kaeo	0.4897	0.3724	0.1173
Trat	0.2404	0.5864	-0.3460
Songkhla	0.7603	0.2367	0.5236

Ultimately, the evidence as seen in Table 14 is likely to be clearly strong that Songkhla is the best site to establish the potential freight village, followed by Sa Kaeo, Kanchanaburi, Nakhon Phanom and Nong Khai, respectively, which their net flows are positive.

Table 14 Rank of alternatives

Rank	Alternative	Phi
1	Songkhla	0.5236
2	Sa Kaeo	0.1173
3	Kanchanaburi	0.0610
4	Nakhon Phanom	0.0151
5	Nong Khai	0.0003
6	Mukdahan	-0.0903
7	Tak	-0.2810
8	Trat	-0.3460

5. Conclusions and Discussions

With an uncertainty of world economy, Thailand's government has recently launched a variety of programs to sustain the country's economy. One of them is the establishment of SEZs along border provinces for promoting cross-border trade. Nevertheless, such facility as freight village should be taken into account due to logistics operations in relation to goods moving and storing. Hence, site selection of freight village based on a MCDM problem, where eight SEZ-based provinces (or alternatives) and

12 conflicting sub-criteria were involved, was investigated. By fulfilling each other, the integrated fuzzy AHP-PROMETHEE methodology was proposed in this study. Fuzzy AHP was applied to obtain weights of criteria, while PROMETHEE was used to rank those alternatives. According to Table 7 by displaying rank of sub-criteria, % weight of border trade is the highest value (18.50), followed by weights of highway (12.90), labor (12.60), rental cost (11.80) and railway (10.40), respectively, whereas weights of seaport, airport, electricity, water supply, pollution, hospital and site expansion are lower than 10%. Moreover, as shown in Table 10, Songkhla has more outstanding sub-criteria than others (eight out of 12), which are railway, airport, seaport, labor, border trade, hospital, electricity and water supply. Trat is considered as the highest weight on highway. Site expansion and environment show the highest values on weights of Tak and Mukdahan, respectively. Then, PROMETHEE was applied to rank SEZ-based border provinces from the best to worst one, represented by Phi values. Thus, as tabulated in Table 13, Songkhla has the highest Phi value of 0.5236, while Trat shows the lowest one with Phi value of -0.3460.

Furthermore, on the basis of the Provincial Development Plan of Songkhla from 2018 to 2022 (Songkhla, 2018), the following advantages of Songkhla in regard to an establishment of freight village are, for example:

- It has the largest economy (241,701 million baht) in Thailand's Southern region;
- Its cross-border trade is viewed as the highest values, approximately 62% of total ones;
- It is the most important economic province in Southern zone with respect to trade, finance, investment and service;
- There is one Southern region industrial estate in order to support both Thailand and Malaysia manufacturing sectors;
- Investors have more rights of investment than other areas, when investing in its SEZ;
- It is regarded as the rubber city, where is Thailand's rubber center concerned with trade and processing;
- It is the consolidated center of agricultural and agricultural processed products in Southern part;
- It is the gateway to link Northern Corridor Economic Region (NCER) of Malaysia for trade and investment; and
- It is the transport center of land, sea and air to connect ASEAN and other countries. It holds the road network to link other Southern provinces and Malaysia. Hatyai railway station, a junction one, is connected by the domestic railway network and that one from neighboring nations of Malaysia and Singapore. Also, Hatyai international airport is the most important Southern one to connect other domestic and overseas terminals.

Therefore, the evidence of MCDM result and supporting reasons is likely to point out that Songkhla is the most attractive province for establishment of freight village in Thailand.

However, despite using fuzzy set theory to combine with AHP on purpose to reduce vagueness of opinions from experts, the limitations of this study have been still existed. For instance, the combined fuzzy AHP-PROMETHEE approach is not compared with other MCDM ones, yet. This may lead to unreliable results. With respect to expert, different experts have different perspectives. If eight experts in this study are replaced by others, the outcomes concerned with weights of criteria will be altered. In addition, sensitivity analysis should be taken into consideration. This helps to compare rank of alternatives when weights of criteria are changed. Also, data of criteria of each alternative have been varied over time, so results could not be the same.

In terms of the future study, those criteria in this study should be reviewed because some of them may be removed or added with regard to any circumstance at that time. Also, some social factors (e.g. wealth, education level, population density and relevance) should be taken into account. Moreover, a comparison to previous papers related to location selection of freight village and/or SEZ, for instance Ahmed et al. (2020), with the same criteria may be examined.

Apart from this, other MCDM methodologies (e.g. SAW: Simple Additive Weighting, ANP, CBR: Case-based Reasoning; MAUT: Multi-attribute Utility Theory, MACBETH: Measuring Attractiveness by a Categorical Based Evaluation Technique, DEA: Data Envelopment Analysis TOPSIS, ELECTRE, GP: Goal Programming and VIKOR) or techniques (e.g. GIS: Geographic Information System) for site selection should be compared to the one in this study. This assists in proving reliable consequences.

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