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Application of Fuzzy Delphi TOPSIS to Locate Logistics Centers in Vietnam: The Logisticians' Perspective

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ABSTRACT

Logistics centers have emerged as an important logistics infrastructure in supply chains. Hence, the problem of locating logistics centers plays a crucial role in designing and practicing logistics and supply chain management. Acknowledging the significance of logistics centers, Vietnam approved a master plan for the development of a logistics center system. However, the plan has been difficult to implementation because of the lack of the prioritization of the determinants used to locate logistics centers. This study aims to develop a benchmarking framework for choosing the locations of logistics centers based on the findings of logisticians by applying a hybrid of the fuzzy method and the technique for order of preference by similarity to ideal solution (TOPSIS), both of which are utilized extensively to overcome problems in selecting locations. The results indicate that freight demand, closeness to market, production area, customers, and transportation costs are regarded as the most important factors in deciding the location of logistics centers. In addition, among the three locations considered, the northeast provinces of Ho Chi Minh City were the best location for logistic centers, followed by North Hanoi and Da Nang city. The findings of this study make a significant contribution to both academic and practical aspects of locating logistic centers.

1. Introduction

Logistics performance, which is an accelerator of the competitiveness of a market economy (Oden et al., 2016), has become an imperative indicator for not only individual firms but also public authorities because of its contribution for economic development (Notteboom and Rodrigue, 2009). Moreover, as a result of the tendency to outsource logistics functions in order to concentrate on core competences (Rabinovich et al., 1999), a "one–stop-shop" or logistics center (Altuntas and Tuna, 2013) is a comparatively recent phenomenon (Sheffi, 2012) offered by logistics service providers to customers in order to reduce costs and increase customer satisfaction (Onden et al., 2016). Logistics centers are a special

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intermodal hub in the transportation system, which provide comprehensive and value-added services that are integrated in various logistics facilities and logistics activities. These services are connected to transportation, logistics, and distribution in large geographical areas (Europlatforms, 2004). The concept includes several different terms, such as freight village, logistics node, distribution center, logistics park, and distribution park (Rimiene and Grundey, 2007; Tang et al., 2013; Meidute, 2007; Notteboom and Rodrigue, 2005).

Notably, the location problem of logistics centers has emerged as imperative in the design and study of logistics and supply chain management (Rao et al., 2015). The appropriate location of facilities contributes to the efficiency of the freight system and supply chain. In contrast, an unfavorable location might incur additional costs (Kayikci, 2010). In this context, the question of how logisticians such as freight forwarders, warehouse and transportation operators, and third- and fourth-party logistics service providers, who take a leading role in integrating the supply chain (Panayides, 2004), choose the locations of logistics centers is an important issue for logistics service providers, shippers, and public authorities. It is then not surprising that there have been calls for papers to shed light on the issue. In response, several studies used different methodologies to determine the selection of the locations of logistics facilities (Kuo, 2011; Chen, 2001; Liu et al., 2011; Onden et al., 2016; Kayikci, 2010; Ou and Chou, 2009; Elevli, 2014; Awasthi et al., 2011; Onut et al., 2010; Chou et al., 2008; Rao et al., 2015; Demirel et al., 2010). Many empirical studies provided useful insights on the determinants of location of logistics centers in various countries, which have significant implications for both policy and practice (Ou and Chou, 2009; Regmi and Hanaoka, 2013; Elevli, 2014; Yildirm and Onder, 2014; Onden et al., 2016).

Acknowledging the role of logistics centers in logistics industry in particular and economic growth in general, in 2015, the Vietnamese government approved a master plan for the development of a logistics center system through to 2020 and beyond to 2030. According to the plan, 21 logistics centers are involved in the development of a system to facilitate economic growth. The plan proposed three national and international logistics centers (class 1) north of Hanoi, Da Nang, and the northeast city of Ho Chi Minh as the three key centers in the three regions (North, Central, and South) in which to develop a range of satellite logistics centers. However, the implementation of the plan has faltered because of the lack of the prioritization of the determinants used to locate the logistics centers. The rational allocation and mobilization of resources would be valuable benefits of prioritization, and they would serve to develop the overall logistics sector (Regmi and Hanaoka, 2013). Hence, clarifying the location problem of logistics centers in Vietnam from the perspective of logisticians is theoretically and practically significant.

This study attempts to develop a benchmarking framework for the selection of the locations of logistics centers based on the logisticians' perspective. The paper applies a hybrid of the Fuzzy-Delphi-TOPSIS approach, which is extensively utilized to solve location problems. The key criteria that influence the location choice are identified based on the strengths and weaknesses of the locations of the three logistics centers. The findings of this study have considerable implications for both research and practice.

2. Literature Review

2.1. *Decision environment*

Weber (1909) conducted the first study using location theory to shorten the distance from warehouses to customers (Owen and Deskin, 1998). Subsequently, a plethora of research in various fields focused on location science. Owen and Deskin (1998) attributed problems in the selection of facility location to "static and deterministic" and "dynamic and stochastic" factors. Although several studies attempted to address the location selection problem in certain deterministic environments, the latter feature was assessed realistically because of the complexity of the uncertainty issue (Demirel et al., 2010; Rao et al., 2015) caused by imprecision and vagueness in the decision-making process (Ou and Chou, 2009).

Many previous studies have utilized the fuzzy method to deal with the problem of location selection. Li et al. (2011) introduced a hybrid axiomatic fuzzy set clustering method and TOPSIS. Kuo (2011) selected an optimal site in Pacific Asia for the location of an international distribution center by using a combination of the fuzzy DEMATEL and the analytic hierarchy/network process. Liu et al. (2011) combined a heuristic algorithm, rough set methods, and fuzzy theory to solve the problem of locating distribution centers. A multi-stage methodology consisting of the fuzzy analytic hierarchy process (FAHP), spatial statistics and analysis was demonstrated to assess the suitable locations of logistics centers in Turkey (Onden et al., 2016). A hybrid FAHP method and artificial neural networks were applied to choose the most suitable location for an intermodal freight logistics center (Kayikci, 2010). Aiming to select the optimal location for an international distribution center, Ou and Chou (2009) applied fuzzy theory to solve the problem. Elevli (2014) used fuzzy sets and the preference ranking organization method for enrichment evaluation (PROMETHEE) to estimate the potential locations of logistics centers. Awasthi et al. (2011) developed a combination of fuzzy theory and fuzzy TOPSIS to judge criteria and alternatives to locate an urban distribution center. Onut et al. (2010) selected a shopping center site by applying fuzzy AHP and fuzzy TOPSIS. In order to deal with the multiple-attribute decision-making involved in the problem of selecting locations, Chou et al. (2008) presented a new fuzzy method that included objective and subjective attributes under group decision-making conditions. Similarity, Rao et al. (2015) applied a fuzzy method with a linguistic 2-tuple model to solve various decision-making problems regarding the location of logistics centers in urban areas.

2.2. *The determinants of selecting the locations of logistics centers*

Location selection is critical in strategic planning (Demirel et al., 2010) because various criteria need to be evaluated simultaneously (Rao et al., 2015), and the competing interests of multiple stakeholders need to be considered (Kim et al., 2013). Logistics centers have gained the attention of government authorities because of their important role in social and economic growth (Notteboom and Rodrigue, 2009). According to Tsamboulas and Kapros (2003), the actual decision-makers in the operation of logistics centers are shippers, who influence cost-savings, quality, reliability, and lead-time. However, because of severe the competitive and rapidly globalizing economy, achieving comparative advantages derived from the integration of supply chains is a common goal. Moreover, integration has been driven by the majority of third-party service logistics providers who aim to offer competitive advantages to their end customers by providing cost savings and efficient solutions (Magala and Sammons, 2008).

Kuo (2011) proposed ten criteria for selecting international distribution center location including port rate, import/export volume, location resistance, extension transportation convenience, transhipment time, one stop service, information abilities, port & warehouse facilities, port operation system, and density of shipping line. In contrast, Ou and Chou (2009) investigated six factors named valued added service, transportation and distribution systems, market potential, environment, infrastructure and culture to identify international distribution center from a foreign market perspective. In order to assess location planning for urban distribution center, Awasthi et al. (2016) examined eleven factors named accessibility, security, connectivity to multimodal transport, costs, environment impact, proximity to customers, proximity to suppliers, resource availability, conformance to sustainable freight regulations, possibility of expansion and quality of service. Li et al. (2011) presented a wide range of criteria to select a region logistics center by considering weather condition, landform, water supply, power supply, solid castoff disposal, communication, traffic, candidate land area, candidate land shape, candidate land circumjacent main line, candidate land land-value, freight transport, and fundamental construction investment.

Some empirical studies have addressed the problem of locating logistics centers with various factors from different perspectives. Based on the perspectives of an expert in the finance sector, a logistics operation manager, a professor, and an advisor from the government, Onden et al. (2016) identified the criteria that influenced the location of logistics centers in Turkey, which included the proximity to highways, railways, airports, seaports, the total population, the volume of international trade, and the handling capabilities of seaports. Elevli (2014) assessed the five criteria of site suitability, background activities/facilities, access to transportation/ networks connection; property conditions and location, and interconnected business activities to evaluate five proposed locations for a logistics center in Samsun, Turkey. Similarity, in order to decide the optimal locations of freight villages in Istanbul, Yildirm and Onder (2014) considered seven criteria: proximity to industrial zones, airports, railways, highways, harbours, cost of land, and opportunities for possible site expansion. Regmi and Hanaoka (2013) considered the preferences of the public sector and the private sector in locating logistics centers in Laos. The relative weights of determinants and the location of the alternative sites were determined by five main criteria and 12 sub-criteria. Although there was a consensus of the freight forwarders and government policy-makers in terms of ranking the alternatives, some differences in weighting the criteria were recorded between the two groups. However, transport connectivity, regional development, and environment impacts were assessed as highly important in general.

In Vietnam, little research on the location problem has been conducted. Nguyen and Notteboom (2016) developed a conceptual framework from the perspective of multiple stakeholders to evaluate the location of a dry port in order to facilitate the flow of goods between the seaport and the hinterland. However, little research has addressed the problem of selecting the locations of logistics centers. Therefore, this empirical study explores the preferences of logistics service providers as a means of solving the problem of selecting the locations of logistics centers in Vietnam.

3. Methodology

Tsai et al. (2010) found that the preferential model of the decision-making process does not accommodate the comparison of numerical values. Indeed, their study applied the commonly used fuzzy theory to solve the uncertainty and imprecision of evaluations in order to improve the accuracy of judgments (Akkaya et al., 2015). Moreover, in order to clarify the priority of the determinants and the optimal location, the Fuzzy-Delphi and Fuzzy-TOPSIS, or a hybrid Delphi-Fuzzy- TOPSIS method, has been employed.

The Fuzzy-Delphi method has the advantages of both fuzzy theory and the Delphi approach. The outcomes of the Delphi method were objective and reasonable even when a small sample was used (Ma et al., 2011). Consequently, the hybrid method saved the time and cost required to achieve consensus without distorting the results (Duru et al., 2012; Ishikawa et al., 1993). Furthermore, TOPSIS is widely employed to solve multi-criteria decision making problems deriving from its effectiveness in identifying priorities among alternatives and computational simplicity (Wang and Chan, 2013; Wang and Yeo, 2016). However, the classical TOPSIS method with crisp numerical is unsuitable to preferential model (Bao et al., 2012). Consequently, the fuzzy TOPSIS method was well developed to strengthen the comprehensive and rational assessment of the alternatives' performance in under consideration of uncertain and vague judgment and linguistic assessments of decision makers in multi-criteria decision environment (Buyukozkan and Cifci, 2012).

Therefore, the hybrid Fuzzy – Delphi – TOPSIS is applied as the benchmark framework in this study (Figure 1). The procedure consists of establishing criteria based on the literature and expert reviews (Delphi method), assessing criteria weights (Fuzzy Delphi method), and ranking the proposed alternative locations of the logistics centers (Fuzzy TOPSIS method).

3.1. *Fuzzy Delphi method*

The Fuzzy-Delphi approach, which combines the Delphi technique and fuzzy theory, was presented by Ishikawa et al. (1993). The Delphi method was used to achieve the consensus of anonymous experts who had experience in and knowledge of particular topic (Tsai et al., 2010). A repeated "group response" to sequential questionnaires enabled the reduction of the number of responses (Helmer, 1967). This method has been used to achieve "anonymity," "iteration," "controlled feedback," and "statistical group response" (Rowe and Wright, 1999). In the Delphi method, a group of five to nine experts is adequate to achieve a rational evaluation (Delbecq et al., 1975).

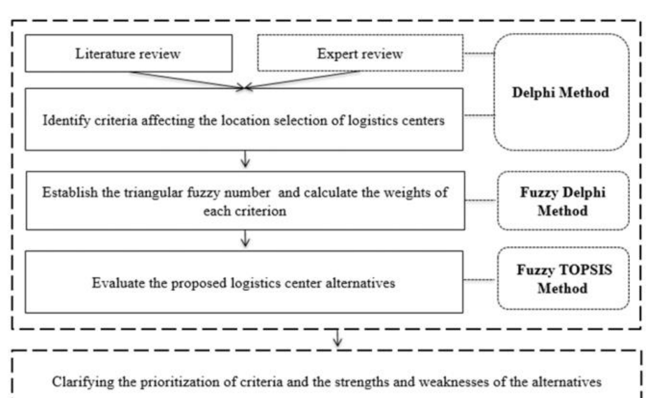

Fig. 1: Research diagram for the selection of locations of logistics centers

The fuzzy method is utilized to judge the relative significance of the criteria. The method has been commonly utilized to overcome the multi-attributes decision-making problem based on linguistic expression on a continuum of grades of variables. A fuzzy set is characterized by a membership function in which the grade of membership ranges from zero to one. In fuzzy set theory, classical bivalent sets are commonly named crisp sets. A triangular fuzzy number comprised of three parameters and a membership function is given as Equation 1.

$$\mu A(\chi) = \begin{cases} 0, & \chi \prec a_1 \\ \dfrac{\chi - a_1}{a_{2-}a_3}, & a_1 \le \chi \le a_2 \\ \dfrac{a_3 - \chi}{a_3 - a_2}, & a_2 \le \chi \le a_3 \\ 0, & \chi \succ a_3 \end{cases} \qquad (1)$$

The ith triangle fuzzy number in membership function n is calculated by Equation 2.

$$\bar{A} = \left(a_1^{(i)}, a_2^{(i)}, a_3^{(i)}\right), i = 1, 2, \ldots, n \qquad (2)$$

Furthermore, fuzzification is measured as follows:

$$\bar{A} = A_{ave} = \frac{\overline{A_1} + \overline{A_2} + \cdots + \overline{A_n}}{n} = \frac{\left(\sum_{i=1}^{n} a_1^{(i)}, \sum_{i=1}^{n} a_2^{(i)}, \sum_{i=1}^{n} a_3^{(i)}\right)}{n} = (a_1, a_2, a_3) \qquad (3)$$

Using the fuzzy approach, the linguistic variables were expressed as words or sentences. The linguistic terms can be used to indicate fuzzy set. The relatively important weights of criteria used to assess logistics center locations are divided into seven grades. A seven-point Likert scale ranging from "very high" = 7 to "very low" = one was used to score of each indicator as shown in Table 1.

To convert all the results to actual values, defuzzification is the final step in which the center of gravity is commonly applied in Equation (4):

$$y^* = a_3 - \sqrt[2]{(a_3 - a_1)(a_3 - a_2)/2} \qquad (4)$$

where y^* is the G-factor and its value is measured by the center of gravity.

Table 1.
Linguistic variables for the importance weight of each criterion

Linguistic scale	Fuzzy score
Very Low (VL)	(0.0, 0.0, 0.1)
Low (L)	(0.0, 0.1, 0.3)
Medium Low (ML)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
Medium High (MH)	(0.5, 0.7, 0.9)
High (H)	(0.7, 0.9, 1.0)
Very High (VH)	(0.9, 1.0, 1.0)

3.2. *Fuzzy-TOPSIS method*

The TOPSIS method is a well-known technique used to define priority by similarity to the ideal option. It was first developed by Hwang and Yoon (1981). The selected alternative has the furthest distance from the negative ideal option and the shortest distance to the positive ideal option. The positive ideal option comprises the best criteria, whereas the negative-ideal option is a composite of the worst performances (Bao et al., 2012). However, to deal with the imprecision and subjectivity of experts' judgments, fuzzy TOPSIS is applied, in which evaluations are stated in linguistic terms and then altered to fuzzy terms (Buyukozkan and Cifci, 2012). The procedure of the Fuzzy-TOPSIS method is as follows:

Step 1: Establish the linguistic values $x_{ij,} i = 1, 2 \ldots n; j = 1, 2 \ldots m$ for the alternatives relating to the criteria. In order to eliminate the normalization step, the fuzzy linguistic rating x_{ij} , the ranges of normalized triangular fuzzy numbers are from 0 to 10.

Table 2.
Linguistic variables for the preference of each alternative

Linguistic scale	Fuzzy score
Very Poor (VP)	(0, 0, 1)
Poor (P)	(0, 1, 3)
Medium Poor (MP)	(1, 3, 5)
Medium (M)	(3, 5, 7)
Medium Good (MG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very Good (VG)	(9, 10, 10)

Step 2: Calculate the weighted normalized fuzzy-decision matrix as follows

$$\tilde{v} = \left[\tilde{v}_{ij}\right]_{n*j}, \; i = 1, 2, \ldots n; j = 1, 2, \; m \qquad (5)$$
$$\tilde{v}_{ij} = \tilde{x}_{ij} * w_j \qquad (6)$$

where w_j is measured using data collected in expert questionnaires.

Step 3: Measure positive-ideal (FPIS, A^*) and negative-ideal (FNIS, A^-) options using Equations (7) and (8):

$$A^* = \{v^*_{1,\ldots\ldots\ldots\ldots}, v^*_i\} = \{(max_j v_j, \; i \in \omega_b), \; (min_j v_j, i \in \omega_c)\} \qquad (7)$$
$$A^- = \{v^-_{1,\ldots\ldots\ldots}, v^-_i\} = \{(max_j v_{j,} \; i \in \omega_b), \; (min_j v_j, i \in \omega_c)\} \qquad (8)$$

where ω_b are the sets of benefit criteria, and ω_c are the sets of cost criteria

Step 4: Calculate the distances of each alternative from the positive ideal option and the negative ideal option:

$$D_i^* = \sum_{j=1}^{m} d(\tilde{V}_j, \tilde{V}_i), i = 1, 2 \ldots n \qquad (9)$$
$$D_i^- = \sum_{j=1}^{m} d(\tilde{V}_j, \tilde{V}_i), j = 1, 2 \ldots m \qquad (10)$$
$$\mathrm{d}(\tilde{a}, \tilde{b}) = \sqrt{(1/3)\,[(a_1 - b_1)^2 + \; (a_2 - b_2)^2 + (a_3 - b_3)^2]} \qquad (11)$$

where a and b are two triangular fuzzy numbers represented by $(a_{1,} a_{2,} a_3)$ and $(b_{1,} b_2, b_3)$.

Step 5: Identify the relative closeness of each alternative to the ideal option. The relative closeness of the alternative A_i to A^* is characterized as follows:

$$FC_i = \frac{D_i^-}{D_i^* + D_i^-}, i = 1, 2 \ldots n \qquad (12)$$

4. Case Study

4.1. *Logistics performance in Vietnam*

The logistics sector in Vietnam is at the beginning of its development. However, the objective and subjective advantages of the country's geographical position and globally integrated economy show great promise for boosting the sector in the near future. Located in Southeast Asia, Vietnam borders China to the north, and Laos and Cambodia to the west. The Eastern Sea, with a coastline of approximately 3,200 km, enables Vietnam to engage in cross-border trading activities with neighbouring countries. The country also trades internationally throughout the main shipping routes between Asia and Europe. Indeed, because of its favourable location, Vietnam has the potential to become a gateway and transhipment hub in the region. Moreover, the entrance of Vietnam into the global economy has boosted Vietnamese economic growth dramatically in previous years. While many countries have endured slow growth rates because of the slowdown of the global economy, Vietnam has experienced strong economic growth. Additionally, with the help of the steady growth of foreign direct investment (FDI), the value of exports and imports were 350 billion USD in 2016, which was three times higher than in 2006. Vietnam has emerged as a major "recipient economy," and 60% of Korean FDI projects in ASEAN have located in the country (UNCTAD, 2016).

However, the development of the logistics sector in Vietnam has been hindered by several challenges (World Bank, 2014). The performance of Vietnam's logistics sector is still far from that of other countries in the region. According to the World Bank, in 2016, Vietnam ranked 64th of 160 countries in the logistics performance index, much lower than Singapore in 5th place, Malaysia in 32th place, and Thailand in 45th place. It is notable that the development of the logistics industry in Vietnam regressed, falling from 48th place in 2014 to 75th place with regard to the infrastructure criterion (70th) and the logistics competency criterion (62th), which caused the logistics cost of the annual GDP in Vietnam to be considerable higher than its peers at 20 to 25% and 10 to 13%, respectively (The Vietnam Logistics Association, 2015). Indeed, the development of a competent logistics infrastructure in both the public and private sectors is urgently needed to foster the seamless flow of commodities and reduce the cost of logistics.

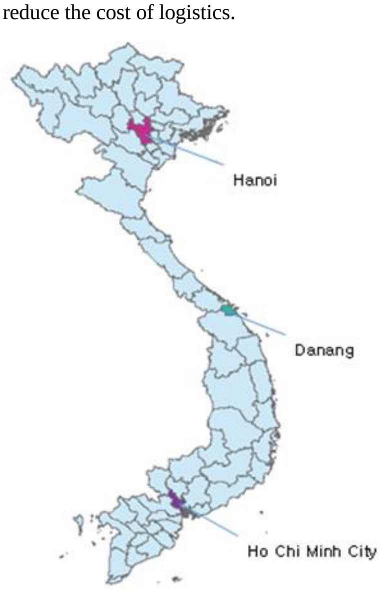

Fig. 2. The three proposed locations for logistics centers in Vietnam

In 2015, the Vietnamese government approved a master plan for the development of a nationwide network of logistics centers. The system comprises 21 logistics centers with varying sizes and serving areas. The proposed locations of these national and international logistics centers (class 1) are North Hanoi, Da Nang City, and the provinces northeast of Ho Chi Minh City. These locations would allow for a fully integrated function and all-in-one logistics services. They all provide a port, a container yard, a bonded warehouse, and 20-hectare container freight station. All locations are capable of serving a minimum area of 100 kilometers. In North Hanoi, the proposed location will be at least 20 hectares by 2020 and more than 50 hectares by 2030. The scope of its operation is mainly in Hanoi, localities in the capital region, and provinces near North Hanoi. This location has connections to dry ports and seaports in Hai Phong and Quang Ninh. The logistics center located in Da Nang City will be at least 30 hectares by 2020 and more than 70 hectares by 2030. It will support Da Nang City and provinces near Danang's seaports. The logistics centers in the provinces northeast of Ho Chi Minh City will be at least 60 hectares by 2020 and 100 hectares by 2030. Its operation focuses on the provinces of Dong Nai, Ba Ria-Vung Tau, Binh Thuan, Binh Duong, Tay Ninh, Dak Nong, and Lam Dong. It has connections to dry ports and seaports in Sai Gon and Ba Ria-Vung Tau. Because the three locations proposed by the plan have same role and characteristics as root centers in a range satellite logistics centers in the three key economic zones of Vietnam in the North, Central, and the South, thus, all the three locations, North Hanoi, Da Nang City, and the provinces northeast of Ho Chi Minh City are considered in the present study.

4.2. *Determinant factors and data collection*

The criteria used to select the locations logistics centers were determined using the Delphi method based on the findings from the literature review and data collected in interviews with experts. Six logisticians from top logistics service companies, including CEOs and general managers with more than 10 years of professional experience, were invited to participate in interviews. In order to discard superfluous factors and add missing factors, the interviews were conducted face-to-face by phone, and emails were circulated to achieve the concession of fourteen influential factors. Table 3 shows the determinants based on the findings of the literature reviews and the data gathered in interviews with the experts.

Table 3.
Determinants of logistics center location

No.	Criteria
1.	Proximity to market, production area, and customers (Regmi and Hanaoka, 2013; Yildirm and Onder, 2014; Chen, 2001; Demirel et al., 2010; Thai and Grewal, 2005)
2.	Proximity to seaports (Regmi and Hanaoka, 2013; Onden et al., 2016; Yildirm and Onder, 2014)
3.	Proximity to airports (Onden et al., 2016; Yildirm and Onder, 2014)
4.	Proximity to highways (Regmi and Hanaoka, 2013; Onden et al., 2016; Yildirm and Onder, 2014)
5.	Proximity to railways (Regmi and Hanaoka, 2013; Onden et al., 2016; Yildirm and Onder, 2014)
6.	Proximity to inland waterways (Regmi and Hanaoka, 2013)
7.	Capability for expansion of area (Yildirm and Onder, 2014; Chen 2001; Thai and Grewal, 2005)
8.	Freight demand (Regmi and Hanaoka, 2013; Onden et al., 2016)
9.	Development policies for economic zone and free trade zone nearby (Regmi and Hanaoka, 2013; Demirel et al., 2010)

10.	Land acquisition cost (Regmi and Hanaoka, 2013; Yildirm and Onder, 2014; Liu et al., 2011; Rao et al., 2015)
11.	Construction cost (Regmi and Hanaoka, 2013)
12.	Transportation cost (Regmi and Hanaoka, 2013; Liu et al., 2011; Demirel et al., 2010)
13.	Environmental impact of construction activities (Regmi and Hanaoka, 2013; Rao et al., 2015)
14.	Environmental impact of transportation activities (Regmi and Hanaoka, 2013; Rao et al., 2015)

The second questionnaire was designed to assess the relative importance of the criteria and the three proposed locations of logistics centers. The second round survey was conducted with 18 experts with more than seven years of experience in managerial positions in logistics service companies including 6 experts who participating in the first round.

4.3. *Assessment of factors and alternatives*

To clarify the importance of the criteria, the fuzzy method was applied using linguistic variables and then quantified as the triangular fuzzy numbers. For example, if one expert chose "absolute importance" for "closeness to market, production area, and customers," the assessment would be translated to (0.9, 1.0, 1.0). The final fuzzy scores of each factor were based on Equation (2). To obtain the crisp number, the fuzzy scores were defuzzified using Equation (3). The results are shown in Table 4.

The ranking of the determinants of logistics centers locations showed that the highest priorities were freight demand, transportation cost, and closeness to market, production area and customers. In order to gain the comparative advantages of economy of scale, the findings showed that freight demand is the first priority in selecting the location of a logistics center. Thus, in order to increase freight demand, decision-making process takes development policies for economic and free trade zone into account. However, in order to reduce the cost of logistics, related costs need to be considered, particularly transportation costs followed by land acquisition cost and construction cost. Additionally, logistics center should be located near its customers to improve customer responsiveness. Logistics centers are characterized by integrated logistics facilities and intermodal transport hubs, therefore, among transportation modes, proximity to waterways (seaways and inland waterways) and highways are preferred deriving from the absolute advantages of cost and flexibility, respectively comparing to airways and railways. Furthermore, the capacity for the expansion of areas is a critical factor for long-term development. The lowest priorities are environmental impact of construction activities and transportation activities in decision-making process, but acknowledge in environmental responsibility as a part of social responsibility is taken into account.

Table 4

Importance weights of criteria

Factors	Fuzzy score	Defuzzification	Rank
Proximity to market, production area, and customers (C1)	(0.70,0.86,0.95)	0.84	3
Proximity to seaports (C2)	(0.63,0.81,0.93)	0.79	4
Proximity to airports (C3)	(0.37,0.57,0.75)	0.56	13
Proximity to highways (C4)	(0.49,0.69,0.85)	0.68	7
Proximity to railways (C5)	(0.38,0.58,0.76)	0.57	12
Proximity to inland waterways (C6)	(0.49,0.69,0.84)	0.67	8
Capability for expansion of area (C7)	(0.54,0.73,0.87)	0.71	6
Freight demand (C8)	(0.74,0.89,0.97)	0.87	1
Development policies for economic zone and free trade zone nearby (C9)	(0.54,0.74,0.89)	0.72	5
Land acquisition cost (C10)	(0.49,0.67,0.83)	0.66	9
Construction cost (C11)	(0.45,0.63,0.81)	0.63	10
Transportation cost (C12)	(0.74,0.88,0.95)	0.86	2
Environmental impact of construction activities (C13)	(0.38,0.58,0.77)	0.58	11
Environmental impact of transportation activities (C14)	(0.26,0.43,0.63)	0.44	14

The 14 selected determinants used to assess alternatives were linguistics variables that were transformed into fuzzy ratings. The weight-normalized fuzzy-decision matrix derived from the fuzzy ratings multiplied by fuzzy weights was obtained using Equation (6) shown in table 5. Consequently, the positive-ideal (A^*) and negative-ideal (A^-) options under each factor were derived from Equations (7) and (8). The distances of each alternative from the positive-ideal option (D_i^*) and the negative-ideal option (D_i^-) and the relative closeness of each alternative to the ideal solution (FC_i) were calculated. The rankings of the three alternatives were determined, and the strengths and weaknesses of the three locations and strategic recommendations are shown in Table 6.

Table 5

Global score of the three alternatives

	North Hanoi	Danang city	Provinces northeast of HCM city
C1	(2.80, 5.16, 7.42)	(1.28, 3.15, 5.36)	(4.20, 6.88, 8.84)
C2	(2.11, 4.20, 6.38)	(2.53, 4.88, 7.31)	(4.43, 7.05, 8.87)
C3	(2.20, 4.34, 6.65)	(1.71, 3.68, 6.15)	(2.44, 4.82, 7.28)
C4	(3.24, 5.84, 8.25)	(1.62, 3.66, 6.26)	(3.24, 5.95, 8.39)
C5	(2.41, 4.74, 7.22)	(1.39, 3.29, 5.70)	(1.90, 3.96, 6.33)
C6	(2.43, 4.81, 7.14)	(1.46, 3.43, 5.88)	(3.41, 5.84, 7.98)
C7	(3.42, 5.93, 8.09)	(2.34, 4.60, 7.08)	(3.78, 6.30, 8.23)
C8	(4.19, 6.85, 9.08)	(2.96, 5.36, 7.46)	(5.18, 7.89, 9.57)
C9	(3.06, 5.67, 8.04)	(1.80, 3.95, 6.55)	(2.88, 5.30, 7.74)
C10	(1.22, 2.92, 5.10)	(1.46, 3.59, 6.18)	(2.27, 4.49, 6.89)
C11	(1.04, 2.74, 5.11)	(1.64, 3.59, 6.18)	(1.79, 3.80, 6.32)
C12	(2.71, 4.99, 7.26)	(2.47, 4.69, 6.94)	(4.19, 6.45, 8.20)
C13	(1.14, 2.90, 5.37)	(1.20, 2.90, 5.24)	(1.27, 3.09, 5.62)
C14	(0.95, 2.46, 4.75)	(0.95, 2.46, 4.86)	(1.13, 2.74, 5.17)

Table 6

Logisticians' assessments of alternatives

Alternatives	A^*	A^-	FC_i	Ranking
North Hanoi	11.154	11.404	0.506	2
Da Nang City	20.439	2.102	0.093	3
Provinces northeast of Ho Chi Minh City	1.033	21.421	0.954	1

Based on the perceptions of logisticians, the results indicated that among the alternatives, the provinces northeast of Ho Chi Minh City was the best location for logistics centers in Vietnam, followed by North Hanoi and Da Nang City in that order. According to the benchmark criteria, the provinces northeast of Ho Chi Minh City were superior to the other locations with the exception of development policies for economic and free trade zones, construction cost, environmental impact of construction activities, and proximity to railways. In particular, a detrimental factor was the lack of development policies for economic and free trade zones. The assessment of the logisticians corresponded with the actual situation of foreign direct investment attraction by cities and provinces as well as investment flows moving from the South to the North. In recent years, the cities and provinces in Northern Vietnam have attracted investors because of the improved infrastructure, agglomeration advantages of tax incentives, streamlined registration procedures, lower labor costs as well as geographical advantages such as the proximity to the administrative centers of Vietnam and main importers and exporters such as China, Japan, and Korea. Therefore, in order to assist the provinces northeast of Ho Chi Minh City in becoming the ideal location for logisticians, the investment environment needs to be prioritized. Consequently, a substantial source of freight demand, which was assessed as the most crucial factor, should be generated to boost the demand for logistics services in general and logistics centers in particular.

In contrast, the second alternative, North Hanoi, was evaluated as having the best performance in terms of attracting both domestic and foreign investments. North Hanoi also has the advantage of a central railway system. Although the railway sector in Vietnam is minor compared to other modes of transport with less than 1% of freight tonnages in 2014 (General Statistics Office, 2015), the logistics centers would benefit from the connectivity with the railway, which, compared to other transport modes such as trucking, is more cost-effective trucking, safer for long-haul traffic, and produces lower carbon emissions. However, the location in North Hanoi has the disadvantages of higher-costs for construction, land acquisition, and transportation. In addition, it is the farthest from the seaports located in Hai Phong and Quang Ninh, which are prominent centers of domestic and international shipments in Vietnam.

The lowest preference was shown for Da Nang City. Although the location of logistics centers in Da Nang City would have the advantages of lower-costs, including transportation cost, and low environmental impacts compared to the location in North Hanoi, it lacks the most highly prioritized factors in the benchmark framework: freight demand and proximities to market, production area, and customers. Moreover, except proximity to seaports, the lack of connectivity of the location with modes of transportation such as highways, railways, inland waterways, and airports would not serve the aim of logistics centers as intermodal hubs. Hence, in order to comply with the leading role in Central Vietnam and create a linking node in the East–West economic corridor of Laos, Myanmar, Thailand, and Vietnam in the Greater Mekong sub-region, the priority would be to improve the infrastructure and develop incentive policies to attract multinational investors.

5. Conclusion

Although the problem of location selection has been explored by many studies in the literature, a satisfactory solution has yet to be found because of changing requirements and inappropriate frameworks (Kuhn, 1970). Logistics centers have emerged as an important component of the infrastructure in the supply chain to provide "one-stop-shop" services. Hence, the selection of their optimal location has drawn the attention of both public and private sectors for both economic and social reasons (Notteboom and Rodrigue, 2009). However, logistics service providers no longer simply offer services to satisfy customers' needs. As specialists, they also play a leading role in maximizing the efficiency of supply chain (Panayides, 2004). Accordingly, this study presented a benchmarking framework for the selection of the locations of logistics centers in Vietnam based on the perceptions of logistics service providers. Based on this framework, a hybrid Fuzzy-Delphi-TOPSIS model was used to evaluate the criteria and alternatives in an environment of uncertain information. The results indicated that freight demand, transportation cost, and proximity to market, production area and customers are regarded as the most crucial factors in selecting the locations of logistics centers. In addition, in the case study, among the three locations considered for establishing logistics centers, the provinces to the northeast of Ho Chi Minh City were ranked as the best location, followed by North Hanoi and Da Nang city.

As a result, the study provides several important implications for academic and practice. For academic side, the present research is one of the few empirical studies to address problems in selecting the locations of logistics centers from the perspective of logisticians. Thus, the study would contribute to literature review in location problem as well as the concept of logistics center. Additionally, the location problem of logistics centers was deal with multiple criteria and uncertainty environment by using experts' knowledge with an integrated Fuzzy Delphi and Fuzzy TOPSIS methods to clarify the determinants as well as the optimal location. Besides, the study also provides insights for public authorities and logistics service providers. The public sector plays an important role in land resource management, policy development, economic enhancement, and strategic infrastructure development, including logistics centers. Therefore, in order to avoid the misuse of public funds, logisticians who are specialists in supply chain management could provide guidelines for the creation of master plans. In addition, the results of this study contribute to the knowledge necessary for logistics service providers to make decisions based on limited resources.

The study identified and prioritized criteria for selecting logistics center locations, but the results pertain to the conditions in a developing country as Vietnam. Thus, future research could be conducted in developed countries having a competent transportation system would be replicated. Besides, this study has limitation as the size of logistics centers was excluded in the criteria that need to revise in the future study. Moreover, although the hybrid Delphi-Fuzzy-TOPSIS model is suitable in complex decision-making that needs to consider multiple criteria in the context of vague assessments, the method is inappropriate for other forms of value such as real numbers or interval numbers. Although logisticians are specialists in selecting the optimal locations for logistics centers, other interested parties, such as policy makers, shippers, and residents, should be included in the selection process. Hence, future research could contribution further insights into solving the problem of selecting the locations of logistics centers, by involving additional groups, thereby taking into account not only the economic aspect but also environmental sustainability and social responsibility.

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