Research Article

A Selection Model to Logistic Centers Based on TOPSIS and MCGP Methods: The Case of Airline Industry

Kou-Huang Chen,[1] Chin-Nung Liao,[2] and Li-Chun Wu[1]

[1] *Department of Industrial Engineering and Management, China University of Science and Technology, Taipei 115, Taiwan*
[2] *Department of Business Administration, China University of Science and Technology, Taipei 115, Taiwan*

Correspondence should be addressed to Chin-Nung Liao; lliao@cc.cust.edu.tw

The location selection of a logistics center is a crucial decision relating to cost and benefit analysis in airline industry. However, it is difficult to be solved because there are many conflicting and multiple objectives in location problems. To solve the problem, this paper integrates fuzzy technique for order preference by similarity to an ideal solution (TOPSIS) and multichoice goal programming (MCGP) to obtain an appropriate logistics center from many alternative locations for airline industry. The proposed method in this paper will offer the decision makers (DMs) to set multiple aspiration levels for the decision criteria. A numerical example of application is also presented.

1. Introduction

In recent years, airline industries have been struggling to look for suitable locations to save logistics costs and increase competition advantage. Because all the activities in a logistics chain system have a relationship with customers and suppliers, the evaluation and selection of a suitable logistics center location has become one of the most important issues for logistics businesses [1]. In addition, the location selection should take many factors into consideration, such as labor characteristics (e.g., skilled labor), markets (e.g., closeness to customer and suppler), infrastructure (e.g., transportation, water, and power systems), and macroenvironment (e.g., policies of government and industrial regulations laws) [2]. Location selection is a crucial decision in the cost/benefit analysis of distribution center, logistics center, or other facilities for the airline industry. However, the problem of location selection is difficult because there are many conflicting and multiple goals to be solved [3]. Therefore, when considering various criteria, the evaluation and selection of logistics centers location is a multiple criteria decision-making (MCDM) process and a problem disturbed by logistics managers of airline industry. In order to select a suitable location for airline

logistics centers, both qualitative and quantitative criteria are needed to be considered at the same time. In the past, many qualitative and quantitative criteria methods of MCDM for evaluating/selecting consideration have been developed and widely used in various fields, such as management decisions, strategy selections, and decision-making problems.

Many studied on location evaluation and selection considering qualitative criteria has been addressed in previous studies. Cheng et al. [4] adopted the analytic network process (ANP) approach to select a shopping mall location that takes five qualitative criteria into consideration, including transportation, competition, one stop service, commercial area, and environment factors. Yang et al. [5] applied fuzzy theory for logistics distribution centers location problem under fuzzy environment. Chou et al. [6] presented a fuzzy MCDM model for hotel location selection by considering traffic conditions, geographical conditions, hotel characteristics, and operation management criteria. Lee and Lin [7] presented a fuzzy quantified SWOT procedure for the environmental evaluation of an international distribution center. Demirel et al. [2] had taken into account the main criteria, including costs, labor characteristics, infrastructure, and markets in a warehouse location selection. Turskis and Zavadskas [8]

presented a newly developed ARAS-F method to select the most suitable site for logistic centre by considering investment cost, operation time, expansion possibility, and closeness to the market. Awasthi et al. [9] used the technique for order preference by similarity to an ideal solution (TOPSIS) to optimize urban distribution center location by considering accessibility, security, connectivity to multimodal transport, costs, environmental impact, proximity to customers, proximity to suppliers, resource availability, conformance to sustainable freight regulations, possibility of expansion, and quality of service criteria. Kampf et al. [10] designed a useful tool to support the decision-making process for the location of a public logistic center. Li et al. [11] presented a TOPSIS methodology for the selection of logistic center location with five criteria, such as traffic, communication, candidate land area, candidate land value, and freight transport. Moreover, Kuo [1] integrated the analytic network process (ANP), TOPSIS, and DEMATEL techniques and determined a location for an international distribution center by considering port rate, import/export volume, location resistance, extension transportation, convenience, transshipment time, one stop service, information abilities, port and warehouse facilities, port operation system, and density of shipping line. For the analytic hierarchy process (AHP)/ANP or TOPSIS approaches, decision-makers (DMs) can define the criteria weights effectively; however, only a few candidate locations can be evaluated by these criteria whereas the complex interrelations in each criterion [3]. In practice, DMs cannot efficiently evaluate and select many candidate locations simultaneously among AHP, ANP, or TOPSIS. In other words, DMs need to develop an efficient method to improve the efficiency of location selection problems.

In addition, there are many studies on the location evaluation and selection problems by using mathematical quantitative criteria approaches. Jovanovic [12] presented an integer programming method to optimize the location selection for a new distribution transformer with the suitable size by calculating voltage drops, load of feeders, substations, and annual investment costs. Cheng and Li [13] used the approaches of data envelopment analysis (DEA) and binary integer linear programming (BILP) to determine whether location is valuable for investment. Klapita and Švecová [14] applied mathematical programming methods and the theory fuzzy sets to determine a unique solution of a location problem at uncertain costs. Sun et al. [15] presented a bilevel programming model for the location of logistics distribution centers evaluation and selection. Bhaumik [16] expressed the delocation problem as an integer linear programming method and did a case study for an existing distribution network with retailer and distributor locations that needs to downsize its distribution chain. In these studies, DMs can determine the optimal location selection from a lot of candidate locations with limited quantitative criteria; however, DMs may encounter the difficulty to evaluate candidate location with many qualitative criteria. For example, DMs may not easily determine the suitable weights on each goal in location evaluation problems [3].

Previous publications of evaluation and selection issues mostly focus on single or several important qualitative or quantitative factors and rarely take qualitative and quantitative factors into consideration. In the recent years, some studies adopted AHP, TOPSIS, and multichoice goal programming (MCGP) for evaluation and selection problems. Lee et al. [17] adopted fuzzy AHP and fuzzy multiple GP to help cooperation to select their downstream businesses of thin film transistor liquid crystal display suppliers. Liao and Kao [18] integrated Taguchi loss function, AHP, and MCGP to evaluate and select supplier. Ben Mahmoud et al. [19] used AHP and MCGP for a quality management system designing. Liao and Kao [20] integrated a fuzzy TOPSIS and MCGP approach to supplier selection problems in supply chain management. Liao [21] presented an evaluation model by using fuzzy TOPSIS and GP for TQM consultant selection. Hsu and Liou [22] provided a systemic analytical model for the selection of outsourcing providers from the point view of cost. Costs invested to classical facility or logistics location selections may be highly uncertain [23]. Moreover, Ho et al. [3] integrated AHP and MCGP as a decision reference to obtain an appropriate house from many alternative locations that better suit the preferences of renters under their needs.

In order to improve the quality of location selection decision-making problems, this paper will present a hybrid evaluation technique to help logistics businesses to select an appropriate location with both qualitative and quantitative criteria. The TOPSIS and MCGP methods, which will help DMs to determine the best location, are integrated in this paper. First, the Delphi method is applied to assess selection criteria. Then, the fuzzy TOPSIS is applied to calculate the relative weight of each location. Finally, MCGP model is formulated and used to identify the best logistics center location. The integrated method is shown in Figure 1.

The rest of this article is organized as follows. Section 2 presents the preliminaries of fuzzy set theory. Section 3 describes the methodology of TOPSIS-MCGP model. In Section 4, a numerical application to illustrate the proposed approach is presented. The sensitivity analysis is shown Section 5. Finally, the conclusions and future work are presented in Section 6.

2. Fuzzy Set Theory

A fuzzy set is characterized by a membership function, which assigns to each linguistic variable a grade of membership ranging $[0, 1]$.

Definition 1. A fuzzy set $\tilde{a}$ in a universe of discourse X is characterized by a membership function $u_{\tilde{a}}(x)$ that maps each component x in X to a real number in the interval $[0, 1]$. The function value X is termed the grade of membership of X in $\tilde{a}$ [24]. The nearer the value of $u_{\tilde{a}}(x)$ to unity, the higher the grade of membership of $u_{\tilde{a}}(x)$ in $\tilde{a}$.

Definition 2. A real fuzzy number A is described as a fuzzy subset of the real line R with member function u_A that represents uncertainty. A membership function is defined as the universe of discourse from zero to one (see Figure 2).
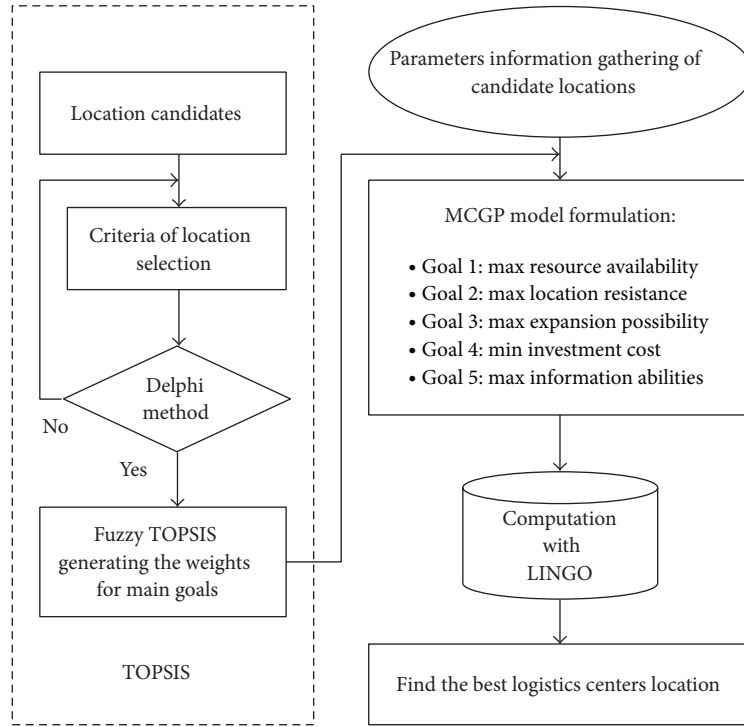
FIGURE 1: The integration procedure for logistics centers location evaluation and selection.

Therefore, a triangular fuzzy number can be defined as a triplet (a, b, c), where $a \leq b \leq c$; the membership function of the fuzzy number A is defined as follows:

$$u_A(x) = \begin{cases} \dfrac{x - a}{b - a}, & x \in [a, b], \\ \dfrac{c - x}{c - b}, & x \in [b, c], \\ 0, & \text{otherwise.} \end{cases} \quad (1)$$

2.1. The Distance between Fuzzy Triangular Numbers. Let $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$ be two triangular fuzzy numbers. Then the distance $(d(\tilde{a}, \tilde{b}))$ between $\tilde{a}$ and $\tilde{b}$ can be calculated by using the vertex method as follows [25]:

$$d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3} \left[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2 \right]}. \quad (2)$$

2.2. Linguistic Variables. For the fuzzy set theory, conversion scales are applied to transform the linguistic terms into fuzzy numbers. In this paper, we will apply a scale of normalized fuzzy preference number 0-1 to rate the alternatives. Table 1 presents the linguistic variables for the importance fuzzy weights of each criterion from Figure 3. In addition, Table 2 presents the linguistic variables of fuzzy ratings for the alternatives preference from Figure 4.

3. Methodology

3.1. Fuzzy Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS). In real life, the decision making
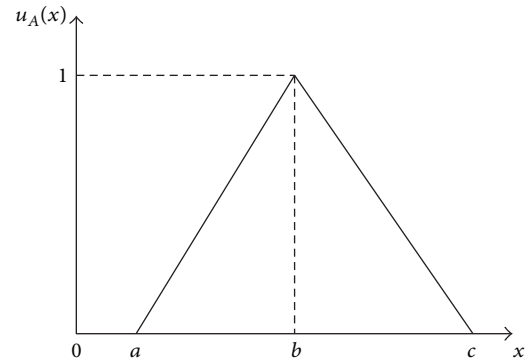

FIGURE 2: A triangular fuzzy number.

of many situations cannot be performed sufficiently and exactly because the available information is vague, imprecise, and uncertain [26]. Moreover, the multiple criteria decision-making (MCDM) situations are also based on uncertain and ill-defined information. This study performs the logistic centers location selection by using TOPSIS method, one of the best known MCDM approaches. TOPSIS is based on the concept that the chosen alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS) [27]. In addition, fuzzy set theory is considered as the most effective approach in managing vagueness and uncertainty problems. To solve MCDM problem, the fuzzy set theory is

TABLE 1: Linguistic variables for the importance weight of each criterion.

Importance	Abbreviation	Triangular fuzzy number
Very low	VL	(0, 0, 0.2)
Low	L	(0, 0.2, 0.4)
Medium low	ML	(0.2, 0.4, 0.6)
Medium high	MH	(0.4, 0.6, 0.8)
High	H	(0.6, 0.8, 1)
Very high	VH	(0.8, 1, 1)

TABLE 2: Fuzzy preference used in this study.

Linguistic terms	Abbreviation	Normalized fuzzy preference
Very poor	VP	(0, 0, 0.2)
Poor	P	(0, 0.2, 0.4)
Medium poor	MP	(0.2, 0.4, 0.6)
Medium good	MG	(0.4, 0.6, 0.8)
Good	G	(0.6, 0.8, 1)
Very good	VG	(0.8, 1, 1)
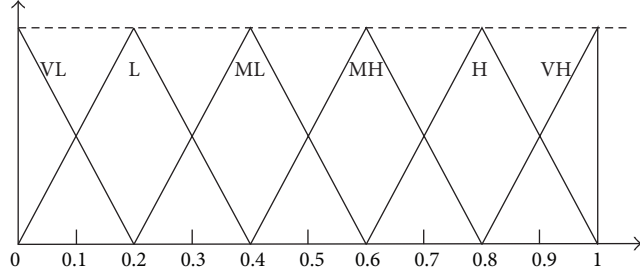
FIGURE 3: Linguistic variables for importance weight of each criterion.
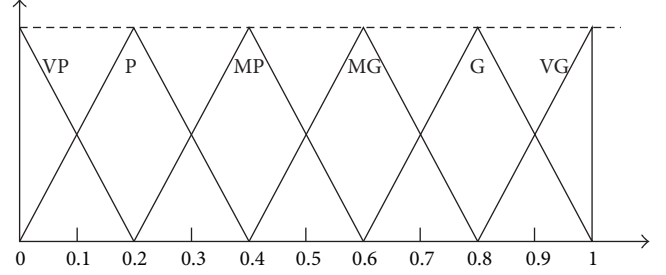
FIGURE 4: Linguistic variables for ratings and normalized fuzzy preference.

introduced to express linguistic terms in the human decision-making process. Zimmermann [28] indicated that a linguistic variable is a variable whose values are expressed in linguistic terms. The concept of a linguistic variable is very useful for handling situations which are very complex or not well-defined and need to be reasonably described by using conventional quantitative expressions. Basic fuzzy set technique and the steps of fuzzy TOPSIS relation analysis are shown as follows.

(1) Three DMs conduct a pairwise comparison of the preferences for criteria and use the linguistic variables to assess the importance of each candidate with regard to each criterion.

(2) Establish a decision matrix for alternative performance. The matrix can be expressed as

$$\widetilde{X} = \begin{bmatrix} \widetilde{x}_{11} & \widetilde{x}_{12} & \cdots & \widetilde{x}_{1m} \\ \widetilde{x}_{21} & \widetilde{x}_{22} & \cdots & \widetilde{x}_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ \widetilde{x}_{n1} & \widetilde{x}_{n2} & \cdots & \widetilde{x}_{nm} \end{bmatrix}. \tag{3}$$

Choose the linguistic ratings $\widetilde{X} = \{\widetilde{x}_{ij}, i = 1, 2, 3, \ldots, n, j = 1, 2, 3, \ldots, m\}$ for alternatives A_j with respect to criterion C_i. The fuzzy linguistic rating $(\widetilde{x}_{ij})$ makes sure the range of normalized triangular fuzzy numbers be in the interval $[0, 1]$; therefore, there is no need for normalization [29].

(3) Calculate the weighted normalized fuzzy decision matrix. The weighted normalized value is calculated as

$$\widetilde{V} = \left[\widetilde{v}_{ij}\right]_{n \times m}, \quad i = 1, 2, 3, \ldots, n, \ j = 1, 2, 3, \ldots, m, \tag{4}$$

where $\widetilde{v}_{ij} = \widetilde{x}_{ij} \otimes w_i$.

(4) The fuzzy positive-ideal solution and negative-ideal solution can be determined as follows:

$$L^* = \left(\widetilde{v}_1^*, \widetilde{v}_2^*, \ldots, \widetilde{v}_n^*\right) = \left\{\left(\max_i \widetilde{v}_{ij} \mid j \in J\right), \left(\min_i \widetilde{v}_{ij} \mid j \in J'\right)\right\},$$

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

$$L^- = \left(\widetilde{v}_1^-, \widetilde{v}_2^-, \ldots, \widetilde{v}_n^-\right) = \left\{\left(\min_i \widetilde{v}_{ij} \mid j \in J\right), \left(\max_i \widetilde{v}_{ij} \mid j \in J'\right)\right\},$$

$$i = 1, 2, 3, \ldots, n, \quad j = 1, 2, 3, \ldots, m, \tag{5}$$

where $\widetilde{v}_j^* = \max\{v_{ij3}\}$ and $\widetilde{v}_j^- = \min\{v_{ij1}\}$; J is associated with benefit criteria; and J' is associated with cost criteria.

(5) Calculate the distance of each alternative from L^* and L^- by using the following equations:

$$d_i^* = \sum_{j=1}^m d\left(\widetilde{v}_{ij}, \widetilde{v}_j^*\right), \quad i = 1, 2, \ldots, n,$$

$$d_i^- = \sum_{j=1}^m d\left(\widetilde{v}_{ij}, \widetilde{v}_j^-\right), \quad i = 1, 2, \ldots, n. \tag{6}$$

(6) Calculate the closeness coefficients (CC_i) of the ideal solution for each alternative as

$$CC_i = \frac{d_i^-}{\left(d_i^* + d_i^-\right)}, \tag{7}$$

where the CC_i ranges between the closed interval $[0, 1]$, $i = 1, 2, 3, \ldots, n$.

(7) Use the CC_i obtained from Step (6) for each candidate and building the integrated model to select the best location.

TABLE 3: Evaluation references source for each criterion.

Criteria of location	Description	Sources
Resource availability (C_1)	It providers the availability of water, power, raw material, and labor resources in the location	Awasthi et al. [9] Li et al. [11]
Location resistance (C_2)	It means the distance from location to main manufacturing and consumer marketplace, respectively. It will affect the logistic cost and time of cargo	Kuo [1] Demirel et al. [2]
Expansion possibility (C_3)	Ability to increase size to accommodate growing demands	Awasthi et al. [9] Turskis and Zavadskas [8]
Investment cost (C_4)	Investment costs in acquiring land, vehicle resources, drivers, taxes, and so forth for the location	Awasthi et al. [9] Demirel et al. [2] Turskis and Zavadskas [8] Hsu and Liou [22]
Information abilities (C_5)	It provides the availability of information service on logistics, business, financing activities, and so forth	Kuo [1]

3.2. Multichoice Goal Programming (MCGP). Goal programming (GP) is one of the most powerful techniques for solving target optimization problems. Sometimes, determining the specific target value of each goal is not easy for DMs because only limited information can be acquired in an uncertain situation. For example, a DM may consider the following as priority, including maximizing profits and increasing lot size services and increasing service quality and reducing operational cost. These problems cannot be solved by a general GP method. The conflicts of firm resources encourage DMs to generate a trustworthy mathematical model formulation to delineate their preferences [20]. A multichoice goal programming (MCGP) was proposed by Chang [30, 31] to solve this problem. MCGP formulation can be defined as follows:

$$
\begin{aligned}
\min \quad & \sum_{i=1}^{n} w_i \left[\left(d_i^+ + d_i^- \right) + \left(e_i^+ + e_i^- \right) \right] \\
\text{s.t.} \quad & f_i(X) - d_i^+ + d_i^- = g_{i1} \text{ or } g_{i2} \text{ or} \ldots \text{or } g_{im}, \\
& \qquad\qquad\qquad\qquad\qquad i = 1, 2, \ldots, n, \\
& g_i - e_i^+ + e_i^- = g_{i,\max}, \quad i = 1, 2, \ldots, n, \\
& g_{i,\min} \le g_i \le g_{i,\max}, \quad i = 1, 2, \ldots, n, \\
& d_i^+, d_i^-, e_i^+, e_i^- \ge 0, \quad i = 1, 2, \ldots, n, \\
& X \in F \quad (F \text{ is a feasible set}),
\end{aligned}
\tag{8}
$$

where g_{ij} ($i = 1, 2, \ldots, n$ and $j = 1, 2, \ldots, m$) is the jth aspiration level of the ith goal, w_i represents the weight attached to the deviation, and d_i is the deviation from the target value g_i; $d_i^+ = \max(0, f_i(x) - g_i)$ and $d_i^- = \max(0, g_i - f_i(x))$ denote under- and overachievements of the ith goal, respectively. In addition, e_i^+ and e_i^- are positive and negative deviations attached to $|g_i - g_{i,\max}|$, $g_{i,\min}$, and $g_{i,\max}$ which are, respectively, lower and upper bounds of g_i.

4. Numerical Example

An airline company ABC would like to select a suitable location for a new logistics center in Shanghai, China. ABC's decision-making group consists of three members: the chief executive officer (CEO) and two logistics experts who are invited to participate in this group and provide their opinions. From the literature reviews, data analysis, and nominal group technique (NGT) with five qualitative and quantitative criteria for the best logistic centers conditions may be determined as follows:

(1) resource availability (C_1),

(2) location resistance (C_2),

(3) expansion possibility (C_3),

(4) investment cost (C_4),

(5) information abilities (C_5).

The criteria are shown in Table 3.

The decision-making group includes three members (D_1, D_2, and D_3), and they have rich experience in logistic centers management and are required to select a best logistic center from five logistics centers location (L_1, L_2, L_3, L_4, and L_5) by applying the Delphi technique. The hierarchical structure of this decision problem is shown in Figure 5.

In order to evaluate candidate of logistics centers location efficiently and properly, the company ABC outsources the location investigate consultants to assist DMs in location parameters decision. The results of characteristics for five candidate locations are provided in Table 4.

The integrated fuzzy TOPSIS and MCGP approaches are applied to solve the location selection problem, and the computational process is summarized as follows.

(1) The DMs use the linguistic weighting variables shown in Table 1 to assess the importance of criteria by using geometry average. The importance fuzzy weights of the criteria are determined by the three DMs, shown in Table 5.
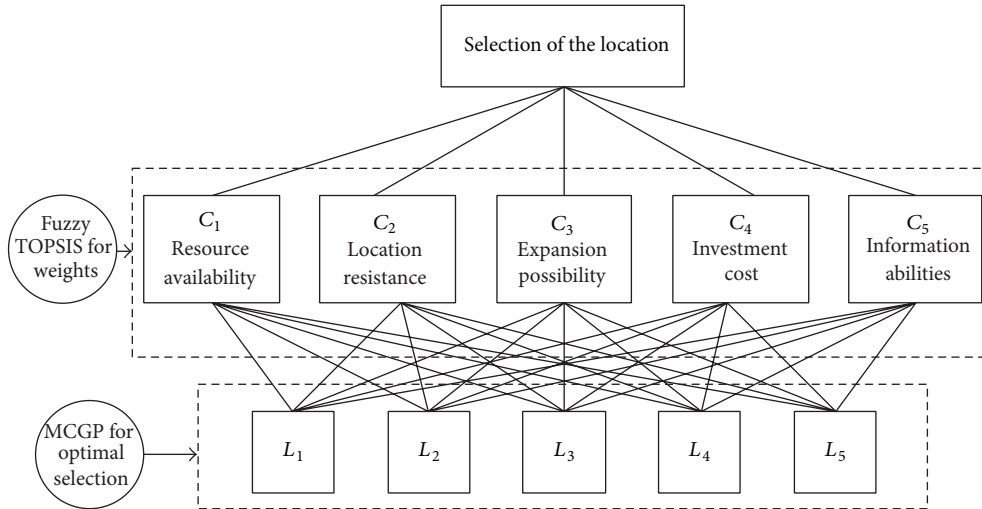
Figure 5: Hierarchy structure of location selection.

Table 4: Location selection parameters.

Criteria	L_1 Location 1 (x_1)	L_2 Location 2 (x_2)	L_3 Location 3 (x_3)	L_4 Location 4 (x_4)	L_5 Location 5 (x_5)
Resource availability (score)	85	90	95	80	75
Location resistance (km^2)	40.9	41.2	38.5	40.9	43.6
Expansion possibility (lot size m^2)	96.56	152.30	148.86	96.56	87.03
Investment cost ($1000)	1266	968	1520	887	1135
Information abilities (score)	70	80	60	90	75

Table 5: Importance of fuzzy weight of criteria from DMs.

	D_1	D_2	D_3	$\widetilde{w}_i$
C_1	(0.4, 0.6, 0.8)	(0.2, 0.4, 0.6)	(0.6, 0.8, 1)	**(0.2, 0.58, 1)**
C_2	(0.6, 0.8, 1)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	**(0.4, 0.66, 1)**
C_3	(0.4, 0.6, 0.8)	(0.6, 0.8, 1)	(0.8, 1, 1)	**(0.4, 0.78, 1)**
C_4	(0.4, 0.6, 0.8)	(0.2, 0.4, 0.6)	(0.4, 0.6, 0.8)	**(0.2, 0.52, 0.8)**
C_5	(0.2, 0.4, 0.6)	(0.4, 0.6, 0.8)	(0.2, 0.4, 0.6)	**(0.2, 0.46, 1)**

Table 6: Fuzzy preferences for the five locations by DMs using various criteria.

	C_1	C_2	C_3	C_4	C_5
L_1	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.6, 0.8, 1)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)
L_2	(0.6, 0.8, 1)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.6, 0.8, 1)
L_3	(0.2, 0.4, 0.6)	(0.8, 1, 1)	(0.2, 0.4, 0.6)	(0.6, 0.8, 1)	(0.4, 0.6, 0.8)
L_4	(0.6, 0.8, 1)	(0.4, 0.6, 0.8)	(0.6, 0.8, 1)	(0.4, 0.6, 0.8)	(0.8, 1, 1)
L_5	(0.4, 0.6, 0.8)	(0.6, 0.8, 1)	(0.2, 0.4, 0.6)	(0.8, 1, 1)	(0.6, 0.8, 1)

(2) DMs use the linguistic rating variables shown in Table 2 to evaluate the rating of each location candidate with respect to each criterion and then present the ratings in Table 6.

(3) From the fuzzy weights of each criterion ($\widetilde{w}_i$) in Table 5 and the linguistic evaluations in Table 6, a fuzzy weighted decision matrix can be established. Table 7 shows the fuzzy weighted decision values.

TABLE 7: Fuzzy weighted decision matrix.

	C_1	C_2	C_3	C_4	C_5
L_1	(0.08, 0.35, 0.8)	(0.16, 0.4, 0.8)	(0.24, 0.63, 1)	(0.08, 0.31, 0.64)	(0.16, 0.27, 0.8)
L_2	(0.12, 0.46, 1)	(0.16, 0.40, 0.8)	(0.16, 0.47, 0.8)	(0.08, 0.31, 0.64)	(0.24, 0.37, 1)
L_3	(0.04, 0.23, 0.6)	(0.32, 0.66, 1)	(0.08, 0.31, 0.6)	(0.12, 0.42, 0.8)	(0.16, 0.27, 0.8)
L_4	(0.12, 0.46, 1)	(0.16, 0.4, 0.8)	(0.24, 0.63, 1)	(0.08, 0.31, 0.64)	(0.32, 0.46, 1)
L_5	(0.08, 0.35, 0.8)	(0.24, 0.53, 1)	(0.8, 0.31, 0.6)	(0.12, 0.42, 0.8)	(0.24, 0.37, 1)

TABLE 8: Distance with positive-ideal solution with respect to each criterion.

	C_1	C_2	C_3	C_4	C_5
$d(L_1, L^*)$	0.662	0.608	0.489	0.351	0.651
$d(L_2, L^*)$	0.596	0.608	0.585	0.351	0.571
$d(L_3, L^*)$	0.747	0.439	0.702	0.460	0.651
$d(L_4, L^*)$	0.596	0.608	0.489	0.351	0.502
$d(L_5, L^*)$	0.662	0.516	0.702	0.460	0.571

TABLE 9: Distance with negative-ideal solution with respect to each criterion.

	C_1	C_2	C_3	C_4	C_5
$d(L_1, L^-)$	0.474	0.394	0.625	0.510	0.375
$d(L_2, L^-)$	0.607	0.394	0.475	0.510	0.502
$d(L_3, L^-)$	0.342	0.572	0.329	0.450	0.375
$d(L_4, L^-)$	0.607	0.394	0.625	0.510	0.523
$d(L_5, L^-)$	0.474	0.532	0.329	0.620	0.502

TABLE 10: Computations of d_i^*, d_i^-, and CC_i^*.

	d_i^*	d_i^-	$d_i^* + d_i^-$	CC_i^*
L_1	2.761	2.377	5.138	0.463
L_2	2.711	2.487	5.198	0.478
L_3	2.999	2.068	5.067	0.408
L_4	2.546	2.658	5.204	0.511
L_5	2.912	2.455	5.367	0.457

(4) The fuzzy positive-ideal and fuzzy negative-ideal are determined by using (5):

$$T^* = [(1, 1, 1), (1, 1, 1), (1, 1, 1), (0.08, 0.08, 0.08), (1, 1, 1)],$$

$$T^- = [(0.04, 0.04, 0.04), (0.16, 0.16, 0.16), (0.08, 0.08, 0.08),$$
$$(0.8, 0.8, 0.8), (0.16, 0.16, 0.16)].$$

$$(9)$$

(5) By using (6), the distance of each location candidate from fuzzy positive-ideal and fuzzy negative-ideal can be calculated with respect to each criterion, respectively, as shown in Tables 8 and 9.

(6) From (7), the closeness coefficient (CC_i) for each location candidate can be calculated as

$$CC_1 = 0.463, \quad CC_2 = 0.478, \quad CC_3 = 0.408,$$
$$CC_4 = 0.511, \quad CC_5 = 0.457,$$

$$(10)$$

and shown in Table 10.

(7) The closeness coefficients (CC_i, $i = 1, 2, \ldots, 5$) obtained from Step 6 for each location candidate in Table 10 are used as priority values to build the TOPSIS-MCGP model, which will be shown later in this section.

5. Sensitivity Analysis

According to Step 6, the best location alternative is L_4. To analyze the location using different criteria weights, a sensitivity analysis was conducted. The purpose of a sensitivity analysis is to exchange each criterion's weight with another criterion's weight; thus, 10 combinations for the five criteria are analyzed, and similarities for the ideal solution (closeness coefficients or CC_j^*) are calculated with each combination stated as a condition. The results of the sensitivity analysis are shown in Table 11.

When applying the analysis proposed by Önüt and Soner [29] to the values in Table 11, L_1 has the highest CC_j^* value (0.464) when the first and second criteria weights are

TABLE 11: Sensitivity analysis for location.

Conditions	Weights					The values of CC_i^*				
	$\widetilde{w}_1$	$\widetilde{w}_2$	$\widetilde{w}_3$	$\widetilde{w}_4$	$\widetilde{w}_5$	L_1	L_2	L_3	L_4	L_5
Main	(0.20, 0.58, 1.00)	(0.40, 0.66, 1.00)	(0.40, 0.78, 1.00)	(0.20, 0.52, 0.80)	(0.40, 0.46, 1.00)	0.463	0.478	0.408	0.511	0.457
1	(0.40, 0.66, 1.00)	(0.20, 0.58, 1.00)	(0.40, 0.78, 1.00)	(0.20, 0.52, 0.80)	(0.40, 0.46, 1.00)	0.464	0.515	0.400	0.483	0.456
2	(0.40, 0.78, 1.00)	(0.40, 0.66, 1.00)	(0.20, 0.58, 1.00)	(0.20, 0.52, 0.80)	(0.40, 0.46, 1.00)	0.459	0.511	0.409	0.483	0.462
3	(0.20, 0.52, 0.80)	(0.40, 0.66, 1.00)	(0.40, 0.78, 1.00)	(0.20, 0.58, 1.00)	(0.40, 0.46, 1.00)	0.440	0.454	0.389	0.487	0.433
4	(0.40, 046, 1.00)	(0.40, 0.66, 1.00)	(0.40, 0.78, 1.00)	(0.20, 0.52, 0.80)	(0.20, 0.58, 1.00)	0.463	0.510	0.408	0.479	0.457
5	(0.20, 0.58, 1.00)	(0.40, 0.78, 1.00)	(0.40, 0.66, 1.00)	(0.20, 0.52, 0.80)	(0.40, 0.46, 1.00)	0.461	0.478	0.412	0.509	0.46
6	(0.20, 0.58, 1.00)	(0.20, 0.52, 0.80)	(0.40, 0.78, 1.00)	(0.40, 0.66, 1.00)	(0.40, 0.46, 1.00)	0.427	0.444	0.361	0.476	0.413
7	(0.20, 0.58, 1.00)	(0.40, 046, 1.00)	(0.40, 0.78, 1.00)	(0.20, 0.52, 0.80)	(0.40, 0.66, 1.00)	0.463	0.516	0.403	0.481	0.458
8	(0.20, 0.58, 1.00)	(0.40, 0.66, 1.00)	(0.20, 0.52, 0.80)	(0.40, 0.78, 1.00)	(0.40, 0.46, 1.00)	0.413	0.435	0.369	0.461	0.415
9	(0.20, 0.58, 1.00)	(0.40, 0.66, 1.00)	(0.40, 046, 1.00)	(0.20, 0.52, 0.80)	(0.40, 0.78, 1.00)	0.459	0.481	0.411	0.514	0.464
10	(0.20, 0.58, 1.00)	(0.40, 0.66, 1.00)	(0.40, 0.78, 1.00)	(0.40, 046, 1.00)	(0.20, 0.52, 0.80)	0.439	0.453	0.384	0.484	0.429

exchanged in condition 1; L_1 has the lowest value (0.413) when the third and fourth criteria weights are exchanged in condition 8. L_2 will have the highest CC_j^* value (0.516) when the second and fifth criteria weights are exchanged in condition 7, and it will have the lowest value (0.435) when the third and the fourth criteria weights are exchanged in condition 8. L_3 will have the highest CC_j^* value (0.412) when the second and third criteria weights are exchanged in condition 5, and it will have the lowest value (0.361) when the second and fourth criteria weights are exchanged in condition 6. L_4 will have the highest CC_j^* value (0.514) when the third and fifth criteria weights are exchanged in condition 9, and it will have the lowest value (0.461) when the third and fourth criteria weights are exchanged in condition 8. L_5 will have the highest CC_j^* value (0.464) when the third and fifth criteria weights are exchanged in condition 6, and it will have the lowest value (0.413) when the second and fourth criteria weights are exchanged in condition 6. In addition, L_4 will be selected if conditions 3, 5, 6, 8, 9, and 10 are met, whereas L_2 will be selected if conditions 1, 2, 4, and 7 are met; however, the solution is not obtained based on these weights alone. With this approach, the DMs can use these different weights and different closeness coefficients (CC_j^*) when considering which control factors to combine, according to their business needs, in the decision-making process.

Though the basic reason for introducing a logistics centers is to enhance qualitative analysis, the ultimate justification should be made using quantitative measures (e.g., location selection parameters in Table 4). Therefore, this paper considers quantitative factors of criteria for logistics centers selection.

According to the business strategic and experts' suggestions by Delphi method, the company ABC points out six goals for location selection which are set below:

Goal 1: for maximizing resource availability, namely, $f_1(x) \geq 80$ (score),

Goal 2: for maximizing location resistance, namely, $37 \leq f_2(x) \leq 45$ (km^2),

TABLE 12: Comparison of logistics centers location selection methods and sensitivity analysis.

	Sensitivity analysis	The best selection
Fuzzy TOPSIS	CC_i^* ranking	L_4
	If conditions 3, 5, 6, 8, 9, and 10 are met	L_4
	If conditions 1, 2, 4, and 7 are met	L_2
Fuzzy TOPSIS + MCGP	Using LINGO	L_4

Goal 3: for maximizing expansion possibility, namely, $85 \leq f_3(x) \leq 160$ (lot size m^2),

Goal 4: for minimizing investment cost, namely, $850 \leq f_4(x) \leq 1580$ ($1000),

Goal 5: for maximizing information abilities, namely, $f_1(x) \geq 60$ (score).

This model can be solved by using LINGO 11.0 [32] on a Pentium(R) 4 CPU 2.00 GHz-based microcomputer in a few seconds (of computer time) to obtain optimal solution as $(x_1, x_2, x_3, x_4, x_5) = (0, 0, 0, 1, 0)$. From these results, we can understand that location 4, saying (L_4), is the best selection for company ABC.

Table 12 has shown the results for logistics centers selection comparisons using a sensitivity analysis.

6. Conclusions

This paper proposes the TOPSIS-MCGP method to assist DMs' of airline industrial finding a satisfying logistics centers location under their preferences and resource limitations. In this proposed that the DMs can determine the criteria weights (e.g., closeness coefficients) from TOPSIS and implement

TABLE 13: Comparison of logistics centers location selection methods.

Methods	Selection criteria		Multiple choice aspiration levels
	Qualitative	Quantitative	
TOPSIS	Yes	No	No
LP/GP	No	Yes	No
DEA	No	Yes	No
CPM	No	Yes	No
AHP/ANP	Yes	No	No
AHP (or ANP) + TOPSIS	Yes	No	No
This proposed method (Fuzzy TOPSIS + MCGP)	**Yes**	**Yes**	**Yes**

it into each goal in MCGP. With different logistics centers intention, DMs can set multiple aspiration levels for each location goal by using MCGP to find the optimal location. Considering both qualitative and quantitative criteria, this paper offers a new practical approach to selecting the best logistics centers location for a given airline industrial business by integrating the fuzzy TOPSIS and GP methods. The integrated advantage of this paper is that it takes both qualitative and quantitative criteria into consideration on logistics centers location problems with "the more/higher is better" (e.g., benefit criteria) or "the less/lower is better" (e.g., cost criteria). The contribution of this paper is that it proposes an easy and effective method to help the logistics business to select the best location.

A number of techniques have been proposed to solve the logistics centers selection problems. These approaches include techniques for order preference by similarity to ideal solution (TOPSIS), linear programming (LP), goal programming (GP), data envelopment analysis (DEA), cost point methods (CPM), the analytical hierarchy process (AHP), the analytic network process (ANP), and fuzzy set theory. However, the modeling of many situations may not be sufficient or accurate, as the available data in real life are vague, inaccurate, imprecise, and uncertain by nature. Table 13 presents a comparison of this proposed analytical method and the others.

The proposed method may also be useful for various MCDM problems, such as business strategy selection, supply chain quality development (e.g., [33]), and marketing activities. Therefore, investigating and identifying suitable criteria affect the transport plan problems, and applying other methods (e.g., fuzzy additive ratio assessment ARAS-F [8]) to improve the effectiveness of the decision-making process can be considered for further research. In addition, we expect that this integrated method can be used in our research in the future, such as logistics strategy selection, logistics service development, and logistics activities planning.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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