A COMBINEDFUZZY AHP-ELECTRE APPROACH FOR SELECTING GLOBAL DISTRIBUTION CENTERS CONSIDERING RISK FACTORS

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ABSTRACT
Global distribution center selection is a fuzzy multi-criteria group decision making problem which includes both objective and subjective factors. The global distribution centers (GDCs) selection is a complex problematic issue than domestic one and it needs more decision making risk analysis. The purpose of this article is to ascertain and deliberate some of the significant and critical decision criteria including risk factors for the development of an efficient system for global distribution center selection. In the proposed approach the criteria weights are calculated by using fuzzy AHP and fuzzy ELECTRE is used to assess the risk impact generated by the six global distribution centers from a foreign market perspectives. Finally, a fuzzy dominance relation (FDR) approach is employed to rank the alternatives from the most risky to the least. A sensitivity analysis is also performed to demonstrate the application of the proposed model effectively under fuzzy environment.

Keywords: Fuzzy AHP-ELECTRE, Risk factors, Global distribution center, Fuzzy multi-criteria group decision-making

1. INTRODUCTION

In today's world, global competition in international trade poses dramatic challenges to companies which must promptly respond to changing marketplace requirements. Effective risk management in supply chain management (SCM) enables organizations to satisfy such requirements. Global distribution centers (GDCs) provide plentiful advantages to shippers, including storage, inland transport service, customs clearance service, consolidation, packaging, labeling and assembly services. In supply chain network design and management, especially large-scale(SCM), the particular role of global distribution centers is increasingly important in transportation and distribution of merchandise (Thai and Grewal, 2005; Kharaman, 2003; Alberto, 2000; Aras et al. 2008).

Decision making in word-wide distribution center selection problems can be multifarious and complex due to the inherent trade-offs between sociopolitical, environmental, cultural, economic and risk factors. Moreover, decisions about risk factors may involve many different stakeholders with different objectives (Janssen, 2001; Badri, 1999; Barker 2011). The selection of appropriate remedial strategies for contaminated sites, land use planning, and regulatory processes often involves multiple criteria such as the distribution of costs and benefits, environmental impacts for different populations, safety, ecological risk, or human values (Yang, 1997;). Considerable research in the area of multi-criteria decision making (MCDM) has made available practical methods for applying scientific decision theoretical approaches to complex multi-criteria problems (Zadeh, 1965; Kiker, Bridges, Varghese, Seager, &Linkovjj, 2005). Fuzzy analytical hierarchy process (FAHP) (Gan, 2010; Turgut et al. 2011, Yuksel, 2009; Liu and Wang 2009),ELECTRE (Sevkli, 2009; Geldermann and Rentz, 2000; Hartmann, 2011), PROMETHEE(Al-Rashdan, Al-Kloub, Dean, and Al-Shemmeri, 1999; Vaillancourt and Waaub, 2002, Wang 2009), and multiple attribute utility theory (MAUT) (Prato, 2003; Store & Kangas, 2001) are among the MCDM techniques which are widely used for handling risks in decision making process.

In MCDM, a given set of alternatives to be evaluated with respect to specific criterion is assumed. In reality, the importance of individual decision makers (DMs) against a decision-making attribute may not be equal or uniform. Sometimes there are DMs/experts on specific issues in a decision group, such as the executive manager of operations department on (GDCs) selection issues, or some experts who are more experienced than others (Awasthi et al. 2011, Chu 2002;). Notably, the final outcome of the fuzzy multi-criteria group decision-making (MCGDM) process may be markedly influenced by the degree of importance of such individual DMs (Boran, 2011; Beamon 2004;). A good method for aggregating the various influences of individual opinions, evaluation, and rating from multiple DMs thus must be considered in (GDCs) selection problems.

This study investigates three aspects of fuzzy decision-making procedure from a foreign market perspective for global DC selection problems with (FMCGDM) processes (Chan, 2007; Chen 2001; Chiou and Cheng 2011). The initial inquiry is the evaluative criteria experts generally consider relevant for appraising (GDCs). Second, the important weights of different DMs on specific criteria and on the ratings of alternatives need not be uniform where fuzzy assessments and multiple expert opinions are considered. Third, once potential criteria are identified, the proposed decision support system employs integrated fuzzy AHP-ELECTRE methodology incorporating a judgmental decision-making process to evaluate such criteria and is also appropriate for appraising alternative target international DC (Farahani 2010; Fleischmann 2001, Kaya 2007; Kuo 2011, Linkov 2007). Specifically, this study presents empirical evidence which elucidates the perceived relative importance of potential evaluative criteria within the international DC selection decision-making process (Berman, 2001;).

The ELECTRE method for choosing the best action from a given set of actions was devised in 1965. The acronym ELECTRE stands for EliminationEtChoixTraduisant la REalite (ELimination and Choice Expressing the REality). ELECTRE is a well-known MCDM method that has a history of successful real world applications. It has been applied in past to various types of decision-making problems. ELECTRE requires an input of criteria evaluations for the alternatives, called decision matrix, preference information, expressed as weights, thresholds, and other parameters. All the ELECTRE-type methods involve two major procedures: the modeling of preferences with outranking relations, followed by an exploitation procedure. The outranking relation of $A_k \rightarrow A_l$ says that A_k outranks A_l, if A_k is at least as good as A_l on a majority of criteria and this result is not significantly based on any of the other criteria. ELECTRE methods can operate with one or several crispy or fuzzy outranking relations (Montazer, Saremi, &Ramezani, 2009; Shanian and Savadogo, 2006, Demirel 2010).

In fuzzy ELECTRE, linguistic preferences can easily be converted to fuzzy numbers. For the determination of the relative importance of evaluation criteria, fuzzy AHP can be used since it is based on pair wise comparisons and allows the utilization of linguistic variables. From paired comparisons a relative scale of measurement is derived. Although the pair-wise comparison approach is demanding in terms of solicited input from the experts, it offers maximum insight, particularly in terms of assessing consistency of the experts' judgment. This technique is ideal for closer examination of a selected set of (GDCs) criteria in an international sea ports or airports location planning context.

In this study, an integrated fuzzy AHP–ELECTRE methodology is proposed for (GDCs). In the proposed methodology, the weights of the assessment criteria are determined by a fuzzy AHP procedure. With the proposed methodology, six (GDCs) which were evaluated in terms of foreign market perspectives. Finally, using a fuzzy dominance relation (FDR) approach, the most risky distribution center will be determined.

The remainder of this paper is organized as follows: In Section 2, a key problem statement described briefly with literature review about multi-criteria group decision making of international distribution centers selection. In the third section, an integrated fuzzy multi-criteria AHP–ELECTRE methodology is presented. In Section 4, following the determination of the selection criteria and alternatives, the proposed methodology is applied to a multi-national corporation (GDCs) problem and a sensitivity analysis is also provided. Finally, in the last section, conclusions and suggestions for further study are given.

2. KEY PROBLEM STATEMENT

In this problem, an ''international DC" is defined as a location which incorporates the operations of manufacturing with land, sea and air transportation, storage, port and customs operations in order to achieve the efficient distribution of commodities. The basic focus of this research study is global DCs at public airports and seaports including warehouses or DCs at airports and seaports. From a high risk foreign market perspectives, global DCs offer value-added functions in an integrated logistics system such as labeling, assembly, logistics processing and inland transportation which can provide an advanced base in a foreign market (Lu, 2003).

The objective of this study is to discuss the relevant decision criteria like service performance, logistics systems, market potential, environmental issues, cultural issues, infrastructure problems, governmental incentives and distributor's profile including the risk factors involved in global distribution center selection and to provide an efficient approach to handle it effectively. The risk factors, discussed in this study, address some of the important and interesting issues like terrorism, government stability, economic status, and geographical location of distributor to match the distribution selection process with the current political and business scenario for greater efficiency.

This research can provide an appropriate and suitable approach to tackle the fuzziness involved in the human decision making, with the aim to remove complex and unreliable process of comparing fuzzy utilities for efficiently solving the global distribution center selection problem. This can provide guidelines to the decision makers for taking decisions regarding their distributor location selection with great precision considering the current relevant issues.

As indicated by the literature reviews, the fuzzy set theory is incorporated into many concepts and procedures when enhancing their capability for handling MCGDM problems in imprecise/vague environments. The judgmental procedure and an open decision system for strategic MCGDM are necessary and sufficient for manager's job. This study presents an integrated fuzzy AHP-ELECTRE frame work to compute fuzzy weights for criteria and ELECTRE procedure for solving distribution centers problems. To solve this problem six alternatives are identified for further evaluations: Alexandra Distripark (Singapore) $A_{1,}$ Port of Bangkok (Thailand) $A_{2,}$ Yokohama Port Cargo center (Japan) $A_{3,}$ Port of Peneng (Malaysia) $A_{4,}$ Seaport of Shanghai (China) A_5 and Hong Kong International distribution center (Hong Kong) $A_{6.}$ In this study, it is aimed to rank the alternative global distribution centers selection from the one with the highest risk impact to the least by using fuzzy dominance relation approach (FDR).

3. FORMULATINGAFUZZY (MCGDM) MODELFOR (GDCs) SELECTION

In this section, we formulate a fuzzy (MCGDM) framework for global distribution center selection which composed of three stages.

3.1 General framework

The general framework for fuzzy multi-criteria group decision making of global distribution centers selection model is presented in step-wise manner. The proposed framework composed of experts workings, fuzzy AHP and fuzzy ELECTRE methods, consists of three main stages: (1) identify and classify the criteria to be used in the model by experts working (2) Fuzzy AHP computations for identification of criterion weights (3) evaluation of alternatives by conducting fuzzy ELECTRE method and determination of final rank by using fuzzy dominance and fuzzy non-dominance relations of each global distribution center with valuable suggestions and sensitivity analysis.

3.2 Identifying the needs of global distribution centers

This case study begins when the management of a multi-national corporation plans to minimize supply chain risk in selecting the potential global distribution centers. The management identifies the needs and profile for global distribution centers. Before selecting the distribution centers the management should discuss essential features according to the available survey of candidate distribution centers A_1, A_2, A_3, A_4, A_5, and A_6, in the market.

3.3 Establishing a team for global distribution centers selection

After the identification of distribution center's needs, the case corporation establishes a team of decision makers. The experts from decision-making team make individual evaluations according to the scale provided in Table 1, to determine the values of the elements of pairwise comparison matrix. The committee consists of four top managers from various functional departments within the corporate, that is, the general marketing manager DM_1, the manager of information department DM_2, the manager of production DM_3, and the external management consultant DM_4has been formed to determine the best alternative for further evaluation. The management committee arranges a series of meetings to determine a profile of the most beneficial potential (GDCs) using the tools provided by this study.

3.4 Determining criteria for global distribution centers selection

After expert's comprehensive discussion, eight selection criteria are chosen. The criteria which are considered here in selection of the global distribution centers are:

- Service performance (C_1)
- Logistics systems (C_2)
- Market potential (C_3)
- Environmental issues (C_4)
- Cultural issues (C_5)
- Infrastructure problems (C_6)
- Government incentives (C_7)
- Risk factors (C_8)

The main criterion relevant to global distribution centers selection is described below. The hierarchy of the selection criterion and decision alternatives can be seen in Fig. 5. In the hierarchy, the overall objective is placed at level 1, criteria at level 2, and the decision alternatives at level 3.

- **Service performance (C_1)**

In a global environment, evaluating service performance is the first primary factor, which concerns the services offered by the (GDCs), including value-added services such as the following: packaging, kitting, labeling, cargo processing and bar coding; storage services: bonded storage and special cargo storage services; and support services: customs clearance, exhibition, insurance service and barcode recognition

- **Logistics systems (C_2)**

The second most important factor is the evaluation of transportation and distribution systems, which scrutinizes import-export distribution, multinational distribution, electronic transmission and inland transportation systems.

- **Market potential (C_3)**

This factor specifically focuses on whether the on-site (GDCs) is in a foreign market in which consumers have the economic means to purchase imported products and whether the needs of the market are adequately satisfied. From market potential point of view, the main areas of interest include the following: product consumption trends in the export market, internal and external competition in the export market and current market position as measured by broad economic performance standards.

- **Environmental issues (C_4)**

Environment is the fourth primary factor. The main areas of interest include: political factors such as the internal policy of a foreign government; attitudes and actions toward private enterprise; legal environment such as government regulations or restrictions that can affect operations, economic factors, social factors, physical factors, technical factors and task environment factors.

- **Cultural issues (C_5)**

This factor focuses on the following: the nature of internal and external shared lifestyles, customs and social relationships; the degree of cultural unity, national integration and extent of ethnic and cultural differences in the foreign market; and cultural differences between the export market and the home market.

- **Infrastructure problems (C_6)**

Infrastructure is the sixth primary factor. This factor focuses on: physical distribution infrastructure, communications infrastructure, IT infrastructure and water and electricity supply infrastructure.

- **Government incentives (C_7)**

Governmental incentive is the seventh primary factor. The main areas of interest include: political factors such as the internal policy of a foreign government; attitudes and actions toward private enterprise; legal environment such as government regulations or restrictions that can affect operations, economic factors, social factors, physical factors, technical factors and task environment factors. The more stable government should be preferred. Because during the change of political leadership, different foreign countries' policies will be changed accordingly and this may create big problems in further maintaining the relationship with international trade partners. In this connection, this must be analyzed in great precision with the help of the relevant experts.

- **Risk factors (C_8)**

The eighth and final factor of the framework is risk factors. Owing to a number of exogenous factors influencing international locations, global distributor selection is much riskier than its domestic counterpart. Consequently, the global distributor selection decision is most strongly affected by perceived risks. Some of the risk factors identified and analyzed in this study could not be seen in any previous study, which have the significant capability to affect the selection process of the global distributor. (Min and Melachrinousdis, 1996) pointed out that international location selection criteria comprise risk levels, economic stability, productivity, market opportunity, governmental incentives, and cost. The existing literature has focused on evaluating new facilities or pure trade but this study, from foreign market perspectives considering risk factors, selects a current airport or seaport as a global distribution centers or cargo warehouses.

3.5 Calculating the criteria weights by using fuzzy AHP

After establishing a decision hierarchy, the criteria weights of the global distribution center can be calculated by using fuzzy AHP methodology. To facilitate the calculation of fuzzy weights, the trapezoidal fuzzy numbers are presented in Fig. 1. Pair-wise comparison matrix is constructed by the experts for evaluations to obtain criteria weights by employing the ratio scale in Table 1. The procedural steps of the fuzzy AHP technique can be summarized as follows:

Step 1. Determine the relative importance of the criteria using pairwise comparisons. The experts are required to provide their judgments on the basis of their knowledge and expertise. The experts' linguistic preferences are converted into trapezoidal fuzzy numbers using Table 2.

Step 2. Aggregate the experts' opinions into group preference by applying the fuzzy trapezoidal averaging operator, which is defined by

$$\tilde{C}_{jk} = \frac{1}{K}\left[\tilde{C}_{jk}^{1}(+)\tilde{C}_{jk}^{2}(+),...,\tilde{C}_{jk}^{K}\right] \quad (1)$$

Where *K* is the total number of decision makers and $\tilde{C}_j^K$ is the evaluation of the *Kth* decision maker on the pairwise importance comparison of *j*th and *K*th criteria.

Step 3. Obtain the fuzzy weights $\tilde{w}_j$. The geometric mean of each row of a matrix is calculated by $\tilde{a}_j$ values and fuzzy weights $\tilde{w}_j$ can be detailed as follows. Let:

$$a_j = \left[\prod_{k=1}^{n} a_{jk}\right]^{\frac{1}{2}} \quad (2)$$

And

$$a = \sum_{j=1}^{n} a_j \quad (3)$$

Similarly, we can define b_j and b, c_j and c, and d_j and d. Then, the fuzzy weight $\tilde{w}_j$ is determined as (Chen & Hwang, 1992):

$$\tilde{w}_j = \left(\frac{a_j}{d}, \frac{b_j}{c}, \frac{c_j}{b}, \frac{d_j}{a}\right) \quad (4)$$

Step 4.Defuzzify and normalize the trapezoidal fuzzy weights. To defuzzify the Trapezoidal fuzzy numbers in Eq. (4), the below mentioned equation is used:

$$w'_j = \frac{\frac{a_j}{d} + 2\left(\frac{b_j}{c} + \frac{c_j}{b}\right) + \frac{d_j}{a}}{6} \quad (5)$$

Now, to normalize the crisp weights Eq. (6) is used:

$$w_j = \frac{w'_j}{\sum_{j=1}^{n} w'_j}, \qquad j = 1, 2, \ldots, n. \quad (6)$$

3.6 Obtaining the outranking relation using fuzzy ELECTRE

Given two alternatives A_k and A_l, ''A outranks A_k'' signifies that the analyst has enough reasons to admit that in the eyes of the decision maker, A_k is at least as good as A_l. Hence, A_k is indifferent from or preferred to A_l. The statement ''A_k does not outrank A_l'' implies that the arguments in favor of the proposition ''A_k is at least as good as A_l'' are judged insufficient and that there exist arguments in favor of ''A_l is at least as good as A_k''. Hence, A_l is preferred or incomparable to A_k (Chen & Hwang, 1992; Roy, 1977).

A fuzzy outranking relation $s^d(k, l)$ can be featured by a membership function $\mu(k,l)$ which shows the level of outranking related with each number of alternatives (A_k, A_l). The properties of fuzzy outranking relation $s^d(k, l)$ should be reflexive, nonsymmetrical, and transitive. According to these characteristics, some preference relations can be induced such as (Siskos, Lochard, & Lombard, 1984): A_k is preferred to $A_l$if sd(k, l) >sd(l, k); A_k is indifferent to $A_l$if $s_d(k,l) = s_d(l,k) \succ 0$;$A_k$ is incomparable to A_l if $s_d(k,l) = s_d(l,k) = 0$. Roy (1977) proposed the application of the degree of concordance and discordance to formulate fuzzy outranking relations. There are three thresholds which must be specified: (1) t^i (indifference threshold), (2) t^p (preference threshold), (3) t^v (veto threshold). The degree of concordance, ψ_j, which expresses the credibility proposition ''A_k over A_l'' with respect to the jth criterion, is defined as (Chen & Hwang, 1992; Zimmermann, 1987):

$$\Psi_j(k,l) = \begin{cases} 1, & r_{kj} + t^i_j \geq r_{ij}, \quad frac\, r_{ij} - \left(r_{kj} + t^p_j\right) t^i_j - t^p_j, \; r_{kj} + t^i_j \leq r_{ij} \leq r_{kj} + t^{p,}_j \\ 0, & r_{ij} \geq r_{kj} + t^p_j. \end{cases} \quad (7)$$

Similarly, the degree of discordance, d_j, which expresses the credibility of the proposition ''A_k is not at least as good as A_l'' is defined as:

$$d_j(k,l) = \begin{cases} 0, & r_{kj+} t^p_j \geq r_{ij} \\ \frac{r_{ij} - \left(r_{kj} + t^p_j\right)}{}, & r_{kj} + t^p_j \leq r_{ij} \leq r_{kj} + t^p_j, \\ 1, & r_{ij} \geq r_{kj} + t^p_j. \end{cases} \quad (8)$$

Fig. 2 presents the concordance and the discordance functions. The concordance and the discordance relations are defined for each pair of alternatives and with respect to a single criterion. The next step is to aggregate all the single criterion concordance relations, $\psi_j, \forall j$, into a unified ψ, as:

$$\psi(k,l) = \sum_{j=1}^{n} w_j . \psi_j(k,l), \qquad \forall k,l \tag{9}$$

Where $w_j, \forall_j$, are the weights given by the experts. The concordance and the discordance relations are aggregated to formulate the outranking relation. To this end a discordance relation, D, is defined in order to reduce the concordance by the discordance. The discordance relation, D is defined as:

$$D(k,l) = \frac{1}{n}\sum_{j=1}^{n} f\left(d_j(k,l).\psi_j(k,l)\right) \tag{10}$$

The concordance relation, ψ, and the discordance relation, D are then integrated to construct the fuzzy outranking relation $s_d(k, l)$ as:

$$f\left(d_j(k,l),\psi_j(k,l)\right) = \begin{cases} 1, \quad d(.) \prec \psi(.), frac1 - d_j(.) \\ 1-\psi(.), d_j(.) \succ \psi(.), \quad \psi(.) \neq 1 \end{cases} \tag{11}$$

The concordance relation, w, and the discordance relation, D are then combined to give the fuzzy outranking relation $s_d(k, l)$ as:

$$s_d(k,l) = \psi(k,l).D(k,l), \quad \forall k,l \tag{12}$$

The algorithmic steps of the approach is explained as follows:

Step 1. All experts assess the number of alternatives with respect to the criteria. The experts' individual linguistic opinions are converted into triangular or trapezoidal fuzzy numbers using Fig. 3.

Step 2. Employing aggregations approach to aggregate the experts' individual preferences as given in Eq. (1).

Step 3. Fix the thresholds values $t_j^i \leq t_j^p \leq t_j^v$ for the criteria in accordance with the evaluations of the experts team.

Step 4. Establish the concordance relation ψ_j for the *j*th criterion, C_j, using Eq. (7).

Step 5. Formulate the discordance relation d_j for the *j*th criterion, C_j, using Eq. (8).

Step 6. Given the single criterion concordance relations ψ_j; an aggregated concordance relation can be obtained using Eq. (9).

Step 7. Given the single criterion concordance relations *d*j, and the aggregated concordance relation ψ, an aggregated concordance relation D can be obtained using Eqs. (10) and (11).
Step 8. By using Eq. (12) to combine the aggregated concordance relation ψ and the aggregated discordance relation D, we can obtain the fuzzy outranking relation s_d.

3.7 Constructing fuzzy dominance and fuzzy non-dominance relations

Finally, a fuzzy dominance relation is used to prioritize the alternatives in descending order. A fuzzy dominance relation is defined by a membership function $\mu_D(k,l)$ that measures the outranking intensity. It is computed as (Chen & Hwang, 1992; Siskos et al., 1984):

$$\mu_D(k,l) = \begin{cases} s^d(k,l) - s^d(l,k) \\ 0, \quad otherwise \end{cases} \quad (13)$$

Since $\mu_D(k,l)$ is the fuzzy set of alternatives Al; 8l, that are dominated by A_k, it is natural to define the non-dominance relation as the complement of $\mu_D(k,l)$. A non-dominance relation can be defined as:

$$\mu_{ND}(k,l) = 1 - \mu_D(k,l) \quad (14)$$

Similarly, we know $\mu_{ND}(l,k)$ is the fuzzy set of alternatives that are not dominated by A_l. The intersection of all $\mu_{ND}(l,k)$ for all alternatives will result in the fuzzy set of alternatives that are not dominated by any alternatives. Thus, we get a fuzzy set of non-dominated alternative, $\mu^*(A,k)$, which is defined by

$$\begin{aligned} \mu^*(A_k) &= \min\left[1 - \mu_D(l,k)\right] = 1 - \max \mu_D(l,k) \\ &= 1 - \max\left[s^d(l,k) - s^d(k,l)\right] \end{aligned} \quad (15)$$

The best alternative is the one that satisfies:

$$\begin{aligned} \mu^*\left[A_k^*\right] &= \max \mu^*(A_k) \\ &= 1 - \min\left(\max\left[s^d(l,k) - s^d(k,l)\right]\right) \end{aligned} \quad (16)$$

The other alternatives are ranked with respect to their $\mu(A_k)$ values.
The algorithm can be represented as follows:
Step 1. Given the fuzzy outranking relation sd, the fuzzy dominance relation $\mu_D(k,l)$ is constructed.

Step 2. Construct the non-dominance relation, $\mu_{ND}(k,l)$.

Step 3. Obtain a set of non-dominated alternatives using, $\mu^*(A_k)$.

Step 4. Identify the best alternative with respect to worst one.

4. PRACTICAL APPLICATION

In this section, a simple numerical example is presented to illustrate the application of the model and solution approach for the global distribution center selection problems. As the global market expands, companies previously focused on domestic competition have been required to assume a more global perspective. A multinational corporation must carefully evaluate market competition and uncertainty of global business environment in the host country before selecting the most appropriate seaport or airport as a global distribution centers (GDCs) which can function as an advance base in the foreign market. Therefore, the model which has been formulated in this study can provide some guidance for decision makers in supply chain risk perspectives. Fig. 4 summarizes the procedure of proposed methodology.

4.1 Presentation of the problem

Global distribution center selection is one of the complicated and most important problem, which is a big challenge for the organizations or corporations these days. A common strategy for corporate growth in recent years has been expansion into global markets. As the global market expands, companies previously focused on domestic competition have been required to assume a more global perspective. A multinational corporation must carefully evaluate market competition in the host country before selecting the most appropriate seaport or airport as a global distribution centers which can function as an advance base in the foreign market. The corporate first collects and analyzes data on each potential location. Compared to selecting global distribution centers is considerably more complex and risky due to the volatility and uncertainty of global business environments.

When evaluating such global distribution centers, not only the expert's judgments may be inexact, but the factors (criteria) themselves may be imprecise and vague. Global distribution center selection thus can be considered a MCDM problem in fuzzy environments. The structure of the proposed problem is given in Fig. 5. The following Global distribution centers selection example is applied to illustrate the proposed fuzzy (MCGDM) with decision marketing processes and case analysis.

4.2 Case solution

After determining the evaluation criteria and the alternatives, the steps of the integrated fuzzy AHP–ELECTRE algorithm are implemented. To obtain the importance of each criterion, the experts employed a scale given in Table 1. The experts provide their opinions on the basis of their expertise and knowledge. The fuzzy linguistic variables are converted in trapezoidal fuzzy numbers using Table 1. Table 2 is used for rating the alternatives with respect to criterion in fuzzy linguistic as well as in numeral form. The evaluation of the pairwise comparison matrix is explained with results in Table 3. In the next step, the aggregated fuzzy evaluation matrix for the criteria weights is obtained as in Table 4. Consistency Ratio (CR) for the defuzzified version of the aggregated fuzzy evaluation matrix is computed as 0.080 and it is less than 0.10. Therefore, the comparison results can be considered consistent.

Next, the fuzzy weights $\tilde{w}_j$ are obtained using Eqs. (1-3). Then, in order to defuzzify and normalize of the obtained weight vector, Eqs. (4) and (5) are employed, respectively. Results of the fuzzy AHP analysis are given in Table 5:
Next step is the determination of the most risky GDCs locations with the proposed fuzzy ELECTRE procedure. To do this, four experts evaluated the GDCs locations. Evaluation results are given in Table 6. Using Tables 3 and 7, fuzzy evaluation matrix is aggregated. Then, employing Eq. (5) the evaluation matrix is defuzzified as in Table 7.
Based on the opinions of the experts and their evaluations on criteria, indifference $\left(t_j^i\right)$, preference $\left(t_j^p\right)$ and veto $\left(t_j^v\right)$ thresholds are determined as in Table 8.
Next, concordance relation ψ_j and discordance relation d_j are constructed using Eqs. (7), (8). Then, aggregated concordance relation ψ (see Table 9) and aggregated discordance relation D
(see Table 10) are obtained using Eqs. (9)–(11). In the next step, the fuzzy outranking relation S_d is maintained by using Eq. (12) (see Table 11).
After maintaining the fuzzy outranking relation, in order to provide a ranking among the alternatives, FDR and FNDR matrices are obtained as in Tables 12 and 13. Finally, the degree of dominance is obtained as in Table 14.

4.3 Case analysis
Selection of these 6(GDCs) are sorted from the best to the worst by the proposed method as shown in Table 14. In this section wediscuss the effectiveness of the proposed methodology and compareit with former research.
According to Table 14, A_4 Port of Peneng (Malaysia) is the location with the highest environmental risk impact among the alternatives. In other words, this area needs urgent attention for the sustainability of the location development. Yokohama Port Cargo center (Japan) A_3 and A_6 (Hong) are the second and third most risky locations. The rank order of the rest from the area with the highest risk impact to the lowest is A_5 Sea port of Shanghai (China), A_2 Port of Bangkok (Thailand), and A_1 (Singapore).

However, our proposed method is more specific in (GDCs) evaluation as it identifies specific criteria and develops an integrated AHP-ELRCTRE methodology for selecting global distribution centers considering risk factors from foreign market perspectives.

4.4 Sensitivity analysis
A sensitivity analysis is conducted in order to monitor the robustness of the preference ranking among the alternative international distribution center to changes in the GDCs criteria weights. Table 15 gives the composition of criteria weights in the considered cases. Fig. 6 shows the order of the alternatives based on their membership of fuzzy dominance $\mu\left(A_k\right)$ values with respect to different weight configurations.

In Fig. 6, the current situation indicates that A_4 Port of Peneng (Malaysia) is the location with the highest environmental risk impact. In Case 1, the situation which all the criteria weights are equal is considered. The ranking among alternatives does not significantly change when the weights are equal. On the other hand, when the weights of the criteria service performance (C_1), logistics systems (C_2), and risk factors (C_8) increase (as in Case 2),Port of Bangkok (Thailand) $A_{2,}$ becomes the most risky area. In Case 3, the weights the criteria of cultural issues (C_5) and risk factors (C_8) are significantly higher than those of the other criteria. This makes Yokohama Port Cargo center (Japan) $A_{3,}$ location the most risky coastal area among the alternatives. When the importance of Infrastructure problems (C_6) is significantly higher than the other criteria and the weight of market potential (C_3) slightly increases (as in Case 4), Seaport of Shanghai (China) A_5 becomes the region with the highest risk impact. In the fifth case, Hong Kong International distribution center (Hong Kong) $A_{6,}$ becomes the most risky area due to the significant increase in the weight of service performance (C_1) criterion.

From the results of sensitivity analysis it can be seen that the leveling among the alternatives is quite sensitive by changing the weights of evaluation criteria.

5. CONCLUSIONS

This study investigated eight criterion of an international DC, including service performance C_1, logistics systems C_2, market potential C_3, environmental issuesC_4, cultural issues C_5, infrastructure problems C_6, government incentives C_7, and risk factors C_8 as (GDCs) selection factors from a high-risk foreign market perspectives. An effective integrated fuzzy AHP-ELECTRE method was then proposed for solving such a problem under a fuzzy group decision environment. International DC selection involves decision making at strategic and management levels, and the subjective, vague and imprecise assessments commonly involved in the process are naturally fuzzy. Fuzzy assessment expressed in linguistic terms is frequently intuitive and effective for DMs during the process of evaluating the above eight selection factors. Additionally, the proposed system assesses individual DMs, which permits management to consider the profession or experience in the decision-making procedure.

The concept of fuzzy sets is a way to deal with vague figures which often better represent the reality. The aim of this study was to propose a(GDCs) methodology based on an integrated fuzzy approach in the context of international distribution centers selection. In the proposed methodology the criteria weights are produced by a fuzzy AHP procedure. A fuzzy outranking methodology, fuzzy ELECTRE is used to assess the risk impact generated by different countries. Finally, a fuzzy dominance relation (FDR) methodology is used to rank the alternatives from the one with the highest impact to the lowest. The sensitivity analysis showed that the ranking among the alternatives are highly sensitive to the changes in the weights of the evaluation criteria.

In the future research, the proposed framework can be applied to assess the risk impact of International distribution centers development plans conducted for different countries or regions. Moreover, similar studies can be conducted based on different fuzzy MCDM techniques such as fuzzy PROMETHEE, fuzzy VIKOR or fuzzy TOPSIS for comparative purposes.

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List of Tables

Table 1
Fuzzy evaluation scale in linguistic variables for rating the weights of criterion.

Linguistic variables	Notations	Fuzzy numbers
Absolutely strong	AS	(2.5, 3, 3.5, 4)
Very strong	VS	(2, 2.5, 3, 3.5)
Moderately strong	MS	(1.5, 2, 2.5, 3)
Slightly strong	SS	(1, 1.5, 2, 2.5)
Equal	E	(1, 1, 1, 1)
Slightly weak	SW	(0.4, 0.5, 0.6, 1)
Moderately weak	MW	(0.3, 0.4, 0.5, 0.6)
Very weak	VW	(0.2, 0.3, 0.4, 0.5)
Absolutely weak	AW	(0.1, 0.2, 0.3, 0.4)

Table 2
Fuzzy evaluation scale in linguistic variables for rating the alternatives.

Linguistic variables	Notations	Fuzzy numbers
Very low	VL	(0, 0, 1, 2)
Low	L	(1, 2, 2, 3)
Medium low	ML	(2, 3, 4, 5)
Medium	M	(4, 5, 5, 6)
Medium high	MH	(5, 6, 7, 8)
High	H	(7, 8, 8, 9)
Very high	VH	(8, 9, 10, 10)

Table 3
Pairwise comparison matrix of all criteria in linguistic form.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
Decision maker 1								
C_1	1	E	SW	MW	SW	E	SW	SS
C_2	E	1	MW	MW	SW	E	SW	SS
C_3	SS	MS	1	SW	E	SS	E	MS
C_4	MS	MS	SS	1	SS	MS	SS	VS
C_5	SS	SS	E	SW	1	SS	E	MS
C_6	E	E	SW	MW	SW	1	SW	SS
C_7	SS	SS	E	SW	E	SS	1	AS
C_8	SW	SW	FW	VW	FW	SW	AW	1
Decision maker 2								
C_1	1	E	MW	AW	VW	VW	AW	MW
C_2	E	1	MW	VW	AW	VW	AW	MW
C_3	MS	MS	1	SW	SW	E	SW	E
C_4	AS	VS	SS	1	E	MS	E	SS
C_5	VS	AS	SS	E	1	SS	E	SS
C_6	VS	VS	E	MW	SW	1	SW	E

C_7	AS	AS	SS	E	E	SS	1	SS
C_8	MS	VS	E	SW	SW	E	SW	1
Decision maker 3								
C_1	1	E	SS	E	E	MS	E	E
C_2	E	1	SS	E	E	SS	E	E
C_3	SS	SW	1	SW	MW	SS	SW	SW
C_4	E	E	SS	1	E	MS	E	E
C_5	E	E	MS	E	1	MS	E	E
C_6	MS	SW	SW	MW	MW	1	MW	MW
C_7	E	E	SS	E	E	MS	1	E
C_8	E	E	SS	E	E	MS	E	1
Decision maker 4								
C_1	1	E	E	SW	SW	FW	E	E
C_2	E	1	E	MW	SW	SW	E	E
C_3	E	E	1	SW	SW	SW	E	E
C_4	SS	MS	SS	1	E	E	SS	MS
C_5	SS	MS	SS	E	1	E	MS	SS
C_6	MS	SS	SS	E	E	1	SS	SS
C_7	E	E	E	SW	MW	SW	1	E
C_8	E	E	E	MW	SW	SW	E	1

Table 4
Pairwise comparison matrix by integrating four expert's opinions of all criteria in numerical form.

	C_1	C_2	C_3	…. ….	C_8
C_1	(1,1,1,1)	(1,1,1,1)	(0.67,0.85, 0.85,0.76)	…. ….	(0.84,0.99,0.99,1.28)
C_2	(1,1,1,1)	(1,1,1,1)	(0.66,0.84,0.84,1.22)	…. ….	(0.84,0.99,0.99,1.28)
C_3	(0.97,1.54,1.54,1.87)	(1.2,1.68,1.68,2)	(1,1,1,1)	…. ….	(0.97,1.12,1.12,1.5)
:	…. ….	…. ….	…. ….	…. ….	…. ….
:	…. ….	…. ….	…. ….	…. ….	…. ….
C_8	(0.99,1.28,1.28,1.5)	(0.99,1.28,1.28,1.5)	(0.85,1.13,1.13,1,30)		(1,1,1,1)

Table 5
Fuzzy AHP computations for the calculation of the criteria weights.

	$\tilde{W}_j$	$W_j^{'}$	W_j
C_1	(0.073, 0.091, 0.091, 0.14)	0.0951	0.0921
C_2	(0.061, 0.091, 0.091, 0.14)	0.0931	0.0900
C_3	(0.071, 0.112, 0.112, 0.19)	0.1140	0.1110
C_4	(0.113, 0.180, 0.180, 0.27)	0.1853	0.1793
C_5	(0.100, 0.160, 0.160, 0.25)	0.1672	0.1624
C_6	(0.070, 0.110, 0.110, 0.18)	0.1182	0.1143
C_7	(0.100, 0.150, 0.150, 0.23)	0.1513	0.1462
C_8	(0.070, 0.112, 0.112, 0.16)	0.1110	0.1075

Table 6

Fuzzy linguistic rating for the alternative evaluations with respect to criteria.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
Decision maker 1								
A_1	H	H	ML	M	M	VL	H	M
A_2	VH	MH	M	M	M	M	M	VH
A_3	MH	F	ML	H	H	MH	H	M
A_4	MH	MH	H	H	H	M	H	M
A_5	MH	ML	MH	M	M	VH	M	M
A_6	H	MH	VH	MH	MH	M	M	M
Decision maker 2								
A_1	VH	MH	M	M	M	L	H	M
A_2	H	VH	M	M	M	VL	H	VH
A_3	MH	M	MH	MH	VH	M	H	H
A_4	MH	H	M	H	H	M	VH	M
A_5	M	ML	M	H	H	H	M	M
A_6	MH	M	M	MH	MH	F	M	MH
Decision maker 3								
A_1	VH	H	M	M	M	L	M	M
A_2	H	VH	M	L	M	ML	M	M
A_3	M	M	ML	H	H	M	VH	H
A_4	MH	MH	ML	VH	H	MH	H	H
A_5	ML	ML	M	M	M	VH	M	M
A_6	H	MH	M	VH	M	M	M	H
Decision maker 4								
A_1	H	H	M	M	M	M	M	M
A_2	H	H	M	L	M	M	M	M
A_3	M	M	M	H	VH	M	M	M
A_4	L	MH	ML	H	H	MH	M	M
A_5	H	H	M	M	M	VH	M	M
A_6	MH	MH	M	MH	M	H	M	M

Table 7

Fuzzy evaluation matrix for all alternatives

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	8.678	7.637	4.630	5.000	5.000	2.513	6.532	5.012
A_2	8.430	8.121	5.000	3.521	5.032	3.563	5.760	7.169
A_3	5.773	5.000	4.525	7.525	8.669	5.377	7.586	6.521
A_4	5.476	6.921	5.000	8.420	8.053	5.776	7.586	5.751
A_5	5.751	4.524	5.436	5.751	5.756	9.435	5.000	5.071
A_6	7.245	6.130	6.099	7.300	5.756	5.756	5.000	6.229

Table 8

Indifference $\left(t_j^i\right)$, preference $\left(t_j^p\right)$ and veto $\left(t_j^v\right)$ thresholds values for the criteria

	$\left(t_j^i\right)$	$\left(t_j^p\right)$	$\left(t_j^v\right)$
C_1	0.981	1.970	6.881
C_2	1.011	2.020	6.051
C_3	0.820	1.634	4.890
C_4	0.512	1.011	3.030
C_5	0.562	1.112	3.340
C_6	0.789	1.591	4.761
C_7	0.634	1.234	3.702
C_8	0.856	1.690	5.071

Table 9

Aggregated concordance relation matrix

	A_1	A_2	A_3	A_4	A_5	A_6
A_1	1	0.834	0.332	0.467	0.745	0.531
A_2	0.791	1	0.387	0.387	0.645	0.651
A_3	0.891	0.891	1	0.815	0.866	0.845
A_4	0.809	0.832	0.976	1	0.866	0.880
A_5	0.673	0.681	0.432	0.432	1	0.683
A_6	0.796	0.854	0.691	0.532	0.866	1

Table 10

Aggregated discordance relation matrix

	A_1	A_2	A_3	A_4	A_5	A_6
A_1	1	1	0.775	0.759	0.877	0.976
A_2	1	1	0.751	0.785	0.877	0.877
A_3	1	1	1	1	1	1
A_4	1	1	1	1	1	1
A_5	1	1	0.893	0.875	1	1
A_6	1	1	0.955	0.993	1	1

Table 11

Fuzzy outranking relation matrix

	A_1	A_2	A_3	A_4	A_5	A_6
A_1	1	0.834	0.257	0.354	0.653	0.518
A_2	0.794	1	0.291	0.304	0.566	0.571
A_3	0.891	0.891	1.000	0.815	0.866	0.845
A_4	0.809	0.832	0.976	1.000	0.866	0.880
A_5	0.673	0.681	0.386	0.378	1.000	0.683
A_6	0.796	0.854	0.660	0.528	0.866	1.000

Table 12
Fuzzy dominance relation matrix

	A_1	A_2	A_3	A_4	A_5	A_6
A_1	0	0.068	0	0	0	0
A_2	0	0	0	0	0	0
A_3	0.619	0.447	0	0	0.505	0.197
A_4	0.480	0.521	0.119	0	0.517	0.375
A_5	0.021	0.113	0	0	0	0
A_6	0.226	0.316	0	0	0.193	0

Table 13
Fuzzy non-dominance relation matrix

	A_1	A_2	A_3	A_4	A_5	A_6
A_1	1	0.932	1	1	1	1
A_2	1	1	1	1	1	1
A_3	0.381	0.553	1	1	0.495	0.803
A_4	0.520	0.479	0.881	1	0.483	0.625
A_5	0.979	0.887	1	1	1	1
A_6	0.774	0.684	1	1	0.807	1

Table 14
Degree of dominance.

	A_1	A_2	A_3	A_4	A_5	A_6
Min (FNDR)	0.520	0.479	0.881	1	0.483	0.625

Table 15
Sensitivity analysis by changing criteria weights with respect to the considered cases

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
Scenario 0	0.0921	0.0900	0.1110	0.1793	0.1624	0.1143	0.1462	0.1075
Scenario 1	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Scenario 2	0.200	0.200	0.050	0.050	0.050	0.050	0.050	0.200
Scenario 3	0.050	0.050	0.050	0.050	0.350	0.050	0.050	0.350
Scenario 4	0.070	0.070	0.150	0.070	0.070	0.370	0.070	0.070
Scenario 5	0.370	0.090	0.090	0.090	0.090	0.090	0.090	0.090

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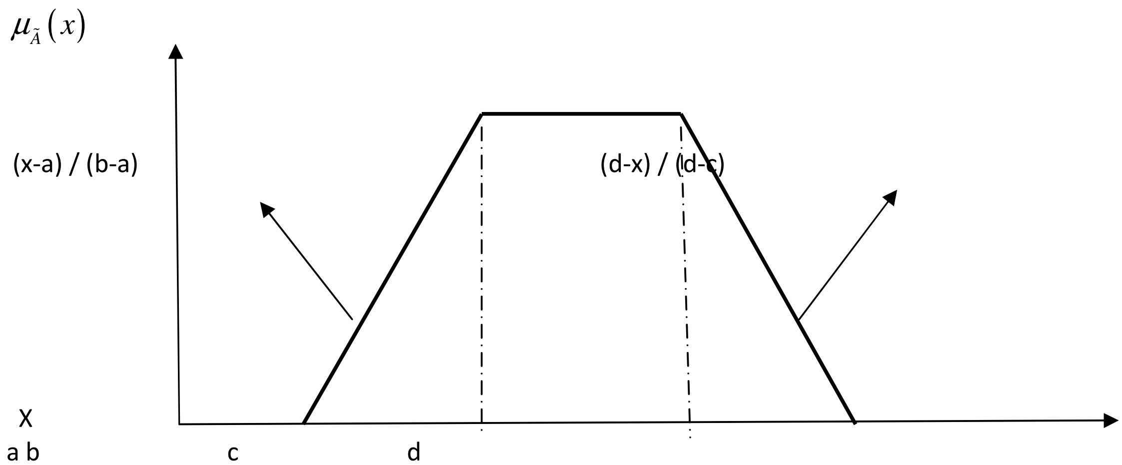

Figure .1. Membership function of trapezoidal fuzzy numbers

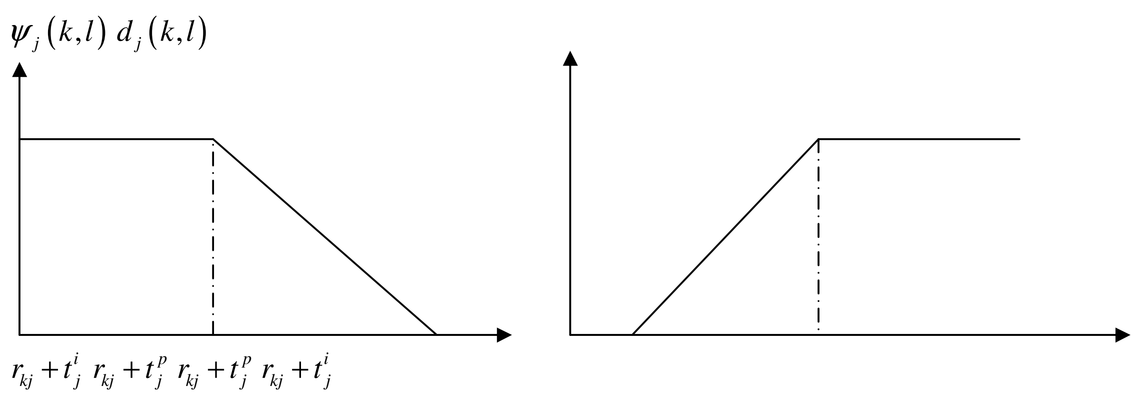

Figure. 2. Fuzzy concordance and disconcordance functions

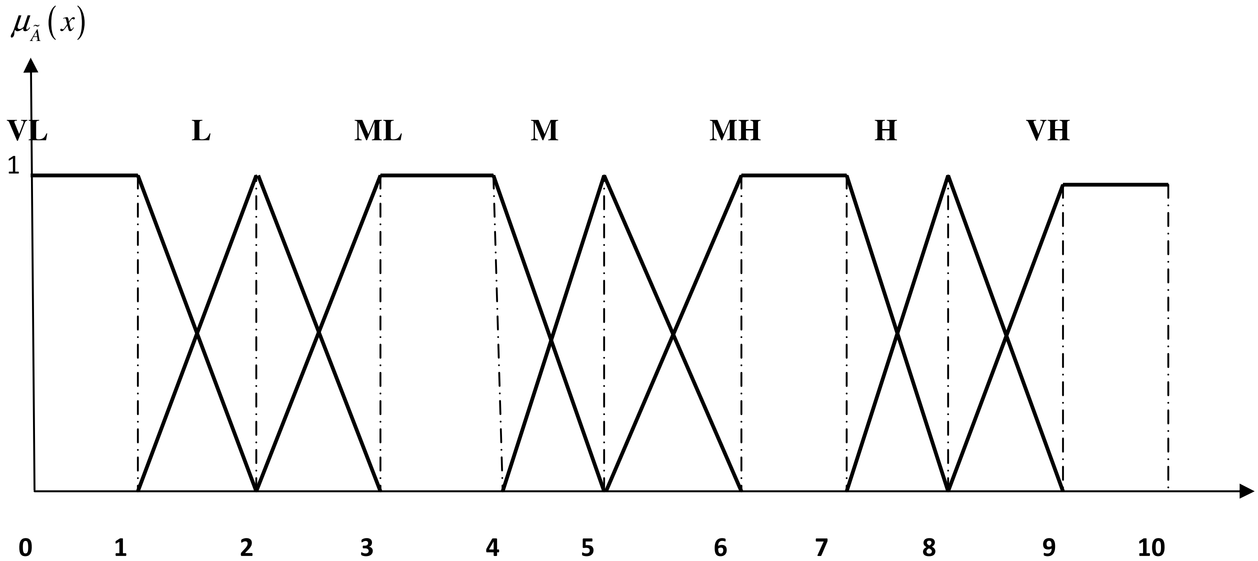

Figure. 3 Fuzzy evaluation scale for rating the alternatives

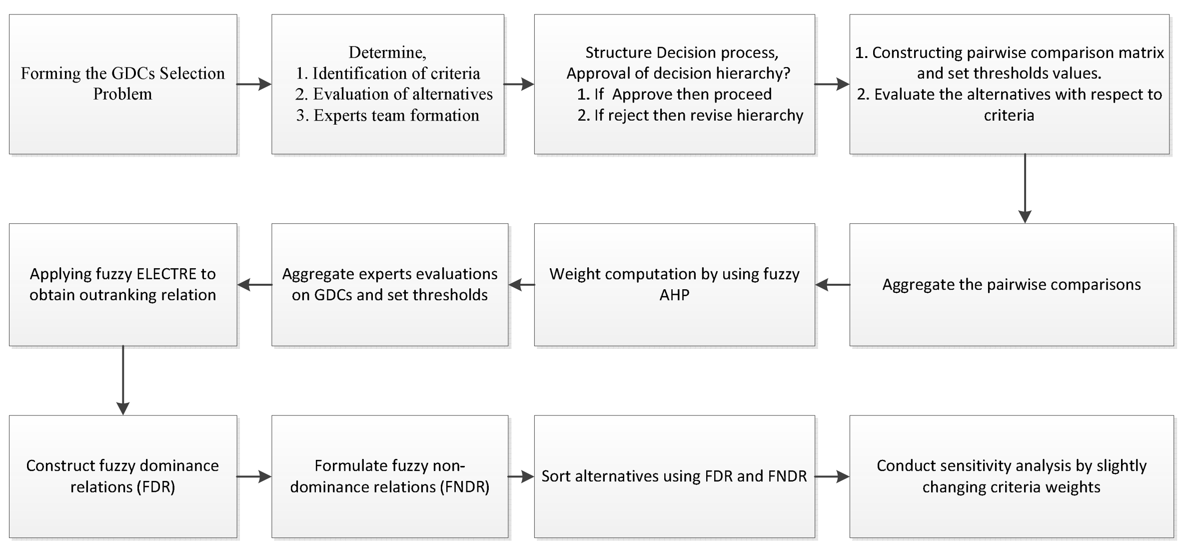

Figure. 4 Proposed hybrid fuzzy AHP-ELECTRE framework for (GDCs) selection

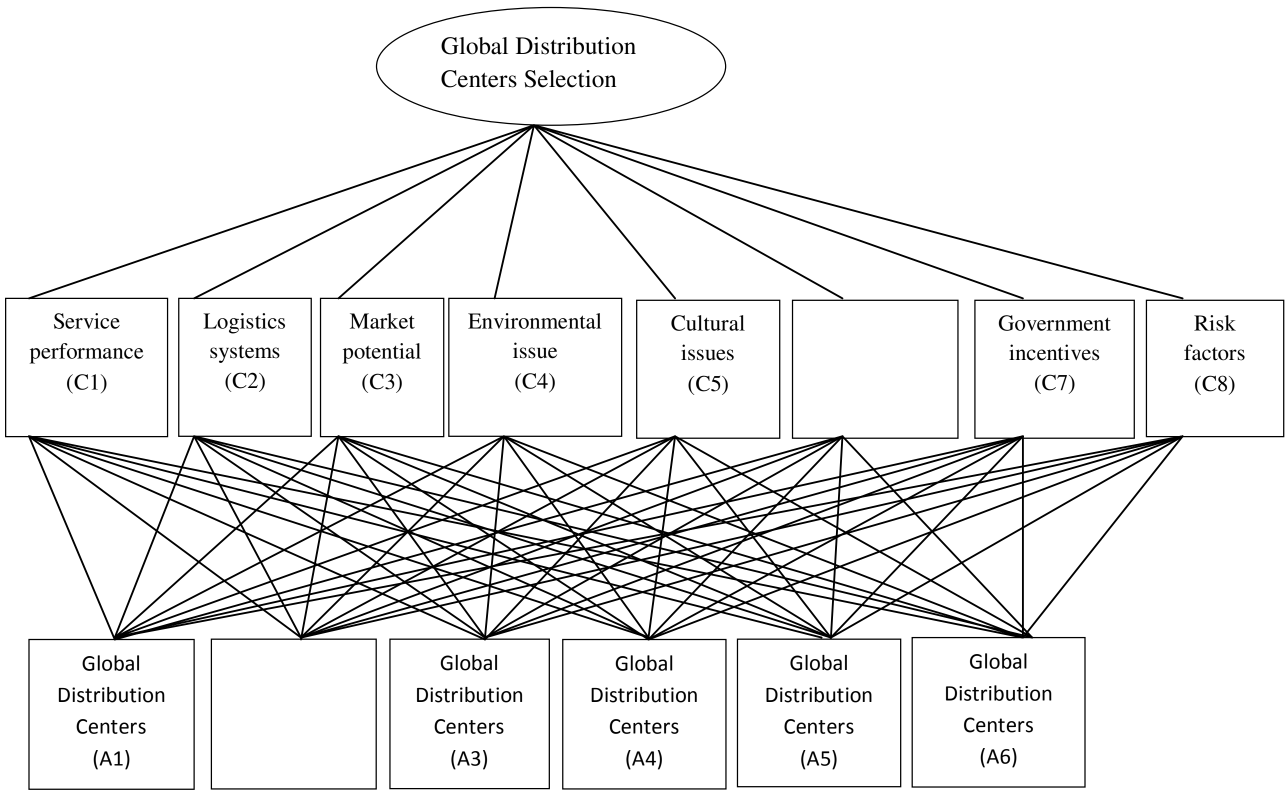

Figure. 5. Decision hierarchy for selecting global distribution centers problem

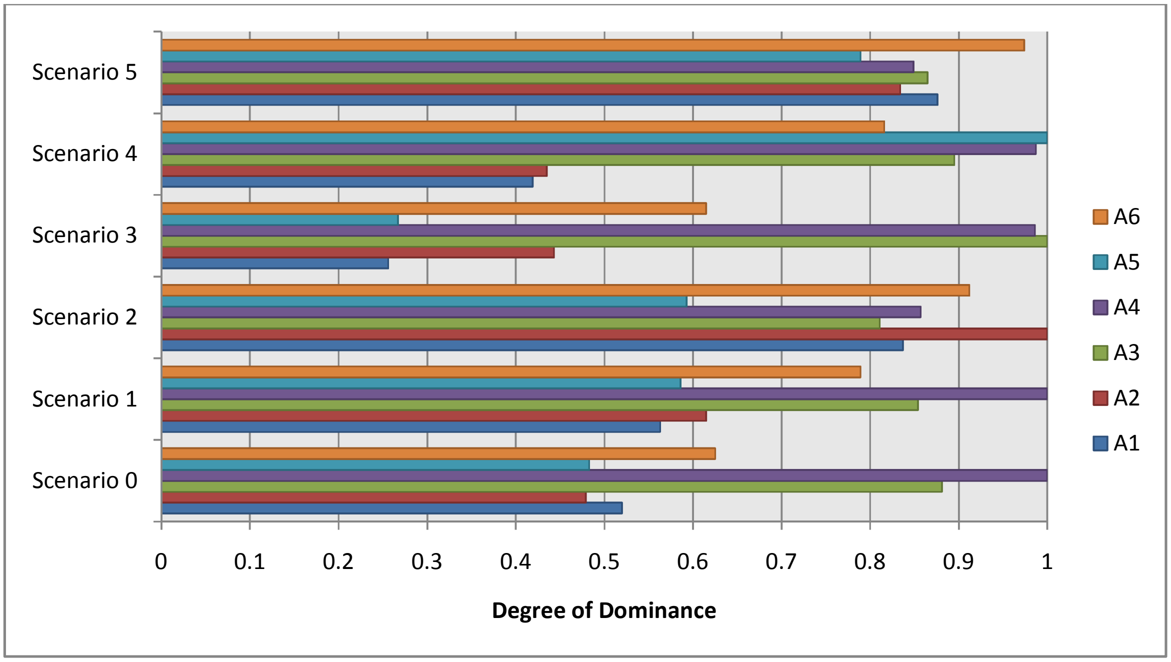

Figure. 6. Sensitivity analysis