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The pre-positioning of warehouses at regional and local levels for a humanitarian relief organisation

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ABSTRACT

Using pre-positioned warehouses at strategic locations around the world is an approach commonly taken by some humanitarian relief organisations to improve their capacities to deliver sufficient relief aid within a relatively short time frame, and to provide shelter and assistance to disaster victims. Although research into the facility location problem is extensive in both theory and application, such approaches have received little attention from the humanitarian relief perspective. In this paper we consider the pre-positioning of warehouses for humanitarian relief organisations from both macro-(which country, which region) and micro-(the immediate locality) perspectives, and analyse the managerial implications of those decisions. In case study A, managerial level officers were interviewed in order to obtain data for an analysis of the positioning of warehouses at a regional level. Case study B identifies a specific location in the Dubai area where stakeholders from different organisations participated in both discussions and interviews. Through the use of the Analytic Hierarchy Process, the relative importance of individual criteria was determined. The fuzzy-TOPSIS method was used to obtain the final ranking of locations where linguistic values handle the vagueness and subjectivity of decisions. The contribution of this work is as follows: useful managerial insights and implications related to the pre-positioning of warehouses at both macro- and micro-levels are provided; further, a range of possible locations for a humanitarian relief organization, using a robust multicriteria decision making framework, is proposed.

1. Introduction

One of the most serious problems affecting the modern world is the vulnerability of nations or regions to natural disasters (e.g. earthquakes, floods, drought) or man-made crises (civil unrest, war, political/tribal disturbance) (Pettit and Beresford, 2005; Roh et al., 2008; Tatham and Altay, 2013). Natural disasters can occur with little or no warning (Wijkman and Timberlake, 1998) and there is strong evidence that globally, natural disasters have increased in terms of both frequency and impact. Disaster-prone areas are experiencing more frequent emergencies and previously benign areas, unaffected by extremes, are now affected. The total number of natural disasters occurring annually peaked in the 2000–2004 period, around 40% higher than between 1995 and 1999. Subsequently the total has reduced slightly to around 2100 recorded events in the most recent five year period 2008–2013. The number of people affected by natural disasters also increased, peaking between 2000 and 2004 at 1.4 billion people, 22% more compared to the 1995–1999 period. As with the number of events, the total number of people affected has also fallen, to around 1.03 billion in the 2008–2013 period (CRED EM-DAT, 2014). The scale of such disasters means that the importance of emergency relief response operations has received increased attention in the last decade (Thomas and Kopczak, 2005, Balcik and Beamon, 2008; IFRC, 2014).

Different regions are subject to different disaster types and while the occurrence of disasters is irregular on an annual basis, there is a trend for large scale disasters to occur in certain areas. Nonetheless, the most common major natural disasters that affect specific regions are floods, windstorms, droughts and earthquakes, giving some predictability which can assist in the preparedness phase, but timing, extent and duration of such emergencies remain unpredictable. Disasters that occur in Africa will not be same as those that occur in Asia; Africa suffers more from famine and drought, while Asia suffers mostly from hydro meteorological disasters, such as floods and windstorms. Areas prone to natural hazards are also vulnerable to civil or political strife which is often precipitated by famine, water shortage or other natural extremes. As the characteristics of disasters around the world vary from region to region it is likely that different combinations of aid stocks could be pre-positioned in different locations. This is in part already serviced through shared facilities provided by for example the United Nations (UN) (Heaslip, 2013).

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Such disasters have highlighted the importance of emergency relief response logistics. The crucial role of logistics in emergency relief has been recognised by the organisations involved in field operations and through research which has highlighted a range of activities dependent on emergency supplies. Humanitarian aid delivery and emergency relief operations are often complex, involving many organisations and several phases of activity: all of which are important. Here, emphasis is primarily on activities related to the preparedness phase.

The unpredictability of natural disasters often leads to relief operations focusing more on response rather than preparedness, so systems are reactive rather than proactive and the structure of the supply chain will determine the effectiveness of the response. Efficient delivery of relief aid is expensive: substantial losses of aid often occur, transport providers charge emergency premiums, and insurance levies are raised. Pre-positioning of aid closer to areas where there is an above average possibility of disasters occurring is one technique which some agencies now use to improve their capacity and response times to major natural disaster events, saving time and reducing the cost of operations (Tomasini and Van Wassenhove, 2004; Beresford and Pettit, 2007; Balcik and Beamon, 2008; Balcik et al., 2010).

Many studies have addressed the importance of the preparedness phase and the need for pre-positioned warehouses in humanitarian relief logistics, but only a small number of papers are related to the location decision (Dekle et al., 2005; Balcik and Beamon, 2008; Ukkusuri and Yushimoto, 2008; Dessouky et al., 2009; Rawls and Turnquist, 2010; Gatignon et al., 2010; Campbell and Jones, 2011). Gatignon et al. (2010) illustrate the implementation of a decentralised model at the International Federation of the Red Cross (IFRC) using the pre-positioned warehouse concept. Campbell and Jones (2011) use a cost model to examine the preposition of supplies and the volume of goods in preparation for a disaster. Nevertheless, where the above studies discuss the optimal location based on a single criteria (e.g. minimum total costs), the evaluation process for strategic decisions often involves several attributes and it is usually necessary to make compromises among possibly conflicting tangible and intangible factors (Onut and Soner, 2007). This transforms the problem to a multi-criteria decision-making (MCDM).

In this paper, we use MCDM for location problems in the context of humanitarian relief logistics. This area of application has been used only to a limited extent because there is a need to consider multiple attributes in the location decision-making area. Subjectivity (e.g. individuals' opinions), uncertainty (e.g. likelihood of occurrence) and ambiguity (e.g. conflicting messages) in the assessment process also need to be considered (Dagdeviren et al., 2009). Here, these issues are addressed by considering two case studies of humanitarian relief organisations operating at both international (macro-level) and local (micro) levels. Consideration of both levels provides insights into how such organisations consider different factors at each level when making location decisions, something that has not previously been addressed in the literature in this context. Interviews, discussion panels, and Analytic Hierarchy Process (AHP) are used to determine the importance of specific criteria, and fuzzy-TOPSIS is used to obtain the final location ranking.

2. Disaster networks

Fundamental decisions forming the basis of logistics system design are the number of facilities, their location, and the assignment of products to facilities and markets (Korpela and Tuominen, 1996). Ballou (2004) defined the key decision areas in logistics system design as inventory policy, facility location, and transport selection and routing. Logistics system design studies are also relevant in the area of humanitarian relief logistics because of the necessity of pre-positioning of stocks in order to cope with uncertainty and the need to respond quickly in the event of a disaster occurring. However, most studies in respect of humanitarian relief logistics use single objective optimisation models that do not incorporate qualitative attributes. The modelling of disaster response has been attempted by, for example, Pettit and Beresford (2005), Banomyong et al. (2009) and Caunhye et al. (2012). These studies demonstrate that if the models themselves become too complex their value in the context of humanitarian relief logistics tends to reduce. This is because first opportunities to rehearse for emergencies are limited, hence communication channels and chains of responsibility must be very clear and unambiguous. Second, the diversity of users tends to drive-out complexity in favour of lowest-common-denominator principles leading again to simpler models.

The literature that relates to emergency logistics covers many different subject areas; such as evacuation, stock pre-positioning, facility location, relief distribution and casualty transportation. Fig. 1 illustrates the structure of disaster operations and the role of warehouse pre-positioning in disaster management. Many studies related to humanitarian relief logistics operational activities focus on the objective of optimising the flow of supplies through existing distribution networks and post-disaster events (Balcik and Beamon, 2008). Tzeng et al. (2007) compared the characteristics of general and relief distribution systems (Table 1). The objectives of traditional distribution systems which have permanent warehouse and distribution centres are to minimise total costs and to maximise service capacity. On the contrary relief distribution systems have temporary storage points and, instead of focusing on profit, work to provide timely response. Cost minimisation and profit are not the key objectives, rather the primary

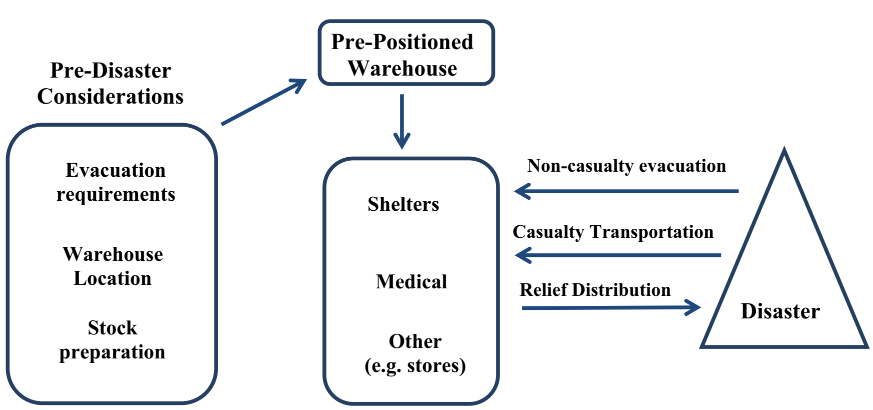

Fig. 1. Disaster operations and role of warehouse prepositioning. *Based on* Caunhye et al. (2012).

Table 1
Comparison of general and relief distribution systems. Source: Tzeng et al. (2007).

Comparison items	General distribution systems	Relief distribution systems
System objectives	Maximise profit	Fairness and efficiency
Dimensional role	Factories	Collection points for commodities
	Distribution centres	Transfer depots for commodities
	Customers	Demand points of commodities
Facility characteristics	Regular facilities	Temporary facilities
	Substantial/tangible existence	
Scheduling plan	Long term: location	Urgent decisions based on available information
	Median-term: vehicle-fleet size	
	Short-term: scheduling	
Trade-offs between algorithm-efficiency and optimisation	Paying attention optimisation	Emphasis of algorithm efficiency
Delivery models	Round-trip delivery; circulating delivery	Round-trip delivery

focus is on the saving of life. Thus the providers of disaster relief are often governments, or not-for-profit organisations who are aiming to pursue efficiency with fairness.

3. Multi-criteria location decision-making

A number of different techniques are available for multi criteria decision making: multi-objective evolutionary algorithms; and classical methods where a weighting is applied to different attributes e.g. AHP or where objective functions are modelled as constraints transforming the problem formulation into a single objective. In this paper a AHP- fuzzy-TOPSIS approach is used to integrate quantitative and qualitative measures and the literature reviewed in this section considers studies in this field (Saaty, 1980).

The attributes considered for warehouse selection vary from case-to-case (e.g. by country or by industry). A comprehensive review of the key attributes for selecting warehouse location, distribution/logistics centres and general facility selection was undertaken to identify similarities among criteria where their importance is assessed differently according to the research characteristics. The inconsistent grouping of criteria depends on how researchers formulate and analyse the problem and how the hierarchical structure of attributes is determined. For the warehouse selection problem, Alberto (2000) grouped attributes into seven criteria: environmental aspects, cost, quality of living, local incentives, time reliability provided to customers, response flexibility to customer's demands, and integration with customers. Demirel et al. (2010) identified cost, labour characteristics, infrastructure, markets and macro-environment in their study of a warehouse selection in Turkey. Korpela and Tuominen (1996) considered reliability, flexibility, and strategic compatibility for their main criteria whereas Özcan et al. (2011) used unit price, stock holding capacity, average distance to shops, average distance to main suppliers, and movement flexibility (see Table 2). Distribution/logistics centre attributes are discussed in Awasthi et al. (2011) where they considered 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 services. The distribution centre selection for Asia-Pacific region was studied by Sarkis and Sundarraj (2002) where cost, accessibility, time, regulatory, risk, labour, and strategic issues. Studies for selecting logistics centre have been researched by Kayikci (2010) and Li et al. (2011). Kayikci (2010) presented a case where an economical scale, national stability, intermodal operation and management, international market location, and environmental effect were considered. Li et al. (2011) considered weather and landform condition, water supply, power supply, solid cast-off disposal, communication, traffic, candidate land area, candidate land shape, candidate land circumjacent main line, candidate land land-value, freight transport, and fundamental construction investment.

A comparative analysis between AHP and TOPSIS is presented by Özcan et al. (2011). Kahraman et al. (2003) used a combination of AHP and TOPSIS for the location decision problem that could be applied to plants, warehouses, retail outlets, terminals, storage yards, and distribution centres. Cinar (2009) presented a decision support model for bank branch location selection in South-Eastern of Turkey to select the most appropriate city for opening a new branch. Lin and Tsai (2010a; 2010b) evaluated where the optimal city in South China for new medical facilities was likely to be. Onut et al. (2010) applied the integration of the AHP-TOPSIS method for selecting the optimal shopping centre locations in Istanbul, Turkey. Hsieh et al. (2006) and Joshi et al. (2011) justified the use of TOPSIS after AHP as it can avoid the predicament that the units under evaluation are not of the same value, and cannot be appropriately ranked.

The AHP and TOPSIS methods use exact values for experts' criteria, sub-criteria, and alternatives (Torfi et al. 2010). However, in many practical cases, the experts' preferences are uncertain and they are reluctant or unable to make numerical comparisons (Torfi et al., 2010; Kelemenis and Askounis, 2010) because in real-life decision problems, perfect knowledge is not easily acquired, it is often unquantifiable or incomplete and may not be obtainable under many conditions (Kelemenis and Askounis, 2010; Olcer and Odabasi, 2005). In addition, qualitative criteria are often accompanied by ambiguities and vagueness (Onut et al., 2010). In such situations, fuzzy decision-making is a powerful tool for assisting in the decision-making process in what have become termed fuzzy environments (Onut et al., 2010; Torfi et al., 2010). Criteria weights and alternative ratings are given by linguistic variables that are expressed as fuzzy numbers (Kelemenis and Askounis, 2010). The concept of applying fuzzy numbers to TOPSIS was first suggested by Negi (1989) and Chen and Hwang (1992). In this paper fuzzy-TOPSIS is applied to solve ranking and evaluation problems (Ashtiani et al., 2009; Wang and Lee, 2009).

4. Methodology

The methodology used in this paper for the humanitarian warehouse location selection problem integrates the AHP and fuzzy-TOPSIS methods and consists of two stages: (1) identification of the criteria to be used in the model through Group Working and AHP computations; and (2) evaluation of the alternatives with fuzzy-TOPSIS and the determination of the final ranking (Amiri, 2010, Yu et al., 2011). Fig. 2 provides an overview of the methodology used in the current study and in subsequent subsections each stage of the methodology is discussed.

4.1. Stage 1: group working and AHP

The process for developing a robust AHP decision hierarchy and the finalisation of the criteria weighting begins with the formation

Table 2
Literature related to warehouse multi-criteria decision problem.

Author	Criteria	Sub-criteria
Alberto (2000)	Environmental aspects	Environmental regulations, proximity to disposal plants, taxation
	Cost	Operating cost; start-up cost
	Quality of living	Climate; crime rate; traffic congestion; living expense
	Local incentives	Tax incentives; union; laws; skilled labour
	Time reliability provided to customers	Proximity to carriers; proximity to suppliers; proximity to customers; waterway; rail; highway
	Response flexibility to customer's demand	Proximity to suppliers; proximity to other company's complementary facilities; proximity to customers;
	Integration with customers	Facilitation of post-sale service; facilitation of co-maker ship; facilitation of co-design
Demirel et al. (2010)	Costs	Labour cost; transportation cost; tax incentives and tax structure; financial incentives; handling costs
	Labour characteristics	Skilled labour; availability of labour force
	Infrastructure	Existence of modes of transportation; telecommunication systems; quality and reliability of modes of transportation
	Markets	Proximity to customers; proximity to suppliers or producer; proximity to suppliers or producer; lead times and responsiveness
	Macro-environment	Policies of government; industrial regulations laws; zoning and construction plan
Korpela and Tuominen (1996)	Reliability	Compliance; accuracy; transportation; facilities/equipment; skills of personnel; damage-free handling
	Flexibility	Special request; urgent deliveries; capacity
	Strategic compatibility	Strategic alliance; strategic fit; co-operation
Özcan et al. (2011)	Unit price	
	Stock holding capacity	
	Average distance to shops	
	Average distance to main suppliers	
	Movement flexibility	

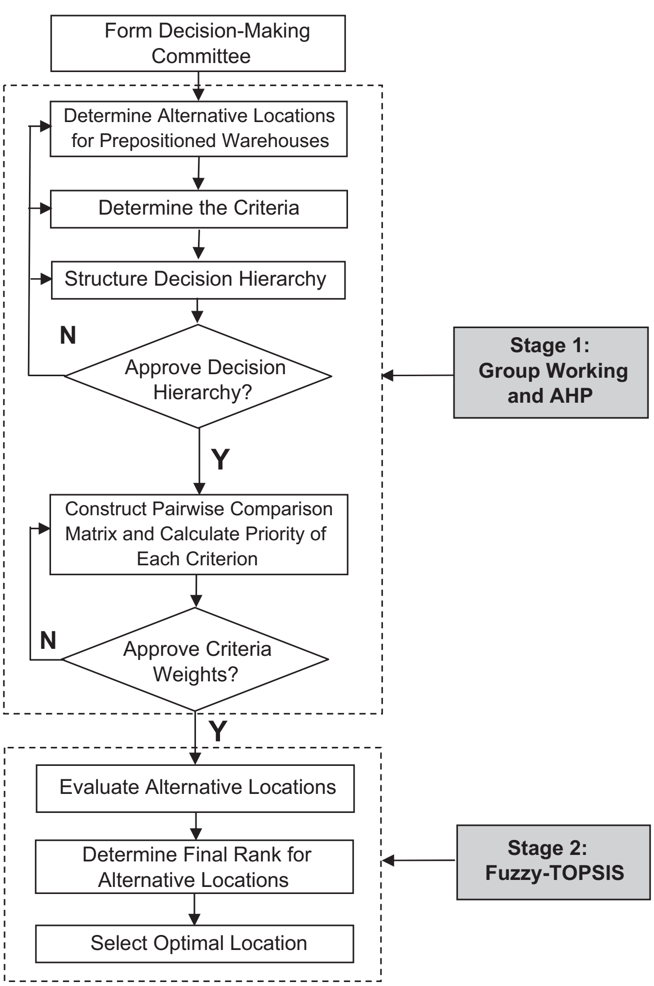

Fig. 2. Methodology for ranking alternative locations. *Based on* Yu et al. (2011).

of a decision making team. Stage 1 involved this team evaluating and approving alternative criteria and determining the decision hierarchy. The increasing complexity of socio-economic environments makes it increasingly likely that decision-makers are unable to consider all the relevant aspects of a problem. Consequently, many organisations employ groups to assist in resolving decision-making problems (Ahn, 2000). Moving from a single to a group decision-maker setting introduces complexity into multi criteria analysis. AHP allows group decision-making, where decision-makers use their experience and knowledge to make decisions in a hierarchical fashion, placing the overall objective of the decision at the top of the hierarchy and the criteria, sub-criteria and decision alternatives on each descending level of the hierarchy.

Table 3
Numerical values of importance of criteria used for comparison.

Definition	Numerical value
Equal importance	1
Moderate importance	3
Strong importance	5
Very strong importance	7
Extreme importance	9
Intermediate values between adjacent scale values	2, 4, 6, 8

AHP allows the determination of the relative importance of individual criteria in a multi-criteria decision problem. The method is based on three principles: (1) the structure of the model; (2) a comparative judgment of the alternatives and (3) the criteria synthesis of the priorities (Saaty, 1980; Amiri, 2010). After the approval of the decision hierarchy, a pairwise comparison matrix is formed to determine the priority of the criteria. The decision-making team makes individual evaluations using a scale of nine levels to determine the values of the elements for the pairwise comparison matrix. Table 3 shows how the relevant importance is determined between two criteria and how it is converted into a numerical rating. The consensus of preferences of the attributes among the participants are calculated using a geometric mean. Entries for the remaining cells of the matrix are completed by taking a reciprocal of the numerical values of importance, when the comparison of two particular criteria is undertaken.

The next step is to calculate the priority of each criterion in terms of contribution to the overall goal of selecting the best warehouse location. This process is known as a synthesisation and can be determined using an exact mathematical method or by applying a procedure that provides a good approximation of the synthesisation result. The following synthesisation procedure is used: 1) calculate normalised pairwise comparison matrix through adding all values in each column and dividing each element by its column total; 2) compute priorities for each criteria by calculating the average of the values in each row of the normalised matrix (Anderson et al., 2013).

Since the comparisons are carried out through personal or subjective judgments, some degree of inconsistency may occur. Therefore to guarantee that the judgments are consistent, consistency verification is undertaken, where if a consistency ratio is less than 0.1, then the judgments are considered to be consistent and the pairwise comparisons are acceptable (Saaty, 1980). If the consistency ratio is greater than 0.1, the pairwise comparisons have to be reviewed by the decision maker before proceeding to Stage 2 where the best location for the prepositioned warehouse is determined. To calculate the consistency ratio (CR), λmax is determined, that is, an average of the values are calculated as follows: each value in a specific column of the pairwise comparison matrix is multiplied by the corresponding priority of that criteria; the values across the rows are added to obtain the weighted sum; then the values in the weighted sum are divided by the corresponding priority of each criterion. Subsequently, the consistency index (CI), CI=(λmax – n)/(n – 1) is computed and then used to calculate CR=CI/RI. RI is the consistency index of a randomly generated pairwise comparison matrix and this index depends on the number of items being computed. In both case studies presented in this paper there are $n=5$ criteria, therefore RI=1.12 according to the random consistency indices table (Saaty and Kearns, 1985; Anderson et al., 2013). For the last step of this stage, calculated weights for the criteria are approved by the decision-making team. The mechanics of the AHP process is described in more detail in Torfi et al., 2010.

4.2. Stage 2: fuzzy-TOPSIS

In many applications it is difficult to handle ambiguous and vague issues, unquantifiable and non-obtainable information, or to deal with incomplete information. Mathematical models cannot always address decision-makers' ambiguities, uncertainties and vagueness (Chan and Kumar, 2007; Kulak et al., 2005). In such cases, linguistic values can be used by decision makers to evaluate the importance of the criteria and to rate alternatives with respect to various criteria, especially in relation to multi-criteria decision making (Farahani et al., 2010). Fuzzy sets theory can be used to present linguistic values and to assign the relative importance of criteria using fuzzy values rather than numerical values (Yu et al., 2011). In this research, Stage 2 involved the evaluation of alternative warehouse locations and the determination of the final ranking of locations using the fuzzy-TOPSIS method. Definitions for fuzzy sets and operational laws between two triangular fuzzy numbers are defined by, for example, Torfi et al. (2010) and Yu et al. (2011).

Triangular fuzzy numbers are defined by a triplet (a_1, a_2, a_3) that can be seen as part of the mathematical formulation of the triangular fuzzy number as shown in the following equation (Yu et al., 2011):

$$\mu_{\tilde{a}}(x) = \begin{cases} 0 & x < a_1, \\ \frac{x - a_1}{a_2 - a_1}, & a_1 < x \le a_2, \\ \frac{a_3 - x}{a_3 - a_2}, & a_2 < x \le a_3, \\ 0 & x > a_3. \end{cases} \quad (1)$$

Then, suppose $a=(a_1, a_2, a_3)$ and $b=(b_1, b_2, b_3)$ are two triangular fuzzy numbers where the distance between the fuzzy numbers is shown in the following equation (Yu et al. 2011):

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

The fuzzy-TOPSIS approach, adopted from Torfi et al. (2010) and Yu et al. (2011) is described below

- Construct a fuzzy evaluation matrix with linguistic values x_{ij} ($i=1, 2 \ldots m$; $j=1, 2 \ldots n$, where m is the number of alternative locations and n is the number of criteria). The current study transforms the precise values to five levels of fuzzy linguistic variables. Values graded as Very Low (VL) rank have a membership function (0.00, 0.10, 0.25), Low (L) use (0.15, 0.30, 0.45), (0.35, 0.50, 0.65) for a Medium (M) rank, High (H) rank uses (0.55, 0.70, 0.85) and (0.75, 0.90, 1.00) for a Very High (VH) rank.
- Construct the weighted normalised fuzzy decision matrix with values v_{ij}

$$v_{ij} = x_{ij} \times w_j \quad i = 1, 2 \ldots m; \quad j = 1, 2 \ldots n. \quad (3)$$

w_j is a weight if a criterion j that is computed in Stage 1 as part of AHP calculations.

- Compute the fuzzy positive-ideal solution (FPIS, A^*) and the fuzzy negative-ideal solution (FNIS, A^-):

$$A^* = \{v_1^*, v_2^*, \ldots, v_n^*\} = \{(\max_j v_{ij} \mid i \in I'), (\min_j v_{ij} \mid i \in I'')\}, \quad i = 1, 2, \ldots, m; \quad j = 1, 2, \ldots, n, \quad (4)$$

$$A^- = \{v_1^-, v_2^-, \ldots, v_n^-\} = \{(\min_j v_{ij} \mid i \in I'), (\max_j v_{ij} \mid i \in I'')\}, \quad i = 1, 2, \ldots, m; \quad j = 1, 2, \ldots, n. \quad (5)$$

where I' associated with benefit criteria, and I'' associated with cost criteria.

- Calculate the distance of each alternative from A^* and A^-

$$D_i^* = \sum_{j=1}^{n} d(v_{ij}, v_j^*) \quad i = 1, 2 \ldots m, \quad (6)$$

$$D_i^- = \sum_{j=1}^{n} d(v_{ij}, v_j^-) \quad i = 1, 2 \ldots m. \quad (7)$$

- Calculate similarities to ideal solution (CC_i)

$$CC_i = \frac{D_i^-}{D_i^* + D_i^-}, \quad i = 1, 2 \ldots m. \quad (8)$$

- Rank the order of alternatives according to CC_i in descending order. The alternative warehouse selection with highest CC_i value is the best location according to fuzzy-TOPSIS calculations.

Elaboration on the process of using the Fuzzy TOPSIS methodology, and its structure, are explained in more detail in, for example, Chen and Hwang (1992) and Kahraman et al., (2003)

4.3. Sensitivity analysis

A sensitivity analysis was undertaken to test for robustness of solutions where different criteria weights are exchanged to analyse if the order of alternative locations will change. The analysis is concerned with a 'what if' question and examines if the best location is stable when the inputs, which can be either judgements or priorities, are changed (Bottero and Ferretti, 2011). This technique is widely used in the AHP-TOPSIS warehouse location selection problem and provides a view of the significance of each criterion relative to each other (Awasthi et al., 2011; Kuo and Liang, 2011; Onut et al., 2010). The sensitivity analysis uses weights for criterions obtained through the AHP process where each criterion's weight is swapped with another criterion's weight. $5! = 120$ different possibilities for five different criteria were modelled and analysed. Once the weights are interchanged, the fuzzy-TOPSIS calculation process is applied to the new weights configuration to determine the new ranking order after applying conditioned weights.

5. Case study A: macro-perspective

The objective of this case study (International Humanitarian Organisation A) is to investigate regional attributes affecting the warehouse location decision-making process. They mainly focus on aiding refugees, returnees, stateless persons and certain Internally Displaced Persons, where the total population under the organisation's responsibility stands at 36.5 million (Respondent A1, see Table 4). Respondent A1 noted that the rapid provision of humanitarian relief and life-saving assistance is often the most critical need in emergencies, and it is a vital component of the organisation's emergency management policy and response strategy. The company has a global responsibility to provide basic relief items to persons of concern and it has to be ready to provide basic Non-Food Items for 500,000 people in case of emergencies. Furthermore, the strategic orientation of the organisation is to become a lead global humanitarian agency for basic non-food (NFI) and shelter items. The establishment of a global system to consolidate the management of its Central Emergency Stockpile (CES) and its regional equivalents has improved efficiency, increased cost savings and strengthened delivery to the organisation's operations (Respondent A1). These items are stored in the CES at locations A and B. The standard NFI kit for a family now includes blankets, sleeping mats, plastic sheeting, kitchen sets, mosquito nets, jerry cans, water buckets and, if required, family tents. The minimum stock of tents in the CES covers up to 250,000 persons. Additional essential items that are stocked in CES also include plastic rolls, Toyota Land Cruisers and trucks. The company also continues to coordinate and harmonise its stocks of non-food and relief items with those of its key partners, including sister agencies: the IFRC and the Red Crescent and the International Committee of Red Cross. Agreements with suppliers have been augmented to allow for the rapid replenishment of the CES and faster delivery to operations. At the time of this study the organisation was looking for a new warehouse location in order to improve further time and cost savings for disaster relief operations.

5.1. Identification of criteria

Decision-making panels consisting of senior officers of the organization in different locations and a consultant (Table 4) were formed to analyse location attributes. The determining factors (as a result of the literature review and a survey) for the warehouse location were given to the participants, where they were asked to add or eliminate any factors. Due to the time constraints, organising the attributes to relevant groups was undertaken as the same time as the selection of the factors. As a result, a total of three rounds were made to finalise location factors: Location (C1), National Stability (C2), Cost (C3), Cooperation (C4), and Logistics (C5). These are outlined in Table 5.

5.1.1. Location (C1)

Locating the pre-positioned warehouse near to the beneficiaries and potential disaster location would reduce the delivery time and cost. However the facility would be unusable if it was destroyed due to a disaster. The geographical location of the warehouse does not have to be near the disaster prone area, but rather could be in the country where the organization has its headquarters next to a regional office for strategic reasons. Proximity to beneficiaries for a potential warehouse is an important consideration. This could be similar to the proximity to disaster prone areas; however proximity to the beneficiaries could be different for a refugee relief incident where the refugees (beneficiaries) could move from their home country to a neighbouring country and thus several hundred miles away. The deterioration of relief items in the pre-positioned warehouse depends on the climate and the environment. Also, a very hot climate will not only affect the relief items in the warehouse, but also the labour force. Smaller humanitarian organisations which receive

Table 4
Participants in the decision making panels.

Location	Respondent	Position	Respondent	Position
I	A1	Senior supply officer	A 2	Supply officer
	A 3	Associate supply officer	A 4	Supply assistant officer
	A 5	Supply assistant officer	A 6	Consultant
II	A 7	Senior supply officer (logistics coordination)		
	A 8	Associate supply officer (logistics coordination)		
	A 9	Senior supply officer (warehouse management)		
	A 10	Senior supply assistant officer (warehouse management)		
III	A 11	Senior supply officer (field logistics)		

Table 5
Criteria and alternatives warehouse selection.

Criterion		Definition
C1	Location	Location affected by geographical location, proximity to beneficiaries, disaster free location, donor's opinion, climate, closeness to other warehouse, and proximity to disaster prone areas
C2	National stability	National stability affected by political, economical, and social stability
C3	Cost	Cost affected by storage, logistics, replenishment, labour, and land
C4	Cooperation	Cooperation affected by support from host government, UN, neighbor countries, logistics agents, and international/local NGOs
C5	Logistics	Logistics affected by availability and capabilities of airport, seaport, road, and warehouse
Alternatives	**Locations**	**V, W, X, Y, Z**

significant funds from donors are likely to have to accommodate their donors' opinion as to where to locate their pre-positioned warehouse. Similarly, humanitarian organisations which are supported by donors who contribute a substantial portion of the funding for their budget would also have to respect their donors' opinion as to locational preference. Some donors insist on a certain location for the pre-positioning of a warehouse for political reasons and business relationships with certain governments. Most relief organisations rely almost solely on donor funding, and so cannot imitate a disaster response before funding becomes available (Seaman, 1999). Potential location assessments should also consider the proximity to other regional warehouses due to cost and time reduction during the relief operation. Generally, this is not a big concern for large International Humanitarian Organisations because the relief items will be shipped via air transport and they operate more than one pre-positioned warehouse.

5.1.2. National stability (C2)

A stable political situation is important for the operation of the pre-positioned warehouse. If the political, economic, and social state of a country is very fragile and unstable, it will be difficult for a humanitarian organisation to operate their supply chain in a risky and dangerous environment. National stability also includes social stability (less risk of riots or protest towards the government) and economic stability (Kayikci, 2010).

5.1.3. Cost (C3)

The panels did not feel that land and labour costs are big issue for their organization because most of the land they use is purchased free of charge from the government while most of the contractors who work in the warehouse are working for low wages. Storage costs include the maintenance of some of the relief items (armoured-vehicles, cold storage items, and forklifts). The panels described how replenishment costs arise from purchasing relief items due to competitive prices, productivity and accessibility in the local and neighbouring countries. Logistics costs include supplying a pre-positioned warehouse to the aid recipients and other regional warehouses.

5.1.4. Cooperation (C4)

The panels discussed that locating pre-positioned warehouses needs the help of the many actors that are involved in the humanitarian relief operation. Logistics companies are important in providing trained and qualified logisticians who are capable of providing an efficient service. However, the panels tended to emphasise the role of the host government because they are the body that will allow tax exemption on relief items and offer facilities including land or warehousing, prompt financial systems, and other benefits such as flexible customs regulations that could attract the organization to contribute.

5.1.5. Logistics (C5)

The connectivity of the transportation modes was highlighted as a major concern during discussions. The existence of airports, seaports, warehouses, and roads are crucial to transport connectivity because of their ability to assist in and provide an effective immediate response. Logistics services provided by these logistics agents are also crucial. The panels also reported that in order to provide a quick response an airport is an important factor because most emergency relief items provided in the initial phases of an emergency are delivered through air-chartered flights. Airports also need to have suitable capacity to handle large aircraft which may be as large as a Boeing 747. Flights are chartered, if there are no national carrier connections to the disaster area, however it is often faster to charter a national carrier than to search for available flights from other countries. Greater availability of national carrier connections would speed the delivery of emergency relief items. An abundant availability of local air cargo companies can lower the burden of chartering aircraft when faced with time constraints. The airport's operational ability should be capable of handling air cargo effectively. Seaports are another important logistics infrastructure factor for pre-positioned warehouse selection. Seaports are normally used to receive large quantities of relief items from suppliers for replenishment purposes and to deliver relief to regional warehouses for long-term post-disaster relief operations. Seaports should be able to accommodate regular shipments which would mean that if a shipment was delayed they would be able to accommodate the next arrival. The facilities at the seaport affect the operating cost, the quality of the storage, and the handling time. The handling capacity has to be adequate for the organization to deal with the large quantity of relief items in one shipment. In addition, the distance from the warehouse is crucial because short transport routes will save time and money. The capacity of the warehouse should provide adequate space to store large amounts of relief items. Relief items are highly valuable and items such as medicines, foods, tents, and amoured-vehicles are always the target for theft. For this reason, the expert panels were concerned with security issues and safety of the warehouse. Warehouses should also be near to electricity and water supplies. As a result, only these criteria were used in the evaluation and a decision hierarchy was established accordingly (Table 5).

5.2. Evaluation of prepositioned warehouse location (macro-perspective)

The ranking preferences of the criteria were determined by the decision making committee and the final results for the pairwise comparison matrix were obtained from the consensus from the working group meeting. Since the comparisons were carried out through personal or subjective judgments, some degree of inconsistency could occur and consistency verification was conducted to ensure consistency. The computational results of the AHP calculations are presented in Table 6. The consistency ratio for the pairwise comparison matrix was $0.0984 < 0.1$, therefore the pairwise comparisons were acceptable and consistent. It is shown that *Cooperation* (C4) is considered to be the most important factor for establishing the pre-positioned warehouse whereas *Location* related factors (C1) were considered to be of least concern.

Five alternative locations were considered for evaluation: Location V, Location W, Location X, Location Y, and Location Z

Table 6
Pairwise comparison matrix and results obtained with AHP.

	C1	C2	C3	C4	C5	Weight	λ_{max}	CI	RI	CR
Location (C1)	1	1/3	1	1/3	1/3	0.1011	5.4410	0.1103	1.12	0.0984
National stability(C2)	3	1	½	1	2	0.2305				
Cost (C3)	1	2	1	½	2	0.2255				
Cooperation (C4)	3	1	2	1	2	0.2905				
Logistics (C5)	3	½	½	½	1	0.1525				

Table 7
Fuzzy evaluation matrix.

Alternative location	Criteria				
	C1	C2	C3	C4	C5
V	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.55, 0.70, 0.85)
W	(0.35, 0.50, 0.65)	(0.55, 0.70, 0.85)	(0.15, 0.30, 0.45)	(0.35, 0.50, 0.65)	(0.15, 0.30, 0.45)
X	(0.15, 0.30, 0.45)	(0.15, 0.30, 0.45)	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.15, 0.30, 0.45)
Y	(0.35, 0.50, 0.65)	(0.15, 0.30, 0.45)	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.15, 0.30, 0.45)
Z	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.15, 0.30, 0.45)

Table 8
Final ranking order comparison.

Fuzzy TOPSIS				
Rank	Location	D_i^*	D_i^-	CC_i
1	W	3.6716	1.3476	0.2685
2	V	3.6997	1.3163	0.2624
3	Z	3.7607	1.2573	0.2506
4	Y	3.8068	1.2134	0.2417
5	X	3.8270	1.1941	0.2378

(Table 5). To evaluate alternative locations with fuzzy TOPSIS and to determine the final rank, decision-makers were asked to build the decision matrix by comparing the alternatives against the criteria. The fuzzy evaluation matrix with fuzzy membership functions is presented in Table 7. Table 8 presents the final ranking order of the warehouse locations using the fuzzy-TOPSIS method.

Every value in the weighted fuzzy evaluation table is a triangular fuzzy number between [0,1], therefore, there is no need for normalisation. Then, a fuzzy positive-ideal solution (FPIS, A^*), and fuzzy negative-ideal (FNIS, A^-) are calculated where $\tilde{v}_i^*=(1,1,1)$ and $\tilde{v}_i^-=(0, 0, 0)$ for benefit criterion, and $\tilde{v}_i^*=(0,0,0)$ and $\tilde{v}_i^-=(1, 1, 1)$ for cost criterion. In this case, C1, C2, C4 and C5 are all benefit criteria and C3 is a cost criteria. Table 8 presents the final ranking order of the warehouse locations using fuzzy TOPSIS method where the final ranking is $W > V > Z > Y > X$.

As a result of the analysis Locations W and V were evaluated to be the best locations based on the selected warehouse criteria Humanitarian Organisation (Table 8). These two locations have very close CC_i values therefore either of them could be used for a prepositioned warehouse. Results of the sensitivity analysis indicate that there is variability between Locations W and V in the final ranking order when different weights for criterions are exchanged. This is due to the very close CC_i values between both locations. Location W contributes to the highest ranking 47 per cent out of 120 possibilities, whereas Location V was evaluated as the best location for 53% of cases. The ranking of both locations changes between first and second rank according to its CC_i value, whereas locations X, Y and Z have the same ranking comparisons using the AHP weights presented in the Table 6.

Location W was identified as the best warehouse position using the defined criteria. As a result of this research International organization A now operates Location W as their main warehouse facility for emergency relief distribution as national stability and cooperation from the government supports their strategy. These criteria were also shown to be among the top priorities that the decision-makers identified as part of the evaluation process. Cooperation from the government, which was the highest priority, was supported at all locations as they were evaluated the same. However, National Stability (C2) was ranked second highest priority in the criteria evaluation, and evaluated highest at Location W compared to the other locations. Respondents gave feedback that it is easier and convenient for them to operate the warehouse if the country is predictable in political, economic and social terms. It will be more difficult for them to manage the warehouse if one of these criteria is uncertain as they would not want to manage their main emergency warehouse under the pressure of having to always consider new locations which would add cost and result in a time-cost due to relocation. The cost (C3) and logistics (C5) at Location V were evaluated higher than at Location W. Location (C1) was the least important criteria as evaluated by the decision-makers. Respondents gave the opinion that the Cost (C3) and Logistics (C5) are important factors; however, these would be worthless if the government was not stable and not cooperative with them. This can also be seen from the result of the evaluation in that Location W was identified as the best location by the decision-makers and evaluated highest for National Stability (C2) even though Location V was evaluated higher for Logistics (C5) and Cost (C3). However, it is important to note that Location W was selected as the best location compared to Location V but only by a very small margin.

Location V is also used, but only operated during emergency crises and for this reason is utilised as the organization's main warehouse at those times. A seamless supply chain by sea and air is ensured through to one of the biggest and busiest seaport in the world. In addition, five international airports are located within a two hour driving radius of the warehouse: consequently, charter planes can be deployed within 24 to 48 h. Location V's logistics services are renowned for their professionalism and cost-efficiency (Respondent A1). One of the major factors contributing to the fact that Location V is also preferred is that it is fully supported by the country's government in terms of the usage of the facilities including factors such as land provision, building, tax, labour, customs, and logistics (Respondent A1 and Respondent A2).

6. Case study B: micro-perspective

The objective of case study B was to identify attributes for the warehouse location problem for the humanitarian relief organisations based in Dubai, from the micro (local) perspective. UN agencies, international and local NGOs are located at the premises of the IHC (International Humanitarian City, Dubai) which are provided free of charge to the organisation. IHC is a global humanitarian aid hub, which aims to facilitate aid and development efforts by providing local and international humanitarian actors with facilities and service specifically designed to meet their needs. The IHC is a non-religious, non-political and non-profit organization and is an independent free zone authority created by the Government of Dubai, which consolidates Dubai as an essential link in the humanitarian value chain. By leveraging the Dubai free zone model, the IHC is able to address the needs of the humanitarian aid and development community, while grouping them in a secure environment that fosters partnerships, social responsibility and global change. At the same time, the IHC offers commercial companies the opportunity to operate from a highly strategic location in a free zone environment that is adapted to their particular industry, while benefiting from attractive incentives and an array of value-added services. The IHC believes that humanitarian operations will benefit from the integration of commercial suppliers of goods and services. By co-locating, non-profit and commercial entities will be encouraged to share best practices to increase their operational efficiencies and improve institutional learning. The IHC had to look for alternative warehouse compounds for several reasons. Due to the increase in members joining IHC, more offices and warehouse spaces were needed. Therefore the IHC looked locally for an alternative compound location for its members as they valued the UN agency officers' opinions because they are their largest partners.

6.1. Identification of criteria

Criteria to be considered in the selection of the new warehouse location were determined by the senior officers and a consultant from the humanitarian relief organisations. Table 9 represents members of the decision-making committee for case study B. In total there were 11 members that participated in the panel discussion to determine factors for the IHC warehouse location problem. Due to the busy schedules of participants, only one meeting was organised by the IHC to discuss the factors where the participants were briefed in advance regarding the attributes. It was an open discussion where everyone expressed their opinion regarding warehouse relocation. Due to the need to move to an alternative warehouse, even though they were satisfied with the current location, most of the factors for evaluation were based on the current location. IHC provided four alternative locations in Dubai for the evaluation (Table 10, Fig. 3): Location A (IHC, current location), Location B (DIC, Dubai Industrial City), Location C (Hellmann, Jebel Ali industrial area), Location D (JAFZA, Jebel Ali industrial area), and Location E (RSA, Dubai Logistics City). The participants of the committee separated the major factors then added the sub-factors into a hierarchical structure and the meeting was concluded when the panel mutually agreed on the factors and the hierarchical structure for evaluation. As a result, participants identified five key criteria (Table 10) for the evaluation of the new location: Distance (C1), Security (C2), Office Facilities (C3), Warehouse Facilities (C4), and Convenience (C5).

Table 9
Participants in the decision-making panels.

Organization	Respondent	Position	Respondent	Position
UN agency	1	Senior logistics officer		
UN agency	2	Senior supply officer	3	Assistant supply officer
	4	Supply associate	5	Supply officer
	6	Consultant		
UN agency 3	7	Senior supply officer	8	Assistant supply officer
NGO	9	Logistics officer		
Company	10	Supervisor emergency & relief		
IHC	11	Logistics manager		

6.1.1. Distance (C1)

The distance attribute considers the warehouse proximity to Jebel Ali seaport, four international airports in Dubai (Dubai airport, Al Maktoum airport, Sharjah airport, Abu Dhabi airport) and the Ministry of Foreign Affairs (MOFA). Seaports handle the large quantities of replenishment goods and they are used to deliver relief goods for post-disaster operations. Closeness to an airport is another essential factor because the goal of humanitarian relief is to get the goods to the beneficiaries as soon as possible after the disaster. The customs-related process is handled in the MOFA and even though humanitarian goods are normally exempted from tax and customs, some goods are very sensitive (armored vehicles, medicines) and without authority exemption documents, the whole process can be delayed.

6.1.2. Security (C2)

Humanitarian warehouses store a variety of valuable goods and the panel agreed that security attributes should include warehouse security, fire stations, police stations, hospitals, and road safety. Warehouse security includes facilities equipped with CCTV cameras in the compound, fire alarm systems and security guards. It is important that the warehouses have a secure perimeter because they stock valuable items (medicines, telecommunication equipment, food and non-food items). Such facilities should also be close to emergency services such as fire, police stations and hospitals in case of any incidents in the warehouse. The warehouse must be located in the safe traffic area where there is less likelihood of traffic accidents.

6.1.3. Office facilities (C3)

The office facilities include facilities suitable for diplomatic work with IT/Communication infrastructure, warehouse distance, and modular space. The warehouse compound should not be isolated from diplomatic work because some of the humanitarian agencies are stationed in IHC solely for diplomatic activities. In addition, facilities should have a modular space with acceptable IT/communication for frequent international calls and teleconferences. Closeness to the warehouse is also important for staff visiting the warehouse for maintenance checking of relief items.

6.1.4. Warehouse facilities (C4)

Warehouse facilities consists of floor capacity, open storage, office facility, spill-over area, ceiling height, loading bays, flood lights, openings, and doors at both ends. Floor capacity and the height of the ceiling of the warehouse are important in determining the volumetric capacity of the warehouse. Availability of open storage is also important to stock the vehicles for relief operations.

Table 10
Criteria and alternatives warehouse selection.

Criterion		Definition
C1	Distance	Closeness to airports, seaports and Ministry of Foreign Affairs
C2	Security	Security of the warehouse, road safety, and related facilities around the area (fire/police station, hospital)
C3	Office facilities	Facilities suitable for administrative office work
C4	Warehouse facilities	Suitable infrastructure for loading, storage and general operations
C5	Convenience	Convenience of the compound facility in terms of welfare for the staff
Alternatives		**Location areas**
A	Current compound	International Humanitarian City (IHC)
B	Alternative location 1	Dubai Industrial City (DIC)
C	Alternative location 2	Hellmann
D	Alternative location 3	JAFZA
E	Alternative location 4	RSA

Fig. 3. Alternative warehouse locations for case study B.

Loading bays are needed for effective loading of relief goods and spill-over areas to store surplus items. Suitable openings for 40′ high-cube containers and flatbed trucks also needed to be considered. Floodlights and doors at both ends of the warehouse are essential for night operations and to speed up loading times. The office facility for warehouse staff needs to have sanitation facilities and air-conditioning.

6.1.5. *Convenience (C5)*

In the warehouse compound, the welfare and the working environment of the staff is an important criterion. Even though Convenience factors are not closely related to humanitarian relief issues, the panels wanted to evaluate the compound as to whether it was suitable for a working environment. Panels considered that the alternative warehouse compound should include, or should be near to, facilities such as the cafeteria, mini-mart, ATM, residential accommodation, and public transportation. The warehouse should also be near to the main city for accessibility.

6.2. *Evaluation of the case study B*

Using the five criteria discussed earlier, the participants of the decision-making committee established priorities using AHP (Table 11) with the CR for the pairwise comparisons being $0.0436 < 0.1$.

The next step was to evaluate alternative locations using fuzzy TOPSIS where the officers were asked to evaluate the locations to construct the fuzzy evaluation matrix by using linguistic variables that were formed by comparing five alternatives under five criteria separately (Table 12).

The criteria weights calculated by AHP (Table 11) were used to establish the fuzzy weighted normalised decision matrix of the location alternatives, calculated by multiplying the fuzzy evaluation matrix (Table 12) against the weights (Table 11). The fuzzy positive-ideal solution (FPIS, A^*), and fuzzy negative-ideal (FNIS, A^-) were evaluated with $\tilde{v}_i^* = (1,1,1)$ and $\tilde{v}_i^- = (0, 0, 0)$ for benefit criterion. In this case, C1, C2, C3, C4, and C5 are all benefit criteria and there are no cost criteria. The next step was to calculate similarities to the ideal solution and to rank the alternative warehouse locations, as illustrated in the Table 13. According to the CC_i values, the result shows that Location C (Hellmann) was evaluated with the highest rank with the same value of CC_i as Location A (the current location). Therefore, the final ranking was: $C > E > D > B$ (Hellmann > RSA > JAFZA > DIC). The small difference between CC_i values for locations C and E could indicate that there is no preference between those locations where all three locations are in close proximity to each other. The sensitivity analysis was undertaken to ensure the robustness of solutions where the Location C is evaluated as the best location.

Results of the sensitivity analysis where weights for different criteria were exchanged also confirmed that Location C is evaluated as the best location for different combinations of weights. In addition, the ranking does not change for other locations and is the same as presented in the base scenario (Table 13). If Location C

Table 11
Pairwise comparison matrix and results obtained with AHP.

	C1	C2	C3	C4	C5	Weight	λ_{max}	CI	RI	CR
Distance (C1)	1	2	4	½	6	0.2852	5.1955	0.0488	1.12	0.0436
Security (C2)	½	1	4	½	4	0.2033				
Office facilities (C3)	¼	¼	1	¼	3	0.0875				
Warehouse facilities (C4)	2	2	4	1	6	0.3776				
Convenience (C5)	1/6	1/4	1/3	1/6	1	0.0464				

Table 12
Fuzzy evaluation matrix.

Alternative Location	Criteria				
	C1	C2	C3	C4	C5
A	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)
B	(0.15, 0.30, 0.45)	(0.15, 0.30, 0.45)	(0.15, 0.30, 0.45)	(0.15, 0.30, 0.45)	(0.15, 0.30, 0.45)
C	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)
D	(0.35, 0.50, 0.65)	(0.15, 0.30, 0.45)	(0.15, 0.30, 0.45)	(0.15, 0.30, 0.45)	(0.15, 0.30, 0.45)
E	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)	(0.15, 0.30, 0.45)	(0.35, 0.50, 0.65)	(0.35, 0.50, 0.65)

Table 13
Final ranking of warehouse location.

Fuzzy TOPSIS				
Rank	**Location**	D_i^*	D_i^-	CC_i
1	A IHC	4.502	0.515	0.103
1	C Hellmann	4.502	0.515	0.103
2	E RSA	4.520	0.498	0.099
3	D JAFZA	4.645	0.378	0.075
4	B DIC	4.702	0.324	0.064

could not be chosen as the warehouse location due to internal and external factors then other alternative locations could be considered according to their ranking. As can be seen from Table 13, there is not a great difference between the ideal solution CC_i value for Location E compared to Location C. However, Locations D and B are evaluated lower than the current location of the warehouse and the proposed best location. Location B is evaluated to be the lowest in the entire dataset of alternative locations according to the priority ranking.

As a result of the analysis, Location C was proposed to IHC for relocation, because it was evaluated as the preferred alternative warehouse location with the most similarity to the current warehouse location. All of the factors for Location C were evaluated to have the same priority as the current location. Location C was evaluated among the highest in warehouse facility criteria (C4) as the panels considered this to be important when they evaluated the warehouse compound. Location C was also evaluated highly in Distance and Security criteria (C1 and C2) which were also among the important criteria for warehouse selection. The distance to the major international airport and seaports is within one hour travel and there is tight security at the compound. When the research was undertaken, it was believed that Location C was the best option for IHC.

After the research, the authors returned to the participants to find out which new warehouse location was selected for relocation. It was surprising to find that Location B, which was evaluated to be the least preferable, was selected as their alternative location. Location B was evaluated lowest in all factors. The decision-makers in IHC admitted that there was a political influence between the government and the international organisations for which they could not disclose the detailed context but was more to do with the incentives from the government, such as the cost of the land, reduction of utility bills and other factors, if they decided to move to Location B. Even though they did not choose the alternative location according to this research, it was acknowledged that this approach helped the decision-makers to prioritise the various factors through the AHP and fuzzy-TOPSIS process. It was a logical method to analyse which factors were their priority for selecting the alternative warehouse. Before this technique was introduced to the organisation they had different opinions on the weight for each factor due to varying humanitarian operational objectives. This research provided the participants with a tool which they can use for future investigations in evaluating alternative locations. The process of fuzzy evaluation provided a more even-handed approach to a major warehouse location selection decision, even though ultimately the alternative warehouse selection was influenced by an external factor that they had to accommodate, but which had not been known about when the original criteria were determined.

7. Conclusion

The need for strategic stock-holding for humanitarian purposes has become increasingly important in recent years following a large number of high-impact natural and man-made disasters in various parts of the world. Almost invariably, whether the emergency has its origins in natural disasters (such as floods, earthquakes or storms) or in civil disturbance or war, there is a need to ramp-up the provision of emergency supplies extremely quickly. The nature, volume and form of these supplies vary considerably and are driven by conditions on the ground which themselves can vary from day-to-day and perhaps even from hour-to-hour.

A key element of the response which can effectively be seen as a service package in crisis conditions is where and what is held as an emergency stock. The question of ‘what’ is usually based on the preceding pattern of crises, and ‘where’ stock is held, is based on a complex algorithm which takes account of accessibility, security, operational freedoms and other criteria which are again built-up over time.

Prior to this research and adoption of the presented methodology, decision-makers of the International Humanitarian Organisation and other humanitarian relief organisations in Dubai were struggling with the selection of the warehouse location. In this paper, a two-stage AHP and fuzzy-TOPSIS methodology was adopted to guide the identification of warehouse location factors and assisting in determining the weights to be applied to those factors, especially where management finds it difficult to make fine judgements on alternative location. One of the limitations of the framework can be viewed as the subjectivity of the rating and evaluation standards for the measuring system. Sensitivity analysis addresses the issue of variation in judgment from person to person or for the same person from time to time.

Through this research it was found that for case study A location W was identified as the best warehouse location with the result for location V being relatively close. As a result the organisation now operates Location W as their main warehouse and Location V is used as their main warehouse during emergency crises. For Case study B a specific location in the Dubai area was identified and proposed as the best location. While this was accepted, at the time of the research Location B, which was evaluated to be the least preferable and evaluated lowest in all criteria, was eventually selected as the alternative location due to government incentives such as, for example, land costs and lower utility bills. Even though the identified alternative location was not chosen it was acknowledged that this approach helped the decision-makers to prioritise the various factors through the AHP and fuzzy-TOPSIS process. The research provided the participants with a tool which they can use for future investigations in evaluating alternative locations, and providing a more even-handed approach to a major warehouse location selection decision.

Overall this work contributes to the literature by considering both macro- and micro-location levels, provides insights into how such organisations consider different factors at each level when making location decisions and offers useful managerial insights related to the pre-positioning of warehouses at each level. Further, the use of a robust multi-criteria decision making framework helps in the assessment of a range of possible locations for humanitarian relief organisations.

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