The Pre-Positioning of Warehouses at Regional and Local Levels for a Humanitarian Relief Organization

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Abstract

Locating pre-positioned warehouses in strategic locations around the world is an approach that is used by some humanitarian relief organizations 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, these problems have not received much 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 local location) 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 Hierarchical Process, the structure of the location selection problems was analysed. 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 as follow: we provide useful managerial insights and implications related to the pre-positioning of warehouses and guide the identification of the warehouse location through a robust framework for multi-criteria decision making for humanitarian relief organisations.

Keywords: Pre-positioning of Warehouses, Humanitarian Relief Organisation, Multi-Criteria Decision Making.

1. Introduction

The goal of emergency response is to provide shelter and assistance to the victims of disasters as soon as possible after an emergency occurs. Pre-positioning of supplies at strategic locations is essential to ensure their availability when required (Rawls and Turnquist 2010; Balcik *et al*. 2010) and for faster response (Tomasini *et al*. 2004). It has been suggested that in the long run such an approach aids in the reduction of the cost of deliveries to those locations due to regular sea replenishments (Gatignon *et al*. 2010).

Many studies have addressed the importance of the preparedness phase and the need for pre-positioned warehouses in humanitarian relief logistics, whereas only a small number of papers are related to the location decision (Dekle *et al.* 2005; Balcik and Beamon 2008; Ukkusuri and Yushimoto 2008; Murali *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 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 areas has had limited research interest where there is a need to consider multiple attributes in location decision-making because of subjectivity, uncertainty and ambiguity in the assessment

process (Dagdeviren *et al.* 2009). In this paper we aim to address this gap by considering two case studies of humanitarian relief organizations at both international (macro level) and local (micro) contexts. Interviews, discussion panels, and Analytic Hierarchical Process (AHP) are used to determine the importance of specific criteria, and fuzzy-TOPSIS is used to obtain the final location ranking.

2. Multi-Criteria Location Decision

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 depend 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. 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.

The comparative analysis between AHP and TOPSIS is presented by Özcan *et al.* (2011) and Shi *et al*. (2007). 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 centers. 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).

3. Methodology

The methodology for the humanitarian warehouse location selection problem integrates the AHP and fuzzy-TOPSIS methods and consists of three stages: (1) identify the criteria to be used in the model through Group Working, (2) AHP computations, (3) evaluation of alternatives with fuzzy-TOPSIS and determination of the final ranking (Amiri 2010, Yu *et al*. 2011). AHP (Saaty 1980) 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 (Amiri 2010).

In the first stage, alternative locations and criteria are used to evaluate and determine the decision hierarchy that is approved by the decision-making team. 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 decision-maker setting to a group decision-maker setting introduces a great deal of complexity into multi criteria analysis. The 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. After the approval of the decision hierarchy, pairwise matrices are formed to determine the criteria weights for the second stage. The decision-making team makes individual evaluations using the scale to determine the values of the elements of pairwise comparison matrixes. The preferences of the attributes are calculated using a mean value that can be viewed as a consensus. 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 final consistency ratio exceeds its limit, the evaluation procedure has to be repeated to improve consistency. The weights of each criteria are calculated based on this final comparison matrix. In the last step of this phase, calculated weights for the criteria are approved by the decision-making team. Stage 3 involved evaluation of alternatives with fuzzy-TOPSIS and determination of the final ranking where the present study adopted the transformation for fuzzy membership functions presented by Torfi *et al.* (2010) where it transforms the precise values to five

levels, which are: fuzzy linguistic variables very poor (VP), poor (P), fair (F), good (G), and very good (VG). The alternative warehouse selection that has the maximum CC_i value is determined as the best location according to the calculations by TOPSIS. Ranking of other alternative location are also undertaken and a sensitivity analysis is performed to test for robustness of solutions where different criteria weights are used to analyse if the order of alternative locations will change.

4. 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). 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 CES in location 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 International Federation of Red Cross and 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 organization was looking for a new warehouse location in order to improve further time and cost savings for disaster relief operations.

4.1 Identification of criteria

Decision-making panels consisting of senior officers of the organization in different locations and a consultant (Table 1) were formed to analyze 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 2.

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 headquarter country or next to a regional office for strategic reasons. Proximity to beneficiaries for a potential warehouse is one of the important considerations. This can be seen in the similar view with the proximity to

disaster prone areas; however, the proximity of the beneficiaries is different for a refugee relief incident where the refugees (beneficiaries) could depart from their home country to neighouring countries which could be more than 1,000 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 organizations which receive significant funds from donors are likely to have to accommodate their donors' opinion as to where to locate their pre-positioned warehouse. Similarly, humanitarian organizations 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 organizations rely almost solely on donor funding, and so cannot imitate a disaster response before funding becomes available (Seamon 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 organizations because the relief items will be shipped via air transport and they operate more than one pre-positioned warehouse.

Location	Respondent	Position	Respondent	Position
I	1	Senior Supply Officer	2	Supply Officer
	3	Associate Supply Officer	4	Supply Assistant Officer
	5	Supply Assistant Officer	6	Consultant
II	7	Senior Supply Officer (Logistics Coordination		
	8	Associate Supply Officer (Logistics Coordination)		
	9	Senior Supply Officer (Warehouse Management)		
	10	Senior Supply Assistant Officer (Warehouse Management)		
III	11	Senior Supply Officer (Field Logistics)		

Table 1. Participants in the decision making panels.

Criteria's	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, labor, and land
C4	Cooperation	Cooperation affected by support from host government, United Nations, 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

Table 2. Criteria and alternatives warehouse selection.

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 (Kayykci 2010).

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.

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 emphasis 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.

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. More availability of national carrier connections will speed the delivery of emergency relief items while using less effort. An abundant availability of local air cargo companies can lower the burden of chartering aircraft when short of time. 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 2).

4.1 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 using a mean value that was considered as a consensus during the working group meeting. Since the comparisons are carried out through personal or subjective judgments, some degree of inconsistency may occur where the consistency verification is conducted to ensure consistence. The results obtained from the computations based on the pairwise comparison matrix are presented in the Table 3. The

Consistency Ratio for the pairwise comparison matrix is 0.0984 < 0.1, therefore the pairwise comparisons are 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 (C1)* related factors were considered to be of the least concern.

	C1	C2	C3	C4	C5	W	λ_{max}	CI	RI	CR
C1	1	1/3	1	1/3	1/3	0.1011	5.4410	0.1103	1.12	0.0984
C2	3	1	½	1	2	0.2305				
C3	1	2	1	½	2	0.2255				
C4	3	1	2	1	2	0.2905				
C5	3	½	½	½	1	0.1525				

Table 3. Pairwise comparison matrix and results obtained with AHP.

Five alternative locations were considered for evaluation: Location V, Location W, Location X, Location Y, and Location Z (Table 2). To evaluate alternative locations with fuzzy TOPSIS and to determine final rank, decision-makers were asked to build the decision matrix by comparing the alternatives against criteria. The fuzzy evaluation matrix with fuzzy membership functions is presented in Table 4. Table 5 presents the final ranking order of the warehouse locations using fuzzy TOPSIS method.

	C_1	C_2	C_3	C_4	C_5
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 4. Fuzzy evaluation matrix.

Every value in the weighted fuzzy evaluation table are triangular fuzzy number between [0,1], therefore, there is no need for normalization. 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 5 presents the final ranking order of the warehouse locations using fuzzy TOPSIS method with final ranking as the final ranking is W > V > Z > Y > X.

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. Final ranking order comparison.

As a result of the analysis Locations W and V are evaluated to be the best locations based on the warehouse criteria Humanitarian Organisation selected as can be seen from the Table 5. The have very close CC_i values therefore either of them could be used as a location for a prepositioned warehouse. At present, we are undertaken a sensitivity analysis of the subjectivity of rating to ensure that the Location W is the best warehouse location under the defined criteria. On the other hand, Location V is only operated during emergency crises and is utilized as the

organization's main warehouse for this reason. 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 hours. 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 was also preferred was 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).

5. Case Study B: Micro Perspective

The objective of Case Study B was to identify attributes for the warehouse location problem for the humanitarian relief organizations 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 by Her Royal Highness Princess Haya Bint Al Hussein. 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.

5.1 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 organizations. Table 6 represents members of the decision-making committee for Case Study B. In total there were eleven 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 7): 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 7) for the evaluation of the new location: Distance (C1), Security (C2), Office Facilities (C3), Warehouse Facilities (C4), and Convenience (C5).

Organization	Respondent	Position	Respondent	Position
UN Agency 1	1	Senior Logistics Officer		
UN Agency 2	**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		

Table 6. Participants in the decision-making panels.

Criteria's	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

Table 7. Criteria and alternatives warehouse selection.

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.

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.

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.

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. 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.

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 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.

5.2 Evaluation of the Case Study B

Using the five criteria discussed earlier, the participants of the decision-making committee established priorities using AHP (Table 8) with the CR for the pairwise comparisons being $0.0436 < 0.1$.

	C1	C2	C3	C4	C5	W	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 8. Pairwise comparison matrix and results obtained with AHP.

The next step was to evaluate alternative locations using fuzzy TOPSIS where the officers were asked to evaluate the locations to construct fuzzy evaluation matrix by using linguistic variables that were formed by comparing five alternatives under five criteria separately (Table 9).

	C_1	C_2	C_3	C_4	C_5
A	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)
B	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)
C	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)
D	F (0.35, 0.50, 0.65)	F (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)	F (0.15, 0.30, 0.45)
E	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)

Table 9. Fuzzy evaluation matrix.

The criteria weights calculated by AHP (Table 8) were used to establish the fuzzy weighted normalised decision matrix of the location alternatives that is calculated by multiplying the fuzzy evaluation matrix (Table 9) against the weights (Table 8). Fuzzy positive-ideal solution (FPIS, A^*), and fuzzy negative-ideal (FNIS, A^-) are 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 is to calculate similarities to ideal solution (CC_i) and to rank the alternative warehouse locations as illustrated in the Table 10. According to the CC_i values, the result shows that Location C (Hellmann) evaluated with the highest rank with the same value of CC_i as the Location A (the current location). Therefore, the final ranking is: 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.

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

Table 10. Final ranking of warehouse location.

As a result of the analysis, Location C was proposed to IHC for relocation. Location C was evaluated the highest in warehouse facility criteria as the panels considered them as the most important criteria when they evaluated the warehouse compound. Location C was also evaluated highly in Distance and Security criteria which were also one of the important criteria for warehouse selection. The distance to major international airport and seaports where within one hour range and had a tight security facility to guard the compound.

6. Conclusion

Prior to this research and adoption of the presented methodology, decision-makers of the International Humanitarian Organisation A and humanitarian relief organisations in Dubai were struggling with the selection of the warehouse location. In this paper, a three-step 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 decide 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.

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