THE PRE-POSITIONING OF HUMANITARIAN AID: THE WAREHOUSE LOCATION PROBLEM

by

Saeyeon Roh

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Transport and Shipping Research Group, Logistics and Operations Management Section of Cardiff Business School, Cardiff University

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ABSTRACT

The overarching objective of this thesis is to explore the warehouse location decision problem by considering regional and specific site attributes in the unique context of humanitarian relief organisation. This is to fill the gaps the revealed in the current understanding of location decision problem, particularly the lack of studies attempting to investigate humanitarian pre-positioned location decision problem with qualitative attributes opposed to the many previous studies focused on computerised optimisation model absence of the human judgements. Specifically, this research develops into case studies of the international humanitarian organisations selecting the warehouse attributes and locating the alternative warehouse locations. International humanitarian relief organisation aiding the refugees participated in the case study of the regional location selection problem for pre-positioned warehouse with five major attributes and 25 sub-attributes. Six international humanitarian relief organisations based in Dubai, UAE participated for specific warehouse location selection problem with five major attributes and 30 sub-attributes.

The overall research design adopted in this thesis is as follows. First, the coherent humanitarian warehouse location decision attributes were developed in the basis of a literature and semi-structured interviews with practitioners whose organisation practice pre-positioned warehouse operation system. Secondly, two case studies were conducted for constructing the hierarchy structure for warehouse evaluation for regional and specific site location. In the first case study, 11 managerial level officers participated to construct the regional warehouse location decision attributes and evaluated the warehouse location for the organisation. In the second case study, panel members were form by 11 decision-makers from six different organisations constructed the hierarchical structure of the specific site warehouse location attributes for the evaluation. Thirdly, Analytic Hierarchy Process (AHP) is executed to acquire criteria weights and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is employed to obtain the final ranking of the warehouse locations. Fuzzy set theory is adopted in the evaluation to deal with the fuzziness of decision-makers' preferences in decision making.

In conclusion, this thesis extends the body of knowledge in pre-positioned warehouse location problem in the humanitarian relief logistics context by suggesting a MADM location method, AHP and TOPSIS, integrated with fuzzy set theory to understand the priority preference of regional (macro) and specific site (micro) warehouse location attributes and the selection of the optimal warehouse.

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LIST OF ABBREVIATONS

ABBREVIATIONS	FULL WORDS
ACFID	Australian Council for International Development's Humanitarian Reference Group
AHP	Analytic Hierarchy Process
ANN	Artificial Neural Network
ANP	Analytic Network Process
ARCS	Austrian Red Cross
AusAID	Australia Aid
BRCS	British Red Cross
CC_i	Relative Closeness to Ideal Solution
CES	Central Emergency Stockpiles
CI	Consistency Index
CIDA	Canadian International Development Agency
CR	Consistency Ratio
DA	Decision Alternative
DCLG	Department for Communities and Local Government
DEMATEL	Decision-Making Trial and Evaluation Laborator
DFID	Department for International Development
EIA	Environment Impact Assessment
ELECTRE	Elimination and Choice Expressing Reality
EMDAT	Emergency Events Database
EVZ	Erinnerung Verantortung Zukunft
FNIS	Fuzzy Negative-Ideal Solution
FPIS	Fuzzy Positive-Ideal Solution
GIS	Geographical Information System
GP	Goal Programming
GPSTEM	Goal Programming Step Method
IDPs	Internally Displaced Persons
IHC	International Humanitarian City
ICRC	International Committee of Red Cross
IFRC	International Federation of Red Cross and Red Crescent

	Societies
IOM	International Organisation for Migration
IPs	Implementing Partners
IPCH	International Peace Cooperation Headquarters
JICA	Japan International Cooperation Agency
JIT	Just In Time
KCOC	The Korea Council for Overseas Cooperation
LINMAP	Linear Programming Techniques for Multidimensional Analysis of Preferences
LM	Linear Programming
LWET	Light Weight Emergency Tent
MADM	Multi-Attribute Decision-Making
MAH	Maximise-Agreement Heuristic
MAUT	Multi-Attribute Utility Theory
MCDA	Multi-Criteria Decision Analysis
MCDM	Multi-Criteria Decision-Making
MIP	Mixed Integer Programming
MOFA	Ministry of Foreign Affairs
MODM	Multi-Objective Decision-Making
MRP	Material Requirement Planning
MSF	Medecins Sans Frontieres
NIS	Negative-Ideal Solution
NFIs	Non-Food Items
NGOs	Non-Governmental Organisations
NOREPS	Norwegian Emergency Preparedness System
NZAID	New Zealand Aid
QFD	Quality Function Deployment
PAHO	Pan American Health Organisation
PIS	Positive-Ideal solution
PROMET	Preference Ranking Organisation METHod for
HEE	Enrichment Evaluation
RI	Random Index
SAW	Simple Additive Weighting

SDC	Swiss Agency for Development and Cooperation
SEMOPS	Sequential Multi-Objective Problem Solving
SMAA	Stochastic Multi-Criteria Acceptability Analysis
SMAAO	Stochastic Multi-Criteria Acceptability Analysis with Ordinal
SMS	Supply Management Service
SRCS	Swedish Red Cross
SRSA	Swedish Rescue Services Agency
STEM	Step Method
TFNs	Triangular Fuzzy Numbers
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
UNHRD	United Nations Humanitarian Response Depot
UNDHA	United Nations Department of Humanitarian Affairs
UNICEF	United Nations International Children's Emergency Fund
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
USAID	United States of America Aid
VIKOR	VlseKrtierijumaka Optimizacija I Kompromisno Resenje
WEM	Weighted Evaluation Matrix
WHO	World Health Organisation
WFP	World Food Programme
WVI	World Vision International

CHAPTER 1

INTRODUCTION

1.1 Chapter Overview

This chapter aims to explain the author's motives for conducting this research project. This chapter begins with a general overview of warehouse decision determinant attributes and a selection of the optimal warehouse locations for humanitarian relief organisations are presented to provide the context of the research. It will then present the research questions and the research aims. Finally, the layout of this thesis is detailed and a brief description of each chapter's content is given.

1.2 Research Motivations

The motivation for conducting this research mainly originated from the author's previous Master's dissertation, which was titled: 'Humanitarian Aid Logistics: Humanitarian Response Depot Network' (Roh, 2007) that was submitted for an MSc in International Transport in Cardiff University. This dissertation explored the locations of humanitarian pre-positioned warehouses in disaster prone areas around the globe. During this research it became clear that only a handful of previous studies have examined the problem of humanitarian warehouse location selection. This leads to further questions about the determinant attributes that can affect the pre-positioned warehouse location problem in humanitarian relief logistics as well as the subsequent selection of optimal warehouse locations using those attributes.

It is clear from recent statistics that natural and man-made disasters are occurring more frequently. For example, it has been shown that natural disasters around the world have increased up to nine fold in the last thirty years (Fritz Institute, 2005; EM-DAT, 2008). An increase in disasters also indicates that more lives are being affected and more damage is being caused than before. Every year, more than 500 disasters are estimated to strike our planet, killing around 75,000 people and impacting more than 200 million others (Van Wassenhove, 2006).

The importance of an emergency relief response operation increases as the numbers of disasters rise. The large number of disasters around the world has illustrated the importance of emergency relief response logistics. One of the most serious problems affecting the modern world is the vulnerability of nations or regions to natural disasters (e.g. earthquakes, floods, droughts) or man-made crises (e.g. civil unrest, war, and political or tribal disturbance) (Pettit and Beresford, 2006). Even though advanced technology is working hard to predict natural disasters, most disasters remain unpredictable.

Disaster relief logistics management is categorised into three phases, which are: prepare, immediate response, and reconstruction (Kovács and Spens, 2006). The three key phases which cannot be designated to specific time periods are consistently part of the preparation-reaction process (Brown, 1979) and logistics serves as a bridge between disaster preparedness and immediate response (Thomas, 2003). The overall goal for preparedness is to improve rapid response facilities so as to allow the timely delivery of food aid in emergency situations (Scott-Bowden, 2003). Speed of delivery is considered one of the important factors in the relief chain where the pressure of time in the relief chain is often not a question of money but the difference between life and death (Van Wassenhove, 2006).

A number of decision support systems and technologies been developed for the preparation phase (Kovács and Spens, 2007). One of the decision support systems is facility location, while stock pre-positioning decisions in the relief chain are critical components of disaster preparedness and, hence, require long-term planning to achieve a high-performance disaster response (Balcik and Beamon, 2008). Pre-positioning in strategic locations around the world is a strategy that has recently been implemented by some humanitarian relief organisations to improve their capacities in delivering sufficient relief aid within a relatively short timeframe and with improved mobilisation (Balcik and Beamon, 2008). The basic purpose for establishing an emergency stockpile is to support life-saving operations during the first few days after a sudden-onset disaster through an immediate delivery of required relief items (UNDHA, 1994). Many relief organisations have recently established a pre-positioned strategic model to carry out extensive work to strengthen their logistical preparedness and capacity (Scott-Bowden, 2003).

The knowledge gained through Roh’s (2007) examination of humanitarian pre-positioning emergency stock lead to research gaps for further exploration in this thesis. Initial research questions regarding humanitarian relief pre-positioned warehouses (such as: What are the determinant attributes of a pre-positioned warehouse? And, where are they located?) triggered an interest to explore the location of humanitarian pre-positioned warehouses in more depth. Accordingly, this study takes a progression approach in exploring the humanitarian pre-positioned warehouse location decision-making problem with regional and specific site determinant attributes.

Interest in conducting this has, accordingly, been stimulated by following the main factors:

1. There has been a lack of studies on the humanitarian pre-positioned warehouse location problem, which is an integral part of the facility location problem. This topic has not received much attention in the domain of humanitarian relief; attention has instead been given to the domain of operational logistical activities, focusing on the objective of optimising the flow of supplies through existing distribution networks and post-disaster events (Balcik and Beamon, 2008).
2. The existing studies of the problem of pre-positioning the location of humanitarian facilities have focused their attention on mathematical calculations and simulation models, and have been mostly quantitative, whereas qualitative studies of the location problem have been neglected. This has allowed the author to adopt both a qualitative and quantitative decision-making process method to locate the optimal approach to the humanitarian pre-positioned warehouse location problem.
3. In analysing the problem of pre-positioning the location of humanitarian facilities, there seems to be a lack of studies that have considered the opinions of the managerial level, which includes the determinant attributes of the warehouse location decision-making process, although there have been many studies that are interested in the mathematical method of facility location optimisation modelling (Balcik and Beamon, 2008; Campbell and Jones, 2011). To achieve a robust result, the location decision-making problem of the current study asks the opinions of the decision-makers in the humanitarian warehouse location problem process and uses a fuzzy set theory to eliminate the vagueness of the linguistic variables.

1.3 Aims and Objectives

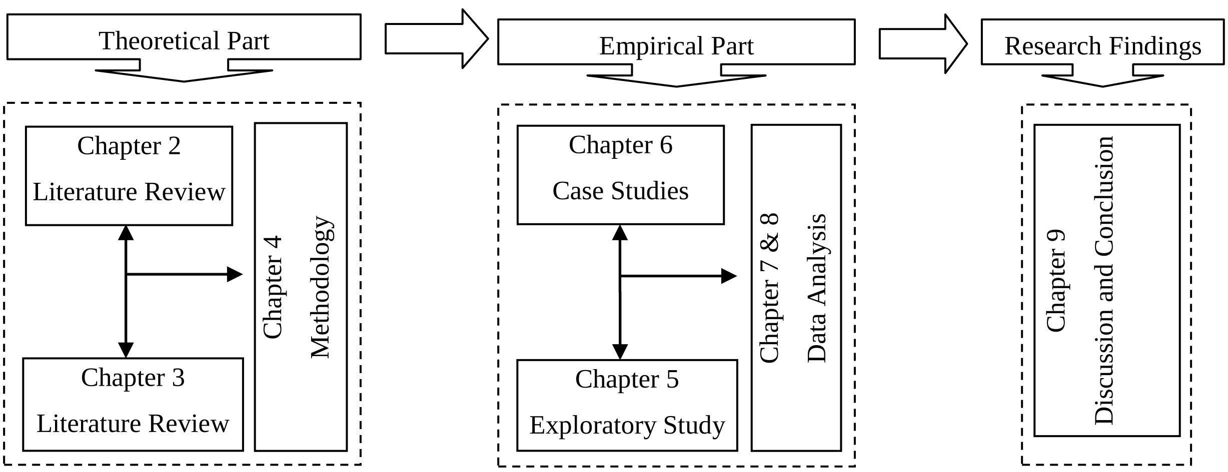
This thesis aims to explore the pre-positioning location problem of humanitarian facilities in the humanitarian relief decision-making process by exploring the regional and specific site determinants of the humanitarian relief warehouse location attributes. To achieve the study's aim, the author employs a combination of case study and Multi-Attribute Decision-Making (MADM) methods. The specific MADM tools that are applied in this study are: Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The fuzzy set theory is also applied to overcome the vagueness of the linguistic values. Different humanitarian relief organisations are investigated to gain in-depth knowledge of the regional and specific site determinant attributes of the warehouse location problem.

Accordingly, the objectives of this thesis are to:

- Explore the regional determinant attributes in humanitarian relief logistics;
- Examine the priorities of the determinant attributes in the warehouse location problem;
- Identify the specific site determinant attributes in humanitarian relief logistics;
- Highlight the priorities of the specific site determinant attributes in the warehouse location problem;
- Suggest the optimal warehouse location with regional determinant attributes;
- Suggest the optimal warehouse location with specific site determinant attributes;
- Carry out a comparison between the fuzzy and non-fuzzy analysis; and,
- Propose a warehouse selection decision-making framework.

1.4 Thesis Layout

Figure 1.1 Thesis layout



Source: Author

This thesis has three main sections, as illustrated in Figure 1.1. The first section consists of Chapters One to Four. Following the present introductory chapter, Chapter Two aims to give an overview of humanitarian logistics and the prepositioned warehouse problem. It describes the results of a review of the literature, which examines four dimensions: humanitarian relief logistics, pre-positioned warehouse, facility location problem, and the humanitarian relief warehouse location problem. The first part of the literature review provides an overview of humanitarian relief logistics, with particular emphasis on humanitarian relief logistics management. The second part of the literature review gives an overview of pre-positioned warehouses, including the locations, structure and warehousing strategy. Chapter Three begins with the third part of the literature review, which describes the facility location problem that has been researched using multi-criteria decision-making methods, especially using the AHP and TOPSIS methods. The last part of Chapter Three discusses the warehouse location problem in humanitarian relief logistics management.

The research questions presented in Table 1.1 were initially derived from the literature review and they have been further developed during the research. Various research methods were applied to examine the questions. The chapters in which each question is applied are also shown in Table 1.1. Chapter Four explains the research design and methods that have been used to execute the research project. The rational for employing case study and survey methods is explained in this chapter.

Table 1.1 Research questions

Reference	Research Questions	Chapters
Q1	What are the humanitarian relief warehouse selection attributes?	5
Q2	What are the priorities and the weights of the regional determinant warehouse location selection attributes?	5, 6 and 7
Q3	Where is the optimal warehouse location (using an evaluation of the regional determinant attributes)?	6 and 7
Q4	What are the priorities and the weights of the specific site determinant warehouse location selection attributes?	5, 6 and 8
Q5	Where is the optimal warehouse location (using an evaluation of specific site determinant attributes)?	6 and 8

Source: Author

The second section of this thesis consists of Chapters Five to Eight. Chapter Five explores the humanitarian relief warehouse selection attributes, with an additional exploration of the reasons for implementing the pre-positioned warehouse strategy in humanitarian relief logistics operations. The priority selections of the attributes have also been studied, with the limitation of the pre-positioned warehouse (which has been set aside for further research). Knowledge gained from the commencement of the study until this stage of the research was implemented in the research survey.

The results of the research case studies are presented in Chapter Six. The first case study was undertaken to examine the identification of the regional determinant attributes that are used in international humanitarian relief logistics operations, which uses a macro level approach. The warehouse locations were also identified for further analysis. The second case study involved a group of international humanitarian organisations based in Dubai, UAE to examine the identification of specific site determinant attributes to understand the warehouse location selection problem and to suggest alternative sites.

In Chapter Seven, the regional determinant attributes for pre-positioned warehouses at a macro level are analysed. The priorities and weights of the attributes are assessed for use in the calculation of the optimal location site for the first case study. The same procedure was processed for the specific site determinant attributes that are presented in Chapter Eight, which uses a micro approach.

The third section of this thesis consists of Chapter Nine, which gives an overview and discussion of the research findings. The overall contributions of the research to the body of knowledge are presented, along with the research implications and a number of recommendations for further research.

1.5 Chapter Summary

This chapter has explained the author’s motives for conducting the research. The research aims and objectives have also been highlighted. In addition, the research questions were presented, together with their relative chapters. Each forthcoming chapter’s content has been briefly overviewed and the structure of the thesis has been stated.

CHAPTER 2

LITERATURE REVIEW I: PRE-POSITIONED WAREHOUSES IN HUMANITARIAN RELIEF LOGISTICS

2.1 Chapter Overview

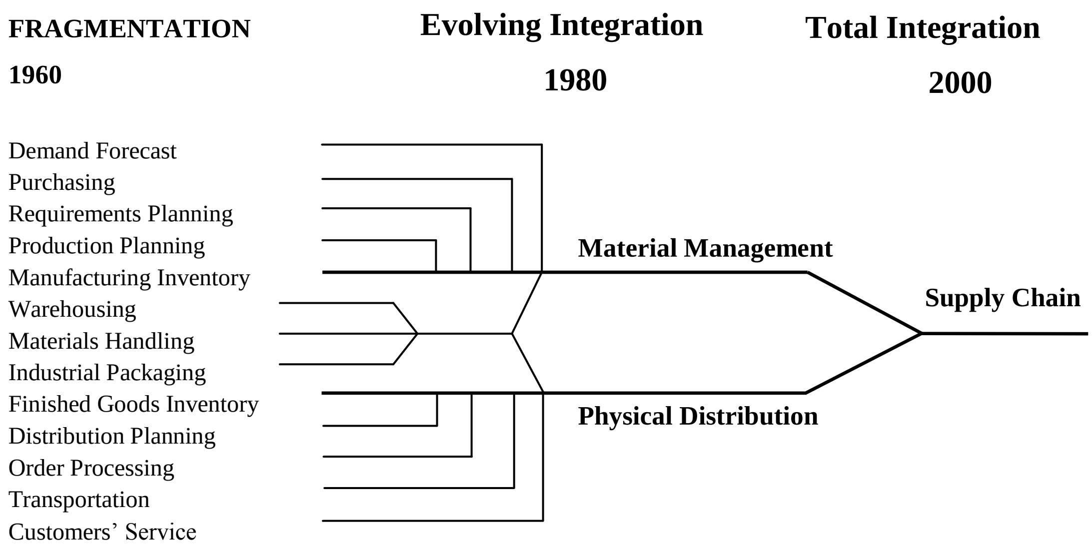
This chapter provides an overview of the published literature relating to the research topic, which has been outlined from the broad view of humanitarian aid before moving on to the specific topic of pre-positioned warehouse in humanitarian relief logistics. The literature review has explored the research methods that are used for locating facility locations in humanitarian relief logistics.

The first section will identify the differences of humanitarian relief logistics from commercial logistics, including the characteristics and involved actors in humanitarian relief logistics. The second section reviews the literature of logistic structure and the process of humanitarian relief, including the different stages of operation phase dealing with disaster occurrence. The importance of the preparedness of the operation phase is described in this section. The third section narrows the topic of preparedness stages specifically into the pre-positioned warehouse preparedness stage. The structure and the location of pre-positioned warehouses will be analysed in this section. The fourth section briefly introduces the various facility location problem research tools. The last section studies the usage of AHP and TOPSIS research tools in the location problem in humanitarian relief.

2.2 Supply Chain Management

The term supply chain management was introduced in the early 1980s (Oliver and Webber, 1992). Its definition subsequently evolved from the management of material within an organisation to the management of material production and distribution channels (Bales *et al.* 2004). During the 1960s, many organisations focused on managing separately what was then defined as the physical supply (i.e. in-bound) and physical distribution (i.e. out-bound) areas. Later developments saw these two areas merge together as many organisations realised the potential savings from managing supply and distribution as one entity. Further development in the 1990s expanded beyond an organisation's boundaries to include supplier and customer chains (Coyle *et al*., 1996). Supply chain management is defined as "*the management of upstream and downstream relationship with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole*" (Christopher, 1998). The supply chain consists of a series of organisations and activities that are required to convert raw materials and deliver them as finished products to the final user (Davis, 1993). This chain is "*lined together via the feed-forward flow of material and the feedback flow of information*" (Towill, 1997).

Figure 2.1 Supply chain development



Source: Coyle *et al.* (1996)

Prior to the mid-1970s, many organisations had pursued a high vertical integration approach in an attempt to realise substantial economies of scales and scope in order to eliminate competition and to reduce market transaction cost (Chandler, 1962; Williamson, 1985). Logistical activities (such as warehousing, transportation, distribution channels, and inventory management) were integral parts of most organisations. However, fierce competition in the early 1970s forced many companies to abandon this model and to replace it with a more disintegrated model.

Accordingly, many organisations realised the importance of supply chain management. As illustrated by Ellram and Cooper (1993), and shown in Table 2.1, the shift in organisations' thinking from traditional to supply chain perspectives was reflected in the coordination and collaboration between different business areas. For example, inventory management from the traditional perspective tended to be focused within the firm; information was rarely shared and this caused the level of uncertainty to increase (Childerhouse and Towill, 2004). Consequently, many firms tended to build mountains of inventories. In another example, cost in the traditional perspective was viewed as inherited cost and little attention was paid to the final product cost or landed cost. The supply chain perspective, in contrast, tends to view the whole chain as one. Inventory cost, for example, is evaluated across the entire chain and efforts to reduce inventory within the chain can benefit all of the players within the chain. In addition, an increase in information flow reduces the uncertainty level, leading to the improved performance of all members of the chain. Joint business planning leads to better collaboration that, in many cases, brings members of one supply chain closer together in the form of joint ventures or partnerships.

Table 2.1 Comparison between the Traditional and Supply Chain system

Factors	Traditional	Supply Chain
Inventory	Firm Focused	Pipeline coordination
Inventory flows	Interrupted	Seamless/Visible
Cost	Firm minimised	Landed cost
Information	Firm controlled	Shared
Risk	Firm focused	Shared
Planning	Firm oriented	Supply chain team approach
Inter-organisational relationship	Firm focused on low cost	Partnership focused on landed cost

Source: Ellram and Cooper (1993)

2.2.1 Logistics

Logistics is defined by the Council of Logistics Management (1998) as "*that part of the supply chain process that plans, implements and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers' requirements*". A key distinction between supply chain management and logistics is that logistics is limited to an organisation's boundaries and its main role is to optimise the flow within these boundaries, whereas supply chain management is seen as extension of the logistics and it acts as a linkage and coordination among other entities in the pipeline to include suppliers, customers and the organisation itself (Christopher, 1998). Therefore, while logistics encompasses all of the activities which occur within an organisation (from material acquirer until delivery of finished product), the supply chain is more concerned with the relationship management among different logistical entities.

The importance of logistics was observed very early by the military; military operations require good planning, with precise implementations and continuous control of operations from start until end. As Christopher (1998) has noted, "*wars have been won or lost through logistics strength and capabilities*". The British Army's defeat in the American War of Independence was due to a *logistical failure* in that the logistic lines supporting the British troops extended all the way back to Britain. In contrast, the success of the allied forces in the Normandy invasion was largely attributed to the ability to provide central support to troops (Song *et al.* 2000).

A similar picture can be seen in the commercial world; the success of Dell the computer manufacturer is a good example of excellent logistics activities' management. On the other hand, the failure of the PowerMac manufactured by Macintosh in the early 1990s was attributed to the organisation's inability to properly manage the company's logistical activities (Song *et al.* 2000).

According to Coyle *et al.* (1996), the main logistics activities within organisations include:

- **Transportation:** This involves the transportation of raw materials or finished goods among the firm's suppliers or customers. Different transportation modes may be used, namely, land, sea or air.
- **Storage:** This activity involves two separate but closely related activities, which are: inventory management and warehousing. These two activities are highly influenced by transportation. If the means of transportation is slow then this affects the size of the inventory and requires an increase in the number of warehouses.
- **Packaging:** This involves moving products to the marketplace. The nature of packing is highly influenced by its transportation means.
- **Materials Handling:** This area of logistics involves the management of materials movement within a firm, including: movement of materials to the warehouse,

movement of materials from the store to the production unit(s), and the movement of materials out of the warehouse

- **Forecasting:** Accurate forecasting of the demand for a product is essential for inventory and material control. This area of logistics has become essential because many companies have shifted to Just-In Time (JIT) and Material Requirement Planning (MRP).
- **Customre Service:** Provide time and place utility in the transfer of ggods and services between buyer and seller. Determned by the interaction of delivery frequency and reliability, stock levels and order cycle time that affect the process of making products and services avavilabe to the buyer.

2.2.2 Humanitarian Relief Logistics

Humanitarian relief logistics is defined as:

> *The process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials, as well as related information, from the point of origin to the point of consumption for the purpose of alleviating the suffering of vulnerable people.* (Thomas and Kopczak, 2005)

Long and Wood (1995) defined relief itself as a ‘foreign intervention into a society with the intention of helping local citizens’. The objective of the relief chain is to provide humanitarian assistance in the forms of food, water, medicine, shelter, and supplies to areas affected by large-scale emergencies (Beamon and Balcik, 2008). Several authors have emphasised that it is crucial that humanitarian logistics should be located in the centre of the disaster relief operation. Chaikin (2003) reported that humanitarian aid logistics require logisticians with professional management experience. Logistics actually serves as a bridge between disaster preparedness and response (Thomas, 2003); therefore, humanitarian logistics is crucial to the effectiveness and speed of response for major humanitarian programs. Procurement and transportation in the logistics function are often one of the most expensive parts of the relief operation (Thomas and Kopczak, 2005).

2.2.2.1 Characteristics of Humanitarian Logistics

The lack of customer pressure makes it harder for humanitarian organisations to pursue their objectives (Tomasini and Van Wassenhove, 2009). Since most natural disasters are unpredictable, the demand for goods in these disasters is also unpredictable (Cassidy, 2003; Murray, 2005). Consequently, it is difficult to rely on demand information for quick-onset disasters for humanitarian relief supply chains (Balcik and Beamon, 2008). Gustavsson (2003) reported the hindering factors that a relief organisation could learn from the commercial supply chain, which are: lack of depth in knowledge, funding that is biased towards short-term responses, and lack of investment in technology and communication. The characteristics of humanitarian logistics are summarised in Table 2.2.

Table 2.2 Characteristics of humanitarian logistics

The main aim	Alleviating the suffering of vulnerable people.
Actor structure	Stakeholder focus with no clear links to each other, dominance of NGOs and governmental sector. Existence of vertical coordination (upstream or downstream activities) and horizontal coordination (coordination with other oganisations at the same level within the chain).
3-phase setup	Preparation, immediate response, reconstruction
Basic features	Variability in supplies and suppliers, large-scale activities, irregular demand, and unusual constraints in large-scale.
Supply chain philosophy	Supplies are ‘pushed’ to the disaster location in the immediate response phase. Pull philosophy added in reconstruction phase. Short lead times for a wide variety of supplies. Unpredictability of demand, in terms of timing, location, type, and size. Lack of resources (supply, people, technology, transportation capacity, and money).
Transportation and infrastructure	Infrastructure destabilised and lack of possibilities to assure quality of food and medical supplies.
Time effects	Time delays may result in loss of lives. Speed of delivery affects people’s lives High stakes associated with adequate and timely delivery.
Bounded knowledge actions	The nature of most disasters demands an immediate response: hence, supply chains need to be designed and deployed at once even though the knowledge of the situation is very limited. Dynamic and chaotic environments.
Supplier structure	Choice limited, there are even sometimes unwanted suppliers.
Control aspects	Lack of control over operations due to emergency situation.

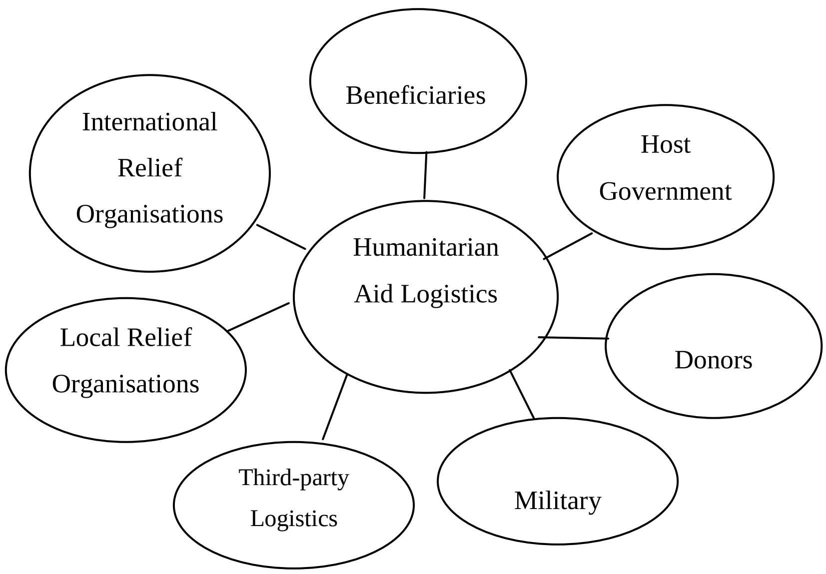
Source: Balcik *et al.* (2010), Balcik and Beamon (2008), Cassidy (2003), Kovács and Spens (2007), Long and Wood (1995), and Murray (2005)

2.2.2.2 Involved Actors

The actors and stakeholders that are involved in humanitarian aid relief logistics are described in Figure 2.2. Relief operations are characterised by many international groups working simultaneously in a distressed area so that there will inevitably be some confusion and initial disorder, especially regarding the responsibilities of individual bodies and the chain of command (Pettit and Beresford, 2005). Although each of the actors involved in the disaster response has the same general goal (i.e. to help and alleviate suffering), their primary motives, missions and operating constraints may differ (Balcik *et al*. 2010).

Although the largest agencies are global actors, there are also many small regional and country-specific agencies (Thomas and Kopczak, 2005). For example, the military, host governments and neighbouring country governments, non-governmental organisations (NGOs) and logistics service providers are also important actors (Kaatrud *et al.* 2003). The heaviest burden and responsibility for planning and executing the response to extreme events usually resides with government agencies (including the military) at local, state, and federal levels (Holguin-Veras *et al.* 2007).

Figure 2.2 Actors in Humanitarian Aid Logistics



Source: Interpreted from Balcik and Beamon (2008), Holguin-Veras *et al.* (2007), Kovács and Spens (2007), Pettit and Beresford (2005), and Salisbury (2007)

The military play an important role in humanitarian relief operations and on many occasions military personnel have been called on to provide assistance (Özdamar *et al*. 2004). The nature of a particular disaster or emergency largely determines the form of the response and the mix of military and non-military response allocation (Pettit and Beresford, 2006). For example, there are certain activities that the military are often better placed to provide during natural or man-made crises (Pettit and Beresford, 2006). The detailed activities that the military will be involved during humanitarian operations include: providing humanitarian assistance; protecting humanitarian assistance; assisting refugees and displaced persons; enforcing a peace agreement; and, restoring order (Byman *et al*. 2000; MoD, 2002, 2003). The military will intervene differently according to the nature of the disaster (i.e. man-made or natural). This requires the balancing of international and national political goals, and military objectives as well as the possibility of having to provide humanitarian relief and the logistics necessary to support it (Pettit and Beresford, 2005). Military involvement tends to be more likely in the case of large-scale sudden events by virtue of the requirements of speed and scale (Pettit and Beresford, 2006).

The host government tends to control assets such as warehouses or fuel depots (Kovács and Spens, 2007). Consequently, government approval is required for relief operations and most governments prefer to work with one United Nations agency, which will act as the 'umbrella' organisation for other relief organisations (Pettit and Beresford, 2006). The logistics or regional service providers of the host country can either facilitate or constrain the operational effectiveness of humanitarian logistics operations (Kovács and Spens, 2007). Donors are important actors because they provide the bulk of funding for major relief activities (Kovács and Spens, 2007). Cash and in-kind donations can be contributed by individuals, governments, and private sectors. (Holguin-Veras *et al.* 2007; Kovács and Spens, 2007). Beneficiaries have very little power and are mostly the victims of the disaster (Tomasini and Van Wassenhove, 2009). The private sector (such as extra-regional logistics service providers) can contribute to the international relief efforts to deliver aid supplies to the people and communities affected by natural disasters in a professional manner (Kovács and Spens, 2007). Volunteer organisations include a wide spectrum of entities, ranging from local civic and faith-based groups to large international organisations (Holguin-Veras *et al.* 2007). Local relief organisations play a crucial role in providing basic human and medical services (such as food and clothing) to disaster victims (Leonard, 2005).

2.2.3 The Differences between Humanitarian Relief and Commercial Logistics

There are clear parallels between business logistics and relief logistics; however, to date the transfer of knowledge between the two has been limited and the latter remains relatively unsophisticated, although more recently greater effort has been put into understanding and developing systems which can improve the relief supply chain (Fritz Institute, 2005). The comparison between the commercial and humanitarian supply chain has been studied by a large body of researchers from a number of different perspectives. Humanitarian logistics, as well as business logistics, encompasses a range of activities, including: preparedness, planning, design, procurement, transportation, inventory, warehousing tracking and tracing, distribution, recipient satisfaction, bidding and reverse bidding, reporting and accountability, and customs clearance (Gustavsson, 2003; Thomas and Kopczak, 2005). The basic principles of managing the flow of goods, information and finances that have been established by commercial logistics are also valid for humanitarian logistics (Kovács and Spens, 2007). The unique characteristics of the disaster relief environment, and a comparison and contrast between commercial supply chains and humanitarian relief chains, have been described by Beamon (2004), Thomas and Kopczak (2005) and Van Wassenhove (2006). A summary of the characteristics of humanitarian logistics that distinguishes from business logistics is shown in Table 2.3.

The fundamental differences between humanitarian and commercial logistics were found to be in terms of the strategic goals, the customer and demand characteristics, environmental factors, and in the motivation for improving the logistics process (Balcik and Beamon, 2008; Ernst, 2003). The ultimate goal of humanitarian relief logistics is to deliver the right supplies in the right quantities to the right locations at the right time to save lives and reduce human suffering within given financial constraints (Beamon and Balcik, 2008). Although cost reduction and service improvement are common considerations for both supply chain and the relief chain, the differences between the two sectors bring different dimensions to these common objectives (Beamon and Balcik, 2008). Humanitarian logistics is characterised by large-scale activities, irregular demand and unusual constraints (Beamon and Kotleba, 2006a). For example, the humanitarian sector often has difficulty establishing reliable transportation routes and it is affected by political instability, in-country infrastructure, and topography (Beamon and Balcik, 2008). Most of the operations are carried out in an environment with destabilised infrastructures or weather delays of air or sea links (Cassidy, 2003; Long and Wood, 1995). The problems can range from a lack of electricity supplies to limited transport infrastructure and include 'controlled' environments with some minor variability (e.g. traffic congestion) (Kovács and Spens, 2009).

Table 2.3 A comparison of commercial and humanitarian supply chains

Criteria	Commercial Sector	Humanitarian
Revenue Sources	Earned from sale of products and services to customers.	Government funding, charitable donations, and in-kind donation.
Goals	Make profits and provide satisfactory financial returns to shareholder interests.	Achieve its social purpose and mission. Financial stability is crucial to missions and survival. Constraints rather than objectives
Motivation	Profit	Beyond profitability to alleviating the suffering of vulnerable people.
Coordination	Well-coordinated	Lacks coordination
Strategic Goals	Cost reduction Capital reduction Service improvement	Mission effectiveness Financial sustainability
Stakeholders	Homogeneous interests of the owners of a firm guide the firm's policy.	Multitude of constituencies whose goals and needs may be heterogeneous.
Demand	Products and service. Individuals or organisations receiving the products. Stable, predictable external demand patterns, often from fixed locations in set quantities, and regular intervals.	Supplies and people (Aid recipients). Generated from random events that are unpredictable in terms of timing, location, type, and size. No 'true demand'. Demand is accessed through aid agencies. Lack of customer pressure.
Lead Times	Customers accept a lead time of several days to one week between the time they place an order and their shipment arrives.	Zero lead time (no warning) between the time a demand occurs and the time the supplies are needed.
Performance Measurement	Profits are measured easily and they are a good test of market-need satisfaction and an organisation's ability to operate efficiently.	Intangibility of the services offered, immeasurability of the missions, unknowable outcomes, and the variety, interests and standards of stakeholders.

Source: Adapted from Beamon (2004), Beamon and Balcik (2008), Beamon and Kotleba (2006a), Cassidy (2003), Ernst (2003), Kovács and Spens (2009), Thomas and Kopczak (2005), Tomasini and Van Wassenhove (2009), Tzeng *et al.* (2007), Van Wassenhove (2006) arranged by author

Commercial logistics are normally planned in advance of demand while most commercial logistics operations are relatively well established while relief chain logistical decisions are made within shorter time frames (Balcik and Beamon, 2008). In addition, commercial logistics usually deal with a predetermined set of suppliers, manufacturing sites, and a stable or at least predictable demand, which are all unknown in humanitarian logistics (Cassidy, 2003). The major factors concerning humanitarian aid logistics in decision making after disasters occur are the uncertainties and variability (Balcik and Beamon, 2008). In the commercial sector many businesses are driven by customers (i.e. demand), while humanitarian organisations are mostly driven by donors (i.e. supply) (Tomasini and Van Wassenhove, 2009). In humanitarian relief operations, the customers, who are aid recipients, actually have no choice and, therefore, 'true demand' is not created in humanitarian logistics (Kovács and Spens, 2009).

2.3 Humanitarian Relief Logistics Management

Humanitarian relief logistics operations should be approached differently according to the various kinds of disaster occurrences (Tatham and Kovács, 2007). The response method and the time to establish the relief supply chain will differ between man-made and natural crises (Ramsbottom and Woodhouse, 1996). Generally, the predictability of a disaster plays a role in the possibilities of responding to it and the occurrence of particular types of disasters can be tied to specific geographical areas (Chang *et al.* 2010). Van Wassenhove (2006) distinguished different types of disasters along with the disaster taxonomies that typically categorise disaster (and their responses) according to the warning time of disaster (i.e. slow versus rapid or sudden-onset disasters) and its causes (see Figure 2.3). The simplified categorisation of disasters is more complex and, therefore, the planning of pre-positioned stock is not as simple as Figure 2.3 may imply. Sudden-onset disasters have a strong negative impact on the physical infrastructure of the region, destroying transport infrastructure (such as bridges and air fields), electricity networks, and communication infrastructure (Barbarosoğlu *et al.* 2002). Meanwhile, forecasting, even planning, is possible in the case of slow-onset disasters; for example, agricultural production can be monitored and refugee camps constructed in advance (Kovács and Spens, 2009). Man-made events generally have a lead-up period which can be monitored and used for a certain amount of preparation (Van Wassenhove, 2006). However, natural disasters may occur with little or no warning and often necessitate a very large-scale response at very short notice (Wijkman and Timberlake, 1988). By definition, disaster relief normally covers sudden catastrophes (such as natural disasters) but very few man-made disasters (Kovács and Spens, 2007). The nature of the disaster relief activities differ not only across the different types of disasters but also with respect to the duration of the disaster relief programme (Tatham and Kovács, 2007). Each type of disaster has a different impact in each of the different sub-regions, depending on geography, demography and socio-economic status (Kovács and Spens, 2009). A generic differentiation can, therefore, be made between long-lasting events that are characterised by continuous aid work (e.g. famine relief), and disasters in which initial problems can be overcome in relatively short order, which is also called disaster relief (Kovács and Spens, 2007, 2009). What is new to humanitarian logistics is the emphasis of the planning and preparedness, not only in slow-onset disasters but also in sudden-onset disasters (Jahre and Heigh, 2008). Oloruntoba and Gray (2006) argue that responding to a sudden-onset disaster calls for agile supply chains, thereby focusing on response times, while the planning horizon for slow-onset disaster enables logisticians to focus on cost efficiencies.

Figure 2.3 Simplified categorisation of disasters

	Natural	**Man-made**
Sudden-onset	Earthquake Hurricane Tornadoes	Terrorist Attack Coup d'état Chemical Leak
Slow-onset	Famine Drought Poverty	Political Crisis Refugee Crisis

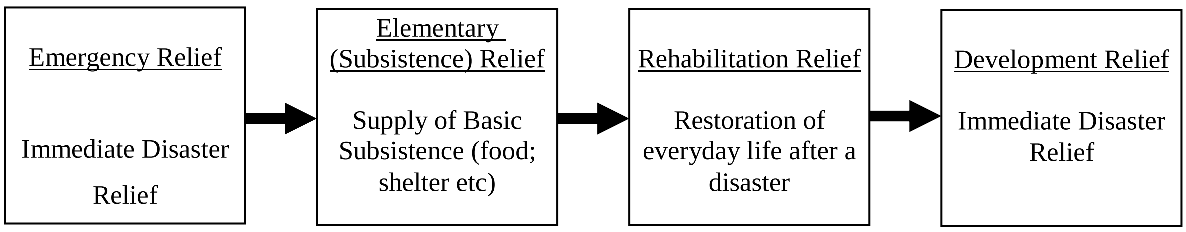
Source: Van Wassenhove (2006)

A number of models have been identified which incorporate many of the key stages of the emergency relief cycle; however, there is no single model that can accommodate all of the variables in the supply of emergency relief materials (Pettit and Beresford, 2006). Humanitarian logistics literature distinguishes between different phases of disaster relief. The minimal distinction is between preparation and post-event phases (Long, 1997; van Wassenhove, 2006; Hass *et al.* 1977). The cycle of activity in a *recovery model* is to identify the overlaps that occur between each of the phases of full emergency relief cycle, showing the most activity involved in the emergency phase after the disaster has struck. Pettit and Beresford (2006) later included military and non-military activities in the model. Park (1991) modelled the *funding and distribution of aid* detailing the flow of aid from official and voluntary sources. Meanwhile, the *disaster management cycle* that was outlined by Carter (1999) shows the continuum of inter-linked activities that comprise disaster and its management. The sequence begins with preparedness, moves through a number of stages to the operational (transport and distribution) phase, and then moves through further stages to a conclusion where its performance is evaluated (Thomas, 2002). Whittow (1980) devised a flow-chart *general systems model* to illustrate the effect of environmental hazards and the possible behavioural adjustments and human responses to extreme events that can occur. The *operational phase* of emergency relief was illustrated by Ludema (2000), which categorises humanitarian relief operations into emergency relief as immediate response to a disaster, elementary or subsistence relief, rehabilitation relief to restore everyday life, and development relief aimed to improve a system. Lee and Zbinden (2003) and Kovács and Spens (2007) further differentiate between preparation, immediate response and reconstruction. *A disaster response model* was developed by Jennings *et al.* (2000) to establish the common criteria which can be applied to all refugee crises with regard to the logistical processes by which food aid is transported and distributed. Waugh (2002) considered the adjustments and responses to hazard events, devising models that consider the *responses to hazard events* in a disaster response model similar to that of Hass *et al*. (1977). Furthermore, the *relief mission cycle* (Beamon, 2004; Thomas, 2002) differentiates between assessment, deployment, sustainment, and reconfiguration and *cyclical phase* of relief mission (Safran, 2003) which differentiates between prevention, transition and recovery illustrate the time frame of the disaster relief operation.

2.3.1 Disaster Relief Logistics Operation Phase

Most relief organisations engage in two broad types of activities: Relief activities and development activities (Byman *et al.* 2000). Firstly, relief activities provide relief for victims of large-scale emergencies, these tend to be short-term activities that focus on providing goods and services to minimise immediate risks to human health and survival. Secondly, development activities provide longer-term aid, focusing on community self-sufficiency and sustainability, these activities include establishing permanent and reliable transportation, healthcare, housing, and food.

Figure 2.4 Typology of humanitarian relief operations



Source: Ludema, 2000

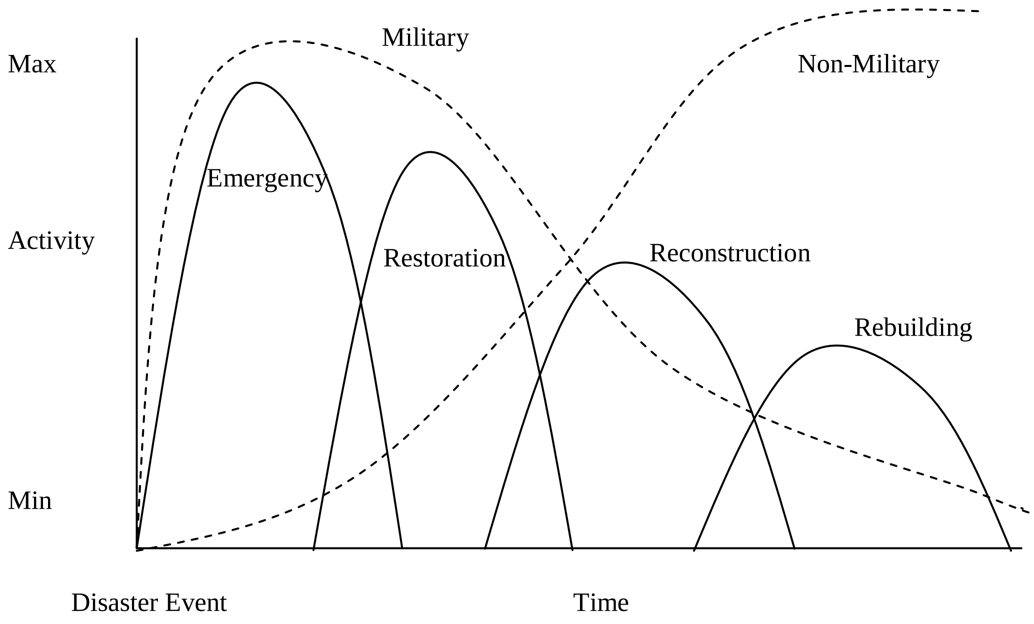
Ludema (2000) categorised the humanitarian relief operation into emergency, elementary (or subsistence), rehabilitation and development relief (Figure 2.4). Figure 2.5 illustrates the recovery diagram with the involvement activities of the military and non-military in the different relief phases (Pettit and Beresford, 2006; Haas *et al.* 1977).

A similar phased approach to the management of such humanitarian disasters is supported by Kovács and Spens (2007, 2009), and Lee and Zbinden (2003) who use a three phase model, which is:

1. Prepare an immediate response and reconstruction;
2. Preparedness during the operation; and,
3. Post-operations (see Figure 2.6).

The phases of disasters can be distinguished as: before the disaster strikes (i.e. preparedness), instantly after a disaster strikes (i.e. the immediate response phase), and the aftermath of a natural disaster (i.e. reconstruction phase) (Kovács and Spens, 2007).

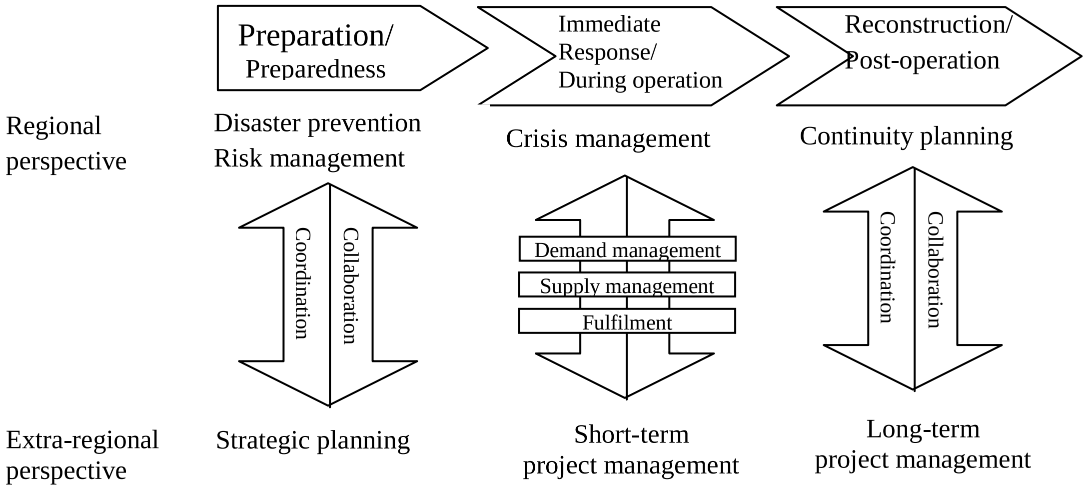
Figure 2.5 Post crisis recovery



Source: Adopted from Pettit and Beresford. (2006), Haas *et al.* (1977)

Disaster management helps regional actors in the phase of preparing for disasters, while extra-regional actors can turn to strategic planning during the disaster relief operation (Lee and Zbinden, 2003). In the immediate response phase, regional actors learn from crisis management, or even from the response to disruptions in material flows in business logistics (Lee and Zbinden, 2003; Kovács and Spens, 2007). The reconstruction phase is in fact similar to a business logistic environment, although it does not aim to generate a profit (Kovács and Spens, 2007).

Figure 2.6 A Framework for disaster relief logistics



Source: Adapted from Lee and Zbinden (2003) and Kovács and Spens (2007, 2009).

2.3.1.1 Preparation Phase

The preparation phase is the time in which aid agencies can develop collaborative platforms (Kaatrud *et al.* 2003). Coordination in the preparedness phase is an important challenge for many different aid agencies because suppliers and local and regional actors all have their own ways and structures of operating (Long and Wood, 1995). Unfortunately, many emergency preparedness plans lack any insight into disaster relief logistics (Chaikin, 2003). In addition, since donors insist that their money goes directly to help victims and not to finance back-office operations, preparation and training are often neglected (Murray, 2005). Meanwhile, the donors place importance on the donated money or goods being used for another emergency or in another place. The failure of an early warning system could lead to a major catastrophic disaster and the improvements that are learnt from the past experience often lead to a successful responding to the future disasters (Hale and Moberg, 2005).

2.3.1.2 Immediate Response Phase

The main problem in the immediate response phase lies in coordinating supply, the unpredictability of demand, and the last mile problem of transporting necessary items to disaster victims (Beamon, 2004; Long 1997; Long and Wood, 1995; Özdamar *et al*. 2004; Tomasini and van Wassenhove, 2004). Less developed regions are also more prone to a larger scale destruction of their infrastructure once a disaster strikes (Kovács and Spens, 2007). Remote aid agencies assume the needs of disaster victims based on very limited information (Long and Wood, 1995). In addition, demand assessment after disaster includes a consideration of the cultural peculiarities of the disaster region (Beamon, 2004; Trunick, 2005). Demand is unpredictable regarding timing, location, and scale (Beamon, 2004; Murray, 2005; Long, 1997; Long and Wood, 1995). Language barriers in a disaster region also complicate the distribution of adequate supplies (Long and Wood, 1995). The length of each phase in the relief cycle varies depending on the disaster characteristics; however, the speed of relief operations during the first days of the disaster significantly affects the lives of many people threatened by the disaster (Balcik and Beamon, 2008).

Aid agencies receive many unsolicited and sometimes unwanted donations (Chomilier *et al*. 2003). For example, during many disaster relief operations unsolicited supplies can clog airports and warehouses (Cassidy, 2003; Murray, 2005). These items can even include drugs and foods that are past their expiry dates (Murray, 2005), laptops or other equipment needing electricity in an area where the infrastructure has been destroyed (Kovács and Spens, 2007), and heavy clothing not suitable for tropical regions (Dignan, 2005). The lack of standard labelling of supplies is one of the biggest problems of distributing aid at sites, and it has driven many aid agencies to start colour-coding items (Murray, 2005).

Transportation itself is often not the biggest problem in disaster relief operation (Kovács and Spens, 2007). Fuel shortages develop very quickly in disaster areas (Sullivan, 2005). Airdrops of supplies are always a last option to deliver the necessary goods to disaster victims (Wichmann, 1999). It has also been discovered that packages often need to be small so they can be handled by a single person (Long and Wood, 1995; Murray, 2005).

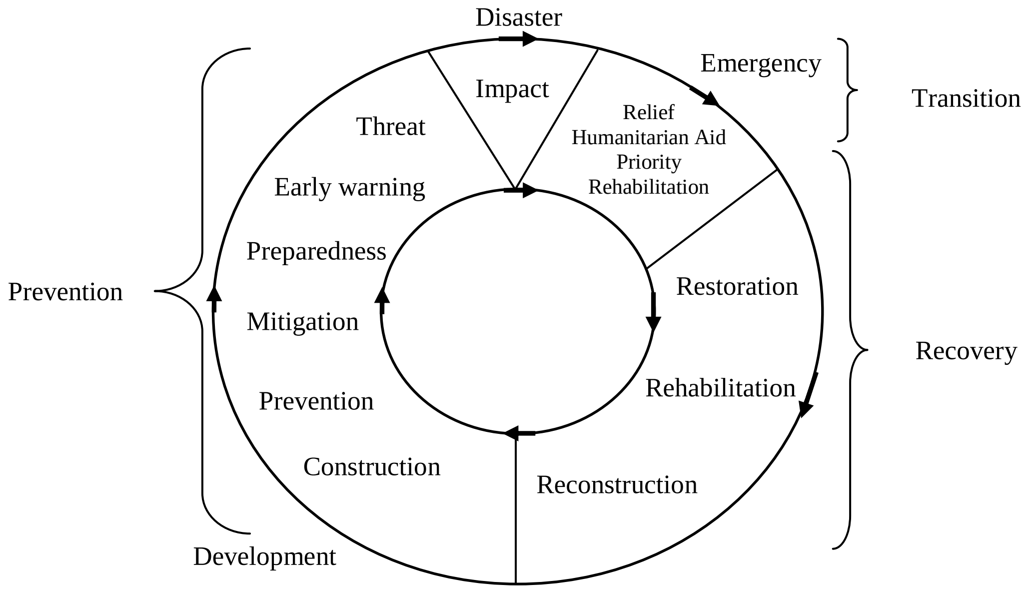
2.3.1.3 Reconstruction Phase

The reconstruction phase is important since disasters can have long-term effects on a region (Kovács and Spens, 2007). In most cases of the reconstruction phase, international aid agencies provide technical and financial assistance for the disaster affected populations (Chang *et al.* 2010). For many disaster-struck areas, funding is often focused on short-term disaster relief (Gustavsson, 2003) and a lack of funding can cause the long-term phase of reconstruction to be neglected (Kovács and Spens, 2007). Disasters have long-term effects on the management of companies, which means that it can be argued that regional actors should also focus on the reconstruction phase for which continuity planning is needed (Kovács and Spens, 2007). Therefore, disaster prevention plans need to be revised to include things that have been learned from current disasters (Thomas, 2003). However, categorising disaster management into the phases and stages referred to above may be too rigid, allowing insufficient flexibility for external influences and unforeseen problems in the crisis management plan (Pettit and Beresford, 2006). The three key elements (i.e. preparedness, response and recovery) cannot be designated to specific time periods but they are all consistently part of preparation-reaction process (Brown, 1979).

2.3.2 Cyclical Nature of Disaster Relief

Safran (2003) usefully emphasises the cyclical nature of humanitarian relief (see Figure 2.7). Therefore, the recovery phases of one disaster need to be linked to a new prevention phase to mitigate the effects of future potential disasters (Tatham and Kovács, 2007). Safran (2003) separates two elements of the immediate response phase, namely the disaster and the emergency elements.

Figure 2.7 Cyclical phases of humanitarian relief



Source: Safran (2003)

Tatham and Kovács (2007) investigated the change from disaster and emergency elements towards recovery and found that the response of national and international humanitarian organisations depended on these elements. For example, search and rescue operations and national disaster relief activities are on-going in the disaster element while international aid agencies would arrive during the emergency element only. They also found that the primary transportation modes between these elements and phases differ.

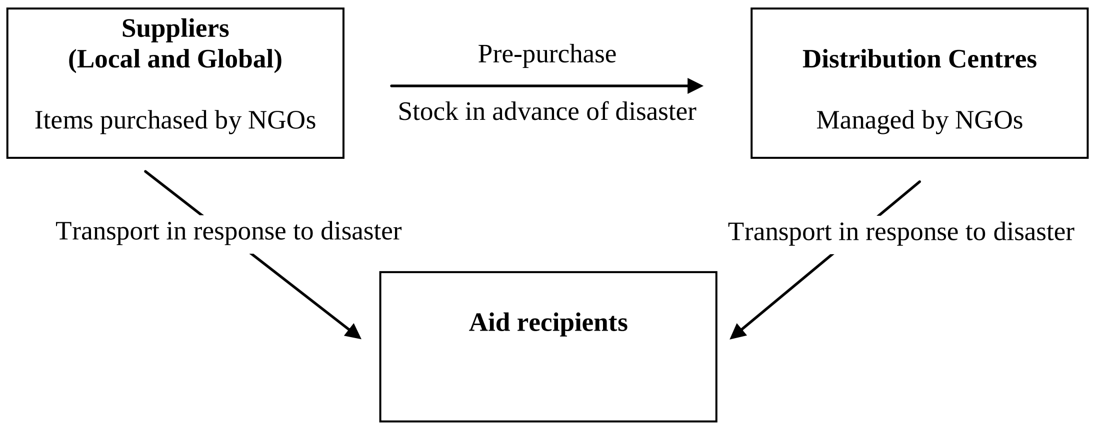
2.4 Humanitarian Relief Supply Chains

Once a disaster occurs, humanitarian organisations can acquire relief supplies from three main sources: local suppliers, global suppliers, and distribution centres (pre-positioned stocks) (Balcik and Beamon, 2008). Figure 2.8 illustrates the simplified overview structure of humanitarian relief chain to show how relief goods are distributed; for example, whether they are delivered straight to aid recipients or through distribution centres where the relief goods are pre-purchased and stocked beforehand. The composite model is presented by Pettit and Beresford (2006), representing a drawing together of the key themes from approaches developed in both military and NGO practice involved in each of the following phases: preparedness, assessment/appeals, resource mobilisation, procurement, transportation execution, stock/asset management, and performance evaluation. Some of the residual funds are then used to award social subsidies or to reimburse the cost of medicines (EVZ, 2012), to provide technical support (UNICEF, 2012), and to support on-going projects (IOM, 2004)

During a disaster logisticians first attempt to procure the supplies from local sources and, if the relief organisation owns a centralised warehouse, the logistician then checks available supplies in those warehouses (Beamon and Balcik, 2008). The initial assessment is usually performed within the first 24 hours of a crisis in order to estimate the supplies required to meet the relief needs of the affected population (Thomas, 2007). A preliminary appeal for donations of cash and relief supplies is often made within 36 hours of the onset of a disaster (Thomas, 2007). Anything that cannot be fulfilled locally or from centralised warehouse is procured from global suppliers through a competitive bidding process (Beamon and Balcik, 2008). The aid agencies typically develop strong relationships with the suppliers of those items that are frequently needed in natural disasters and they usually have long-term purchasing agreements with these firms (Kovács and Spens, 2007).

Stocks can be pre-positioned (Thomas, 2003); for example, the Copenhagen warehouse is able to supply the most frequently required items (Dignan, 2005). Most of the disaster relief procurement decisions are short-term decisions where the procurement process starts after a needs assessments is performed (Balcik and Beamon, 2008). Information technology plays a crucial role in procurement where organisations in disaster-prone regions track their particular needs. This means that at the times of disaster these organisations can develop emergency purchasing procedures with their suppliers (DeJohn, 2005).

Figure 2.8 Simplified relief chain overview



Source: Balcik and Beamon (2008)

Acquiring the necessary supplies for disaster relief chain can be done both locally and globally depending on the various situation and circumstances. There are advantages and disadvantages of the integrated procurement process. Table 2.4 illustrates the advantages and disadvantages of procurement of disaster relief logistics.

2.4.1 Local Procurement

Acquiring supplies locally may be advantageous due to low transportation costs, prompt deliveries (e.g. no customs clearance is required and there are no delays due to congestion at the ports). Local procurement also provides support to the local economy (PAHO, 2001). Although meeting a country's emergency needs from local resources could be considered as the best procurement scenario, it may be risky to develop a response strategy that depends solely on local sources. For example, local supplies may not always be available in the quantity and quality needed (Balcik and Beamon, 2008). Local procurement can also create local competition among relief organisations trying to purchase the same types of supplies and may, therefore, create shortages in the local market (PAHO, 2001). Relief agencies procuring locally must develop contingencies for acquiring supplies from other (i.e. non-local) sources (Balcik and Beamon, 2008).

Table 2.4 Advantages and disadvantages in relief logistics procurement

Procurement type	Advantages	Disadvantages
Local procurement	• Low transport cost • Prompt deliveries • Local economy support	• Risk strategy to operate solely • Unavailability of enough quantity and quality needed • Create shortage in the local market
Global procurement	• Increase the availability of large quantities of high-quality supplies	• Longer deliver times • Higher transportation cost • Supplies not delivered to affected area during the initial critical days due to bidding process
Pre-positioned stocks	• Deliver sufficient relief aid within a relatively short timeframe • Less expensive than post-disaster supply procurement • Increase the ability of mobilisation • Efficient (Low cost, less duplication of efforts, less waste of resource) • Effective (Quick response, satisfied demand)	• Financially prohibitive • Complex • Too many uncertainties • Only few can operate • Impossible to depend solely in case of large scale disasters • Capacity limitations

Source: Adinolfi *et al.* (2007), Beamon and Balcik (2008), Balcik and Beamon (2008), Strash (2004), PAHO (2001), Salisbury (2007)

2.4.2 Global Procurement

Using global suppliers in disaster relief procurement increases the availability of large quantities of high-quality supplies (Balcik and Beamon, 2008). Meanwhile, the potential disadvantages lie in longer delivery times and higher transportation costs (PAHO, 2001). Consequently much needed supplies acquired by the time-consuming bidding process may not be delivered to affected areas during the initial critical days following a disaster (Balcik and Beamon, 2008). This problem has led some humanitarian organisations to begin to establish pre-purchasing agreements with suppliers, specifying the quality and delivery requirements for certain critical emergency items (Balcik and Beamon, 2008). Under framework agreements, these suppliers may hold emergency stocks for humanitarian organisations; however, humanitarian organisation's evaluation of its disaster relief procurement options still depends on the situation and the suppliers are still invited to bid (Salisbury, 2007).

The majority of the NGOs tend to rely on local procurement and international procurement, which may be too slow to meet emergency requirements (Adinolfi *et al*. 2007). The problems of the disaster relief logistics procurement process is that it is unable to obtain and deliver emergency supplies to affected areas within a critical response time period. This emphasises the necessity of the preparedness logistics activities of pre-disaster response (Balcik and Beamon, 2008).

2.4.3 Pre-Positioned Stocks

In the initial days of the deployment phase, most of the critical supplies arriving to the disaster areas are sourced from a relief organisation's global pre-positioned stocks (Balcik and Beamon, 2008). Cost is one of the reasons for pre-purchasing the supplies because it means that they are able to purchase them at a reasonable price (Salisbury, 2007). Once a disaster occurs, demand for supplies increases dramatically and suppliers will often raise their prices in response (Beamon and Balcik, 2008). Meanwhile, the distribution centres are located as close to the emergency as possible, depending on their strategic operations. Furthermore, the pre-disaster activities mean that the relied organisation is able to react quickly to a disaster (Beamon and Balcik, 2008).

Even though there are more advantages operating the pre-positioned facility, there are also several challenges that need to be overcome in order to ensure the smooth flow of the relief logistics. Firstly, difficulty in creating an effective pre-positioning plan includes uncertainty about whether or not natural disasters will occur and, if they do, where and with what magnitude (Rawls and Turnquist, 2010). Consequently, operating a pre-positioning policy can be financially prohibitive and there are only a handful of relief organisations who can support the expense of operating international distribution centres to store and distribute relief supplies (Balcik and Beamon, 2008; Salisbury, 2007). Although pre-positioned stocks may be useful in some cases, their usefulness may be restricted because they require a considerable financial investment (Chaikin, 2003). Meanwhile, NGOs are encouraged to focus on operational disaster relief activities rather than disaster preparedness because this enables them to reduce expenses or make their relief operation more effective over the long-term (Thomas, 2007). In addition, most of the NGOs avoid using a pre-positioning policy because it is both complicated and expensive (Balcik and Beamon, 2008). The other problem of pre-positioning of stocks is that the total volume of demand satisfied from pre-positioned inventory is generally much less than the total volume of supplies sent to the disaster region over the entire relief horizon (Strash, 2004). Financial limitations and other resource restrictions limit the amount of relief supplies that can be stocked and shipped to disaster areas (Balcik and Beamon, 2008). It has also been found that internal transport capacity is one of the most limited resources in determining the capacity where third-party logistics contractors (i.e. 3rd Party Logistics) need to be involved (Salisbury, 2007). Long (1997) argues against the use of centralised distribution facilities since the victims are often weakened and cannot travel long distances to receive aid. For large-scale quick-onset disasters, it is impossible to meet the entire emergency demand solely from pre-positioned stocks (Balcik and Beamon, 2008).

2.5 Preparedness

The overall goal for preparedness is to improve the rapid response facilities so as to allow timely delivery of food aid in both sudden-onset and slow-onset emergency situations (Scott-Bowden, 2003). It is critical to improve disaster preparedness in supply chains because supply chain disruptions caused by external events can have a significant financial and operational impact when not properly prepared (Hale and Moberg, 2005). Speed of delivery is considered another of the important factors in the relief chain, where the pressure of time in the relief chain is not a question of money but a difference between life and death (Van Wassenhove, 2006). For an organisation to enable to perform efficient supply chains management it should improve its preparedness in terms of human resources, knowledge management and finance (Chomilier *et al.* 2003). It was agreed in International Federation of Red Cross and Red Crescent Societies (IFRC) that two elements of disaster management have to be mastered before the right goods arrive at the right place at the right time: disaster preparedness and disaster response (Chomilier *et al*. 2003). One of the reasons why humanitarian relief organisations engage in preparatory activities to enhance their logistic capabilities is that post-disaster supply procurement brings challenges and risk in acquisition and delivery of adequate relief supplies where it tends to time-consuming and expensive (Balcik and Beamon, 2008). Most emergency logistics focus on generating transportation plans for rapid dissemination of supplies inbound to the disaster hit region (Sheu, 2007; Özdamar *et al*. 2004; Lodree and Taskin, 2008a); however, the study of outbound logistics is often ignored (Ben-Tal *et al.* 2010). Most of the decision support systems and technologies developed for disaster scenarios concentrate on the preparedness phase, few concentrate on the second phase (i.e. the immediate response after a natural disaster), and even fewer deal with the dynamic situation of emergencies (Özdamar *et al*. 2004).

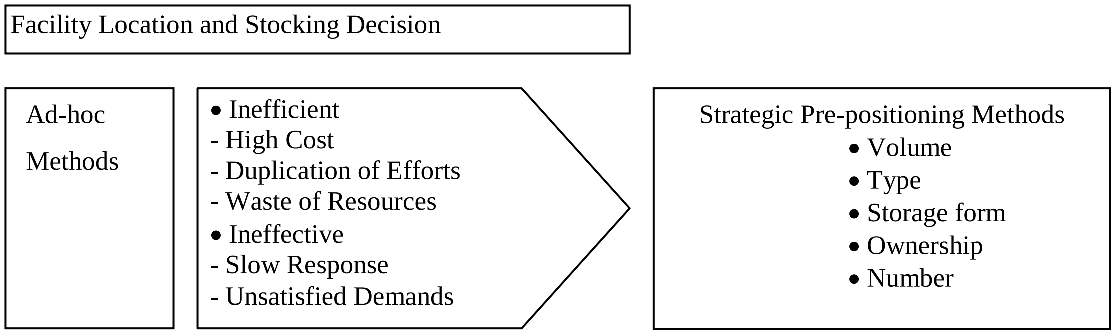
2.5.1 Various Preparedness Stages

The phases of disaster relief can be seen in terms of a cycle that links recovery back to the preparedness phase (Pettit and Beresford, 2006; Safran, 2003). In addition, rehabilitation and reconstruction includes a learning element for further disasters to come (Kovács and Spens, 2009). This is the basis for the implementation of: early warning systems to the preparation planning in the early stage before the disaster strikes (de Leon *et al.* 2006); of disaster awareness in education training programs (Kovács and Spens, 2009); and, of evacuation plans which can prevent the effect for such disasters (Nisha de Silva, 2001). While most major earthquake-prone cities (e.g. Tokyo, San Francisco and Reykjavik) prepare carefully for the possibilities of major earthquakes, other cities and regions cannot ignore evacuation plans for natural disasters (e.g. volcano eruption, avalanches and hurricanes) (Kovács and Spens, 2007). It has been demonstrated that construction on unstable land and collapsing buildings are major causes of death and destruction in many natural disasters (Whiting, 2010). The problem with building construction is not just a lack of seismic building standards, but also inadequate standards of construction (Whiting, 2010). Installing an adequate infrastructure to minimise the effect of a natural disaster is an alternative method of responding to relief (Kovács and Spens, 2007). For example, electricity providers in hurricane-prone areas can put their connections underground, thereby minimising the risk of power shortages and reducing the number of people who die due to electrocution (Longo, 2005). A number of decision support systems and technologies been developed for preparation phase (Kovács and Spens, 2007), including: spatial decision-support systems that creates realistic disaster scenarios and their validation (Nisha de Silva, 2001), simulation techniques, vehicle routing problems (Barbaroşoğlu *et al.* 2002; Özdamar *et al.* 2004) and distribution problems (Hwang, 1999). Facility location and stock pre-positioning decisions in the relief chain are critical components of disaster preparedness and, therefore, require long-term planning to achieve a high-performance disaster response (Balcik and Beamon, 2008). However, many emergency preparedness plans often lack any insight in disaster relief logistics (Chaikin, 2003). Logistical support is needed in prevention and evacuation-related measures before a disaster strikes, in instant medical and food relief procedures once a disaster strikes, and during reconstruction phases (Kovács and Spens, 2007). Logistics actually serves as a bridge between disaster preparedness and response (Thomas, 2003).

2.5.2 Shift to Pre-Positioning

The provision of humanitarian relief pre-positioned warehouses mean that the relief organisation is able to respond rapidly to quick-onset disasters, which affects the performance of relief operations, although the complexities and uncertainties of the operating environment mean that it is difficult set up effective and efficient humanitarian relief networks (Balcik and Beamon, 2008). The inefficiency of ad-hoc methods brings attention to the need for the pre-positioning facility location and stocking decisions (Adinofli *et al.* 2007). Previously, during a sudden-onset disaster a relief provider could assure the urgent provision of basic relief goods to a disaster-affected county by purchasing the supplies directly from a supplier on a case-to-case basis according to United Nations Department of Humanitarian Affairs (UNDHA) (1994). Consequently, related funding constraints, strategic, tactical, and operational techniques used for inventory control and distribution in the relief chain are often ad-hoc and ineffective in the relief chain (Beamon and Balcik, 2008). Furthermore, most of the practices that are used by ad-hoc methods lead to an inefficient and ineffective response (Figure 2.9).

Figure 2.9 Shift to pre-positioning[1]



Source: Balcik and Beamon (2008); Adinofli et al. (2005), Stock and Lambert (1987), UNDHA (1994)

As the number, scale and complexity of emergencies (both natural and man-made) have risen, the relief providers have found themselves unable to respond any longer to a sudden-onset disaster in a timely and appropriate manner using the traditional relief methods (UNDHA, 1994). The objective of a pre-positioning is to minimise the expected cost over all scenarios, resulting from the selection of the pre-positioning locations and facility sizes, the commodity acquisition and stocking decision, the shipments of the supplies to the demand points, unmet demand penalties and holding costs for unused material (Rawls and Turnquist, 2010). Combined with the financial and resource limitations usually inherent in disaster relief activities, this has led international relief providers to establish their own emergency stockpiles (UNDHA, 1994).

Emergency preparedness requirements for large-scale emergency in the pre-positioned or staging areas are critical because they enable a rapid disbursement of supplies from the stockpiles (Rawls and Turnquist, 2010). According to the UNDHA (1994) report, all of the emergency stockpile holders who were approached reported that their stockpiles had been set up in response to their increased and continuous involvement in relief operations following sudden-onset disasters. They also reported that impossibility of being able to ensure (through

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[1] Volume: Size of the warehouse. Type: Supported by different donors or one major donor. Storage form: Storage solely or mixture of medicines, NFIs, food and armoured vehicles. Ownership: Owned, leased or rented. Number: Number of warehouses.

the market and other external sources) an immediate delivery of basic relief items within the framework of their mandates meant that they had set up a stockpile.

2.6 Pre-Positioning in Humanitarian Relief

United Nations Humanitarian Response Depot (UNHRD, 2012) defined humanitarian pre-positioned warehouse as:

> A preparedness tool always on standby to support the strategic stockpiling efforts; to get essential relief supplies and technical personnel rapidly and efficiently of United Nations, International, Governmental and non-Governmental organisations, and reinforcing the capacity of the humanitarian community to respond to emergencies.

The pre-positioning of stock closely relates to the preparation phase of a disaster and means that the organisation can ensure a rapid response when a disaster occurs (Tatham and Kovács, 2007). The importance of a network relation among actors was raised by Uddin and Hossain (2011). Meanwhile, UNDHA (1994) reported that the system of emergency stockpiles represents a balance between the identified needs and the available resources and mandates given to the UN and other international relief organisations. The two most frequently reported advantages of operating the pre-positioned warehouses are that they are cost effective and reliable sources (UNDHA, 1994). Disaster relief items can be bought in advance at the lowest available price through a normal bidding procedure and then delivered to the stockpile by the most economical means of transport (UNDHA, 1994).

Pre-positioning in strategic locations around the world is a strategy that has recently been implemented by some humanitarian relief organisations to improve their capacities in delivering sufficient relief aid within a relatively short timeframe with improved mobilisation (Balcik and Beamon, 2008). The main goal of emergency response efforts is to provide shelter and assistance to disaster victims as soon as possible. To achieve this goal supplies can be pre-positioned at a strategic location so that they are readily available when needed (Rawls and Turnquist, 2010). The basic purpose for establishing an emergency stockpile is to support life-saving operations during the first few days after a sudden-onset disaster through an immediate delivery of required relief items (UNDHA, 1994). The challenge of logisticians consists of propositioning items out of the reach of the potential demolishing impact of a disaster while at the same time ensuring that they are close enough to the disaster to deliver aid quickly and effectively (Balcik and Beamon, 2008). Agencies have established, or are establishing, global and/or regional pre-positioning units that are capable of delivering critical emergency supplies, materials, vehicles and technical assistance to any place in the world within a short timeframe (Gustavsson, 2003). The emergency pre-positioned stockpile is not an end in itself but is instead a specific tool to support the basic activities of the stockpile holder. Although it is a costly operation, it can be considered as a viable solution only if the activities it supports are sufficiently long-term (UNDHA, 1994).

2.6.1 Warehousing Strategy

In recent years, many international logistics businesses have been active in searching for suitable locations for warehouses and international distribution/logistics centres to increase their economies of scale and reduce transportation costs (Kuo, 2011). Since all the activities in an international logistics system often take place between international customers and suppliers, the evaluation and selection of a suitable location has become one of the most important decisions for international logistics firms (Awasthi *et al.* 2011; Kuo, 2011). Defining distribution strategy is a process during which strategic operating alternatives are evaluated to determine the most cost-effective way of providing the required customer service level (Korpela and Tuominen, 1996). Warehousing strategy is an important part of distribution strategy and it consists of the following decisions (Stock and Lambert, 1987)

(1) Should the warehousing facilities be owned, leased or rented?
(2) What is the optimal size and number of warehouses?
(3) What are the optimal locations for warehouses?

The warehouse site selection decision has a significant effect on the types of transport, the markets to be served, and the service level that can be provided to the customers (Schary, 1984). However, warehouse selection is a complex process involving multiple (i.e. both qualitative and quantitative) criteria.

Warehouses are a part of an overall effort to gain place and time utility (Korpela and Tuominen, 1996). The basic requirement for a warehouse to exist in a firm's logistical system is that it can provide cost or service advantages (Bowersox *et al.*, 1986). The main functions for warehouses in a logistical system are:

1. Holding stocks generated by the imbalance between supply and demand;
2. Consolidating shipments from multiple sources into a single shipment to the final destination;
3. Breaking volume-shipping quantities into the smaller quantities requested by customers and trans-loading large-volume shipments; and,
4. Mixing products according to customer orders (Ballou, 1978).

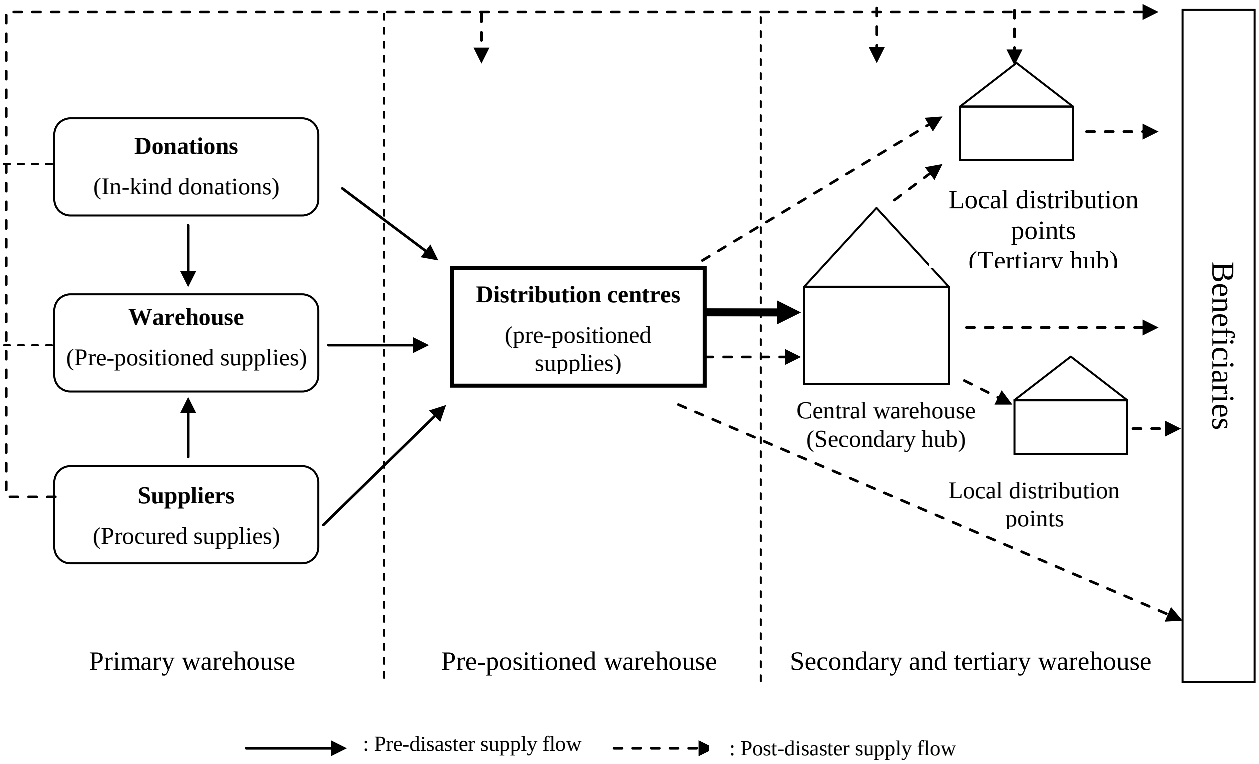
2.6.2 Structure of Pre-positioned Warehouse Supply Chain

The structure flow of supplies in relief chain is proposed in Figure 2.10. Supplies flowing through the relief chain primarily consist of pre-positioned stocks in warehouses, supplies procured from the suppliers, and in-kind donations (Beamon and Balcik, 2008).

Supplies are shipped from various worldwide locations to a primary warehouse, which is usually located near a sea or airport, it is then moved to a secondary hub to be sorted (which is usually a permanent warehouse that is typically located in a larger city) (Beamon and Balcik, 2008). From the secondary hub, supplies are transferred to tertiary hubs (i.e. local distribution centres), from where it is moved to the beneficiaries. The strategic pre-positioned warehouse will provide storage capacity and act as staging areas for response, which does not necessarily involve large stockpiles, with a focus on rapid local procurement capability (Scott-Bowden, 2003).

After a disaster occurs, the demand for aid supplies is likely to change over time (Balcik and Beamon, 2008). Items that are needed immediately at the earliest stage of relief operations tend to be stocked in the pre-positioned facility locations, while other items are safely supplied during the later stages of the relief effort (Balcik and Beamon, 2008). The pre-positioned stocks vary and are chosen to meet the immediate needs of those affected; they include food items, non-food items, medical supplies and equipment (Balcik and Beamon, 2008). Goods that are most commonly needed in disaster relief are water, medicine, chlorination tablets, tents, blankets and protein biscuits for malnourished children (Dignan, 2005). Many relief agencies have pre-purchasing agreements with suppliers of drugs, tents, sheeting or blankets (Murray, 2005).

Figure 2.10 Example structure of pre-positioned relief chain



Source: Modified from Beamon and Balcik (2008), Balcik *et al.* (2010)

2.6.3 Pre-Positioned Warehouse Locations

Relief organisations have established the pre-positioned strategic model in recent years, after carrying out extensive work to strengthen its logistical preparedness and capacity (Scott-Bowden, 2003). Many stockpiles of disaster relief times have been established and are being operated by a variety of organisations around the world. The locations of some of the pre-positioned warehouses that are operated by some of the humanitarian relief organisations are presented in Table 2.5.

Table 2.5 Humanitarian pre-positioned warehouse locations

UN Family	Asia	Europe	Americas	Africa
UNHCR	Dubai, UAE Jordan	Copenhagen, Denmark		Tanzania Ghana
UNHRD	Phnom Penh, Vietnam Subang, Malaysia Dubai, UAE	Brindisi, Italy	Bridgetown, Barbados Panama	Accra, Ghana
UNICEF	Bangkok, Thailand Dubai, UAE	Copenhagen, Denmark	Panama	Abidjan and Yamoussoukro, Cote d'Ivoire Johannesburg, South Africa
UNOCHA		Brindisi, Italy		
WFP		Brindisi, Italy	San Salvador, El Salvador	
WHO		Amsterdam, Netherlands Geneva, Switzerland Brindisi, Italy		
Int'l NGOs				
WVI	Dubai, UAE Brisbane, Australia	Brindisi, Italy Frankfurt, Germany	Denver, USA	
ICRC		Geneva, Switzerland		Johannesburg, South Africa
IFRC	KL, Malaysia Dubai, UAE	Copenhagen, Denmark	Panama, Panama	Nairobi, Kenya
MSF		Bordeaux, France		
Oxfam UK		Bicester, UK London, UK		
Governmental Organisations				
AEIC		Madrid, Spain		
AusAID	Moorebank, Australia			
CIDA			Mississauga, Canada	
DFID	Dubai, UAE	Cirencester, UK		
IPCH	Tokyo, Japan			
JICA	Singapore, Singapore	Frankfurt, Germany	Miami, USA	
NOREPS		Oslo, Norway		Nairobi, Kenya
NZAID	Auckland, New Zealand			
SDC		Bern, Switzerland		
SRSA		Kristinehamm, Sweden		
USAID	Dubai, UAE	Livorno, Italy	Miami, USA	
National NGOs				
ARCS		Vienna, Austria		
BRCS		London, UK		
ERIK AID		Jonkoeping, Sweden		
SRCS		Halmstad, Sweden		

Source: HRN (2008), UNOCHA (2012)

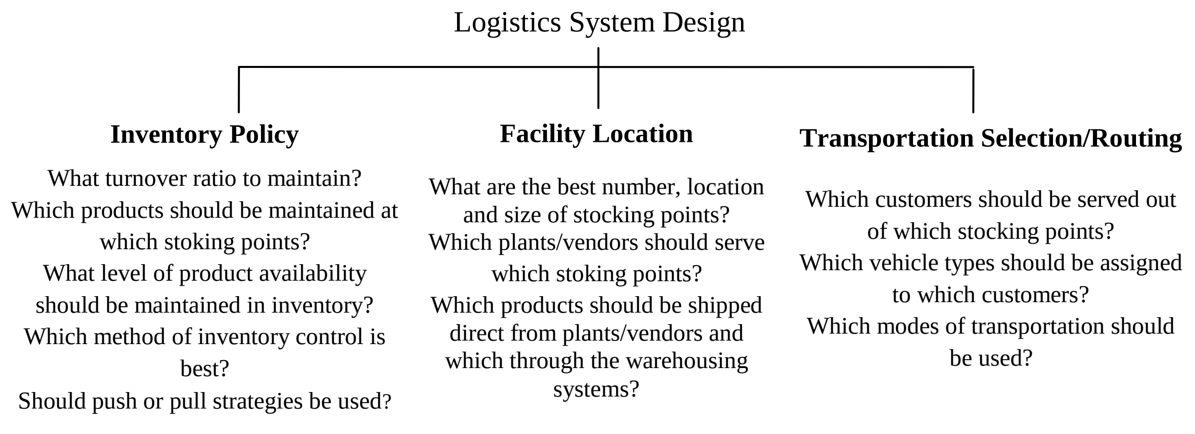
Table 2.5 shows that there are currently more than fifty stockpiles of disaster relief items, which are controlled by twenty-six humanitarian aid organisations (UNOCHA, 2012). The organisations and the locations of the warehouses are still increasing (WFP, 2011). The emergency stockpile holders indicated that they can commit up to 100% of available stock to a disaster anywhere in the world (UNDHA, 1994). All emergency stockpile holders have stressed that promptness of the response is crucial in emergency situations and that the cost of delivery is of secondary importance (UNDHA, 1994). The 'four corner' concept developed by

UNHRD involved establishing strategic response depots to cover the four quarters of the world (Scott-Bowen, 2003). For example, United Nations International Children's Emergency Fund's (UNICEF's) disaster management distribution centre collects most commonly needed items in Copenhagen (Dignan, 2005).

2.7 Logistics System Design

According to Magee *et al.* (1985), the highest level in the hierarchy of logistics problem is called flows and facilities. The fundamental decisions forming the basics 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 (1981) defines the key decision areas in logistics system design as inventory policy, facility location, and transport selection and routing (Figure 2.11). The logistics system design studies are also applicable to the findings in the area of humanitarian relief logistics. However, most of the studies for humanitarian relief logistics are implemented by the optimisation model, which deals with quantifiable solutions that overlooks human factors.

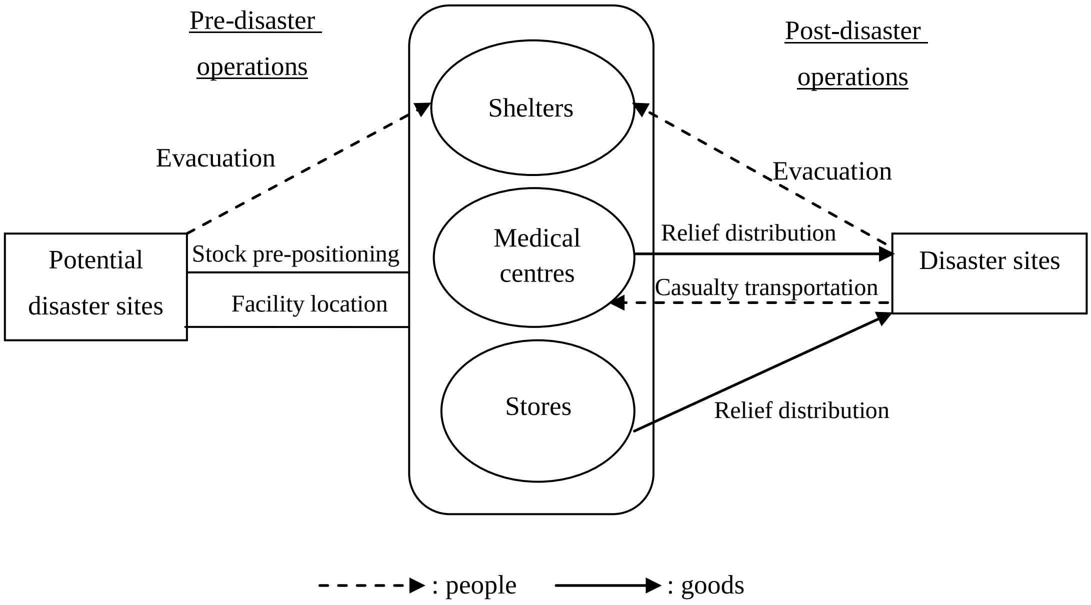
Figure 2.11 The traditional key areas in logistics system design



Source: Ballou (1981)

The literature that relates to emergency logistics covers many different subject areas; such as in evacuation, stock pre-positioning, facility location, relief distribution and casualty transportation. Caunhye *et al.* (2011) developed a framework for disaster operations and associated facilities and flows for optimisation models (Figure 2.12). They have classified the optimisation models into three main categories: firstly, inventory policy; second, relief distribution and casualty transportation; and thirdly, facility location.

Figure 2.12 Framework for disaster operations and associated facilities and flows



Source: Caunhye *et al.* (2011)

2.7.1 Inventory Policy

Inventory management is one of the critical aspects in logistics management; it also applies to humanitarian relief operations. Whybark (2007) distinguished the key different characteristics between enterprise inventories and disaster relief inventories (Table 2.6). The study of logistic needs has an explicit role for famine relief, especially the study of inventory management (Long and Wood, 1995). Mathematical models have been developed to provide insights to solve the complicated management risk of the interrelationships of demand, location, supply availability, transportations, and other logistics factors (Whybark, 2007). Barbarosoglu and Arda (2004) explicitly studied the effects of uncertainty by modelling the response to a disaster in an urban environment using stochastic programming. In the case of a famine in North Korea, inventory allocation and vehicle routing alternatives were explicitly accounted for (Hwang, 1999). This model uses an objective function that minimises starvation instead of distribution costs. Taskin and Lodree (2010) addresses a stochastic inventory control problem for manufacturing and retail firm who face challenging procurement and production decisions associated with hurricane seasons. The multi-period inventory control problem is formulated as a stochastic programming model with recourse where demand during each pre-hurricane season period is represented as a convolution of the demand and an estimated demand.

Table 2.6 Summary of the different characteristics between enterprise inventories and disaster relief inventories

Characteristics	Enterprise inventories	Disaster relief inventories
Amount of research	Extensive	Very limited
Acquisition	Close relations with suppliers	Need suppliers with capacity at time of need
	Few unknown peaks of demand	Future demand quantities highly uncertain
	Orders placed with uncertainty in mind	Demand uncertain in time and space
	Ownership is clearly defined	Ownership is diffuse and not always known
	Supplies can be used for entire enterprise	Some supplies could have restricted use
Storage	Location of storage is a business decision	Location of storage is a political decision
	Security is mostly an internal issue	Security can involve government corruption
	Information available to manage expiry	Information on inventory not integrated
	Market demand consumes oldest items	Product expiry requires special attention
	Storage life not a major concern	Obsolescence defined by infrastructure
		Technology used for extending storage life
Distribution	Costs and benefits used for decisions	Cost may be real but benefits are social
	Theory available for quantification	Very little theory to guide decisions
	Enterprise decides what inventory to us	Inventory use decisions may be political
	Commercial transportation usually used	Transportation may require special carriers
	"Pull" systems can be used for inventory	Demand knowledge may not permit pull

Source: Whybark (2007)

2.7.2 Transportation Selection and Routing

Most of the studies of the operational logistical activities in humanitarian relief logistics focus with 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, which are shown in Table 2.7. General physical distribution systems for business consider material items, cost of materials, number of vehicles, modes of transportation, number of depots, demand of materials, transportation networks, vehicle capacity, travel time of the route, and various operational modes (Tzeng *et al.* 2007). The objectives of the physical distribution systems are to find a combination of those variables that minimises total travelling time, minimises size of vehicle fleet, maximises service capacity, and minimises fixed and variable costs. Similar to general physical distribution systems, relief distribution systems also consist of three separate parts: demand, supply, and transportation. The collection points of commodities in non-devastated areas play the role of supply, while the demand points are the devastated areas where relief is provided to victims who play the role of customers. Additionally, large-scale commodities distribution depots near the demand point or the devastated areas serve the role of a distribution centre. The only difference is that the distribution depots are temporary storage points instated of a permanent distribution centre. Another characteristic of disaster relief operations is that, instead of driving for profit in business, the operators of disaster relief are often government agents or non-profit organisations who claim to pursue efficiency and fairness.

Table 2.7 Comparison of general and relief distribution systems

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

Source: Tzeng *et al.* (2007)

A summary of the literature relating to disaster relief logistics is given in Table 2.8. Knott (1987) considered a single mode of transportation for last mile food delivery to determine the number of trips to each refugee camps to satisfy demand while minimising the transportation cost or maximising the amount of food delivered. In a later study, Knott (1988) combines operations research heuristics with artificial intelligence techniques to develop a decision support tool to support the previous problem. Meanwhile, Rathi *et al.* (1993) identify the optimal number of vehicles to be assigned to each route, the problem then becomes an assignment problem. Haghani and Oh (1996) and Oh and Haghani (1997) developed a multi-commodity multimode network flow model to help to organise detailed load plans for moving commodities after an event. Barbarosoğlu *et al*. (2002) focused on tactical and operational scheduling of helicopter activities in a disaster relief operation. They decomposed the problem hierarchically into two sub-problems where tactical decision are made in the top level, and the operational routing and loading decision are made in the second level. Hwang (1999) studied the inventory allocation and vehicle routing alternatives with a model that uses an objective function that minimises starvation instead of distribution costs, thereby providing different but very acceptable solutions. Viswanath and Peeta (2003) formulate a network design model to identify critical routes for earthquake responses. Barbarosoglu and Arda (2004) consider the uncertainties in available supplies, demands and network capacities through definition of a set of scenarios focus in post-event response. Özdamar *et al.* (2004) generate multi-period vehicle routes and schedules, along with commodity load-unload assignments. Dessouky *et al*. (2006) used facility location and vehicle routing problems in the pharmaceutical supply chain and found that facility that is close to a demand point provides a better quality of coverage to that demand point than a facility located far from the demand point. Beamon and Kotleba (2006a) used multi-supplier inventory model developing an inventory management strategy for a warehouse supporting a long-term emergency relief operation, which optimises the reorder quantity and reorder level based on the costs of reordering, holding, and back-orders.

Beamon and Kotleba (2006b) compare the performance of three inventory management strategies by developing a simulation model and relief-specific performance measurement system to identify system factors that contribute most significantly to overall performance. Meanwhile, Angelis *et al.* (2007) considered a multi-depot, multi-vehicle routing, and scheduling problem for air delivery of emergency supply deliveries. Choi *et al.* (2010) studied the case study of the volatile and fragile supply chain aid in East Africa (post Rwandan Civil War) providing the cost, speed and physical capability to be the most important factors for response. Sheu (2007) describes distribution of emergency supplies through a three-layer supply chain that connects relief suppliers, distribution centres and victims post-disaster situation. Tzeng *et al.* (2007) provides a multi-criteria deterministic model to distribute commodities to disaster areas considering the cost service time and demand satisfaction. Balcik *et al.* (2008) considers vehicle-based last mile distribution system that determines delivery schedules for vehicles and equitably allocates resources, based on supply vehicle capacity and delivery time restrictions. Mete and Zabinsky (2010) used the stochastic optimisation approach for distribution problem of medical supplies to be used for disaster management to select storage locations and required inventory levels. Widener and Horner (2010) explore the use of geographic information systems in conjunction with hierarchical capacitated-median model in post-hurricane settings to accomplish efficient placements of facilities for distributing relief services. Vitoriano *et al*. (2011) proposed several criteria for an aid distribution problem and a multi-criteria optimisation model that was developed to deal with these aspects. The criteria attributes used for their model was cost, time, equity, priority, reliability, and security.

Table 2.8 Transportation selection/routing problem in humanitarian relief logistics

Author(s)	Contribution
Knott (1987)	· Determines to satisfy demand while minimising the transportation cost or maximising the amount of food delivered
Knott (1988)	· Combines heuristics research with artificial intelligence techniques to develop a decision support
Rathi *et al.* (1993)	· Identify the optimal number of vehicle to be assigned to each route and the problem becomes an assignment problem
Haghani and Oh (1996)	· Determine routing and scheduling plans for multiple transportation modes carrying various commodities from multiple supply points
Oh and Haghani (1997)	· Minimise the sum of the vehicular flow costs, commodity flow costs, supply/demand carry-over costs and transfer costs over all time periods
Hwang (1999)	· Inventory allocation and vehicle routing alternatives were accounted · Uses objective function that minimises starvation instead of distribution costs
Barbarosoglu *et al.* (2002)	· Decomposed the problem hierarchically into two sub-problems: Tactical; operational routing and loading
Viswanath and Peeta (2003)	· Identify critical routes for earthquake response
Barbarosoglu and Arda (2004)	· Includes relief network uncertainties related to supply, route capacities and demand requirements
Özdamar *et al.* (2004)	· Distribute multiple commodities from a number of supply centres to distribution centres near the affected areas · Minimise the amount of unsatisfied demand over time
Beamon and Kotleba (2006a)	· Developed an inventory management strategy for a warehouse supporting a long-term emergency relief operation · Optimise the reorder quantity and level based on the costs of reordering, holding and back-orders
Beamon and Kotleba (2006b)	· Compares the performance of three inventory management strategies · Identify system factors that contribute most significant to overall performance · Relief-specific performance measurement system
Dessouky *et al.* (2006)	· Solve facility location and vehicle routing problems in the pharmaceutical supply chain · Shows that a facility that is close to a demand point provides a better quality of coverage to that demand point than a facility located far from the demand point
Angelis *et al.* (2007)	· Consider multi-depot, multi-vehicle routing, and scheduling problem for air delivery of emergency supply deliveries · Maximises the total satisfied demand
Sheu (2007)	· Operation of emergency logistics co-distribution responding to the urgent relief demands in the crucial rescue period · Disaster-affected area grouping and relief co-distribution
Tzeng *et al.* (2007)	· Distribute commodities to disaster areas considering the cost, service time and demand satisfaction
Balcik *et al.* (2008)	· Considers vehicle-based last mile distribution system · Determines delivery schedules for vehicles and equitably allocates resources, based on supply vehicle capacity and delivery time restriction
Ben-Tal *et al.* (2010)	· Generate a logistics plan that can mitigate demand uncertainty in humanitarian relief supply chain · Application for dynamically assigning emergency response and evacuation traffic flow problems with time dependent demand uncertainty
Choi *et al.* (2010)	- Case study of the volatile and fragile supply chain in East Africa - Cost, speed and physical capability considered to be the most important factor
Widener and Horner (2010)	· Accomplish efficient placements of facilities for distributing relief services in post-hurricane settings
Vitoriano *et al.* (2011)	· Developed multi-criteria optimisation model for humanitarian aid relief distribution · Cost, time, equity, priority, reliability, and security were the attributes used for the criteria

Source: Author

2.7.3 Facility Location Models

The facility location optimisation model is a critical aspect of strategic planning for a broad spectrum of public and private firms (Owen and Daskin, 1998). Facility location optimisation model problems derive their importance from two factors: their direct impact on the system's operating cost and the timeliness of response to the demand (Haghani, 1996). They are used to investigate where to physically locate a set of facilities (resources) so as to minimise the cost of satisfying some set of demands subject to some set of constraints (Hale and Moberg, 2003) where strategic planners are often challenged by difficult spatial resource allocation decisions (Owen and Daskin, 1998). Facility location models are mainly based on mixed integer programs with binary location variables associated with either evacuation operations, or stock pre-positioning, or stock pre-positioning and relief distribution (Caunhye *et al.* 2011). Meanwhile, location pre-positioning models are formulated by use of maximal covering location frameworks that locate facilities such that maximum demand discovered by a required amount of stock (Caunhye *et al*. 2011). The optimisation model has a well-developed theoretical background and it has developed actively since the formulation the classical Weber problem (1929) location theory. The facility location is viewed as a substantial body of knowledge with rich variety of models, methodologies and solution techniques that can be found in the literatures (Avella *et al.* 1998, and Francis *et al.* 1992). Most facility location optimisation models in emergency logistics combine the process of location with stock pre-positioning, evacuation or relief distribution (Caunhye *et al*. 2011). Facility location optimisation models are used in a wide variety of applications (Hale and Moberg, 2003) in commercial aspects, including:

1. Locating warehouses within a supply chain to minimise the average time to market;
2. Locating hazardous materials sites to minimise exposure to the public;
3. Locating railroad stations to minimise the variability of delivery schedules;
4. Locating automatic teller machines to best serve the bank's customers; and,
5. Locating a coastal search and rescue station to minimise the maximum response time to maritime accidents.

ReVelle *et al*. (1977), and Marianov and ReVelle (1995) discussed and reviewed the objective of emergency service facility location problem optimisation model with that of commercial facilities. The objective of facility location models for private sector problems is generally to minimise cost or maximise profit while the models addressing public and emergency services instead focus on user accessibility and response time.

2.7.3.1 Facility Location Problems and Applications

Studies of the facility location problem have tended to examine the emergency response. In an emergency, the primary objective is to save lives and, therefore, sending response units to the incident site at the earliest time has the highest priority (Dessouky *et al.* 2006). Murali *et al.* (2009) examined where to dispense medicine in an emergency given the restrictions of capacitated facilities and demand uncertainty. In their study they used location decisions made in advance and supplies which are pre-positioned. Most facility locations in the context of emergency services consider providing a single facility to cover a demand point (Church and ReVelle, 1974; Schilling *et al.* 1979). There has been some work on locating first responders for incidents. For example, Saccommano and Allen (1998) used a location model to determine sites for response-capable units (e.g. fire companies or police units) that could provide aid in case of spills of dangerous goods on a rural road network. Sathe and Miller-Hooks (2005) studied the relocation of first-response units (military and police forces) in order to maintain protection coverage to critical facilities under disaster conditions. However, locating first-response units is different from locating and sizing stocks of supplies where multiple commodities must be considered; for example, the commodities may have differing storage requirements and transportations costs (Rawls and Turnquist, 2010). The strategic decision choice for the optimal location and capacity of emergency clean-up equipment for oil spill response are also solved by optimisation location models (Iakovou *et al.* 1997; Psaraftis *et al.* 1986; Wilhelm and Srinivasa, 1996).

Pre-positioning of the facility is often used in military strategic operations because it helps ensure the timely support of forces during the initial phases of a military operation (King, 1991). The military tend to use pre-positioning strategies for the supply of equipment and ammunition to facilitate rapid and effective response to conflicts (Johnstone *et al.* 2004). In military situations, pre-positioning is defined as a “stockpiling of equipment and supplies at, or near the point of plane use (or point of debarkation)” (Department of the Air Force, 1981). Military approaches may or may not be applicable to peace-time emergencies. For example, Anderson (1998) uses available shipping assets to redistribute weapons based on a predetermined positioning plan for the Pacific Fleet. Sentlinger (2000) looked at the optimal weapons pre-positioning mix of U.S. Naval weapon stations with a focus on minimising demand shortfalls during a myriad of conflicts. Johnstone *et al.* (2004) minimise the overall response time by pre-positioning the equipment and ammunition to facilitate rapid and effective response to conflicts in military. Pre-positioning in military operation has its disadvantages. Pre-positioned stocks require duplicate equipment and supplies, as well as additional training and maintenance to maintain the material in operational condition (Johnstone *et al*. 2004). Pre-positioned assets are safer and easier to defend than land-based counterparts (Department of the Navy, 1998); therefore, the pre-positioned sites require security because the facility is not invulnerable to attack (Johnstone *et al*. 2004). In addition, fiscal constraints come into play as pre-positioning requires additional funding (King, 1991).

2.7.3.2 Humanitarian Relief Pre-Positioning Facility Location Problems

Although research on facility location problem is extensive, in terms of theory and applications these problems have not received much attention in the domain of humanitarian relief (Balcik and Beamon, 2008). The location and capacities of the resource providers are key components in managing response efforts after an event; however, relatively little research has been conducted on the topic on the topic of a priori planning for pre-positioning specific resources (Rawls and Turnquist, 2010). The importance of developing a strategic pre-positioning facility location was discussed by Adinofli *et al.* (2007). The ineffective and inefficient result of ad-hoc methods have been mentioned with regard to facility location and stocking decisions. The lack of a global stock positioning system has made it difficult to provide enough information for the research in their study. Balcik *et al*. (2010) discuss the role of pre-positioning warehouses in the aspect of the coordination practices in disaster relief. Gatigon *et al*. (2010) illustrated the implementation of a decentralised model at the international humanitarian organisation using the pre-positioning warehouse concept. Tatham and Kovács (2007) introduced the alternative strategy of quick response to satisfy a known requirement (i.e. flying supplies into an area to meet the needs of the beneficiaries) with the military ‘sea-basing’ and ‘floating warehouse’. In other words, a suitably sized ship is held at very short notice to transit to the relevant country with a cargo containing sufficient food and non-food items to meet the immediate needs of a significant number of beneficiaries. Balcik and Beamon (2008) studied the pre-positioning of facility location considering the response to the quick-onset disasters. The model considers pre-disaster and post-disaster budget restrictions but does not consider network reliability. Dekle *et al.* (2005) used set-covering location model to locate disaster recovery centres in Florida. Campbell and Jones (2011) examine the decision of where to preposition supplies in preparation for disaster and how much to stock at the warehouse considering the possibility of the warehouse being destroyed. Hale and Moberg (2005) propose the use of a decision process with set cover location model from the location science field to help establish a network of secure site locations. They suggest the optimal location with the balance of operational effectiveness and cost-efficiency by identifying the minimum number and possible location of off-site storage facilities. Rawls and Turnquist (2010) provide an emergency response pre-positioning strategy for disaster threats considering uncertainty in demand for the stocked supplies, as well as uncertainty regarding transportation network availability after the disaster event. Ukkusuri and Yushimoto (2008) developed a model for pre-positioning of supplies and location routing problem incorporating the reliability of the ground transportation network. Table 2.9 summarises the studies of the pre-positioning location models in humanitarian relief operations.

Table 2.9 Humanitarian pre-positioning facility location literature

Author(s)	Contribution
Balcik and Beamon (2008)	· The number and the location of the distribution centre and stock held with affect directly · As the number of distribution centres decreased, the capacity differences among the distribution centres increases · Integrates facility location and inventory decisions, considers multiple item types and captures budgetary constraints and capacity restriction
Campbell and Jones (2011)	· Examine the decision of where to preposition supplies in preparation for disaster and how much to preposition at a location · Cost model use to select the single best supply point location from a discrete set of choices and how it can be embedded within exiting location algorithms to choose multiple supply points considering the possibility of the facility being destroyed
Dekle *et al.* (2005)	· Identity three idealised disaster recovery centre location requiring them to be within 20 miles to the residence · Results provided significant improvements to the original location while maintaining acceptable travel distance
Hale and Moberg (2005)	· Propose secure site location using set cover location model · Minimise the number and possible locations · Consider location of external events which could prevent from accessing the site
Rawls and Turnquist (2009)	· Provides an emergency response pre-positioning strategy for disaster threats · Considers uncertainty in demand for the stocked supplies as well as uncertainty regarding transportation network availability after an event
Soon (2007)	· Models the problem of pre-positioning hurricane supplies for-profit driven supply chains · Incorporates transport cost
Ukkusuri and Yushimoto (2008)	· Incorporate the reliability of the ground transportation network · Maximise the probability that all the demand points can be served by a service location given fixed probabilities of link/node failure and a specified budget constraint

Source: Arranged by Author

The location problem literature which is listed in Table 2.9 mainly focuses on the finding a potential optimal location with optimisation models rather than focusing on finding the important attributes for the location of the pre-positioned warehouse in humanitarian relief sectors. In addition, it is difficult to establish preferences between factors by reference to an explicit set of objectives. In the literature there are a large number of facility location evaluation and selection models and reviews, some of which have concentrated on the selection of the suitable sites in the humanitarian warehouse exclusively. However, few studies have used Multi-Criteria Decision Making (MCDM) especially in Multi-Attribute Decision Making (MADM) methods, considering human judgements, tangible, intangible and multiple criteria. Although there are a limited number of publications evaluating the humanitarian pre-positioned warehouse in the literature (as briefly described above), the use of the Analytic Hierarchical Process (AHP) and the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) is rare. The warehouse selection decision is a process during which multiple criteria must be considered (Gattorna *et al.* 1988). This is the most powerful motivation to consider the site selection problem in this present study.

2.8 Chapter Summary

This chapter has provided an overview of published literature relating to the research topic. The difference between the humanitarian relief logistics and commercial logistics has been discussed and several similar parallel aspects between the two have been identified. The involved actors in humanitarian relief logistics have also been discussed. The study of disaster relief management phases shows the there is no single stage that should be overlooked. The preparedness stage has been emphasised in many studies with various approaches to prevent the crucial impact due to the disaster. For humanitarian relief logistics, pre-purchase of stock has increased the need to establish the warehouse pre-positioning. The structure and the various locations of the pre-positioned warehouse are also presented. The importance of the pre-positioning warehouse strategy is currently increasing within the humanitarian organisations, as can be seen in the literature. The facility location model for humanitarian relief logistics is mainly researched using a mathematical approach. There is a gap in the literature in that few previous studies have applied a study of human opinion for the multi criteria decision-making process.

CHAPTER 3

LITERATURE REVIEW II: AHP AND TOPSIS LOCATION SELECTION PROBLEM

3.1 Chapter Overview

This chapter continues the literature review from the previous chapter. It introduces the previous studies that have researched the facility location problem, especially in humanitarian relief logistics. This chapter aims to review the various facility location problem research tools and the use of AHP and TOPSIS research tools to solve the location problem in humanitarian relief.

3.2 Location Decision

Facility location selection is defined as the determination of a geographic site on which to locate a firm's operations (Ertuğrul, 2010). Decision making and analysis is an important part of management science and is used where the decision maker wishes to pursue more than one target or consider more than one factor or measure (Farahani *et al.* 2010). Selecting a plant location is a very important decision for firms because they are costly and difficult to reverse; they also entail a long term commitment that impacts on operating costs and revenues (Ertuğrul, 2010). A poor choice of location might result in excessive transportation costs, a shortage of qualified labour, loss of competitive advantage, inadequate supplies of raw materials, or some similar conditions that would be detrimental for the operations (Stevenson, 1993). Evaluation procedures involve several objectives and it is often necessary to compromise among possibly conflicting tangible and intangible factors (Önut and Soner, 2007). This kind of desire transforms the decision making problem to a MCDM problem (Farahani *et al*. 2010).

The location decision is a critical aspect of strategic planning for a broad spectrum of public and private firms (Owen and Daskin, 1998). Location decision is a branch of operations research and management science that is related to locating or positioning a new facility among several existing facilities in order to optimise (i.e. minimise or maximise) at least one objective function (e.g. cost, profit, revenue, travel distance, service, waiting time coverage, and market shares) (Farahani *et al.* 2010). The concept of location decision-making was first introduced by Weber (1929), and it has since been argued that this was the starting point of the study of location science (Farahani *et al*. 2010). Plants, warehouses, retail outlets, terminals, storage yards, and distribution centres are typical facilities which must be located strategically. The location decision problem influences an organisation's strategic competitive position in terms of operating costs, transportation costs, delivery speed performance, and the organisation's flexibility to compete in the marketplace (Kahraman *et al*. 2010).

Many papers on the location problem have been published in the literature of the supply chain, especially in warehouse selection. In particular, much research has been conducted on the location decision problem using the concept of the MCDM. In this section, location decision problem applied with MCDM methods will be presented because it is the main research tool that is used in the current study.

3.3 Multi-Criteria Decision Making (MCDM)

The MCDM indicates a concern with the general class of problems that involves a set of Decision Alternatives (DAs) that are evaluated on the basis of conflicting, non-commensurate and multi-criteria by several interest groups (Farahani *et al*. 2010). These are often characterised by unique preferences with respect to the relative preference of criteria against which DAs are evaluated (Whitcom *et al.* 1999). The MCDM was introduced as a promising and important field of study in the early 1970s (Fuller and Carlsson, 1996). Since then the number of contribution to theories and models, which could be used as a basis for more systematic and rational decision-making with multi-criteria, has continued to grow at a steady rate. It is rare for the decision-makers to have in mind a single clear criterion in most situations where a decision must be taken (Figureia *et al.* 2005). Situations, where a single-criterion approach falls short, are referred to as MCDM problems (Kelemenis and Askounis, 2010).

3.3.1 Basic MCDM Concepts

In general, MCDM involves a set of DAs that are evaluated on the basis of evaluation criteria (Malczewski and Moreno-Sanchez, 1997). The first stage in any MCDM problem is to define the set of DAs and the set of decision criteria that the DAs need to be evaluated with (Triantaphyllou, 2000). It is necessary to understand these two concepts, especially since they have no universal definitions (Keeney and Raiffa, 1976).

The nature of decision-making involves choice. The set of DAs should contain all choices that are considered possible by a decision-maker or an expert (Roy, 1985). Criteria are the basis for evaluating DAs. Usually, a direction of preference and a scale have to be specified for each criterion (Belton and Pictet, 1997).

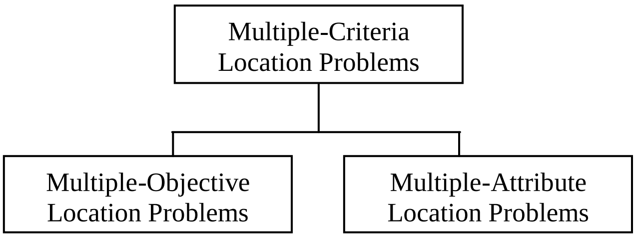
The criteria can be classified into two categories (Liang, 1999). The first category includes tangible criteria, which are information that can be measured numerically. This can be divided into monetary information (e.g. investment cost) and non-monetary information (e.g. labour work hours). The second categories are intangible criteria, which mean information that is not given numerically and may be obtained from obviously subjective opinions (Weber, 1993). These criteria have linguistic or qualitative definitions (e.g. customer demand). It is one thing to acknowledge the existence of different criteria, to classify them, count them, or use them, however, it should also be understood why people use them, what their origins are, and different sets of criteria are used under the same or different circumstances (Zeleny, 1982).

There are many variations on the theme of MCDM depending upon the theoretical basis used for the modelling. In the following section, the major MCDM methods are described.

3.3.2 Major MCDM Methods

MCDM, also known as Multi-Criteria Decision Analysis (MCDA) methods, are recommended as being helpful in reaching important decision that cannot be determined in a straightforward manner (Wu *et al.* 2010). MCDM is both an approach and a set of techniques, whose goal is to provide an overall ordering of options, from the most preferred to the least preferred option (DCLG, 2009). MCDM mainly divides into Multiple-Objective Decision-Making (MODM) and MADM methods based on the background of their decision approach (Farahani *et al.* 2010; Torfi *et al.* 2010) (Figure 3.1). All MCDM approaches make the options and their contribution to the different criteria explicit, and all require the exercise of judgement differing in how they combine the data (DCLG, 2009). MCDM techniques can be used for all types of facility location models, including: single facility location, multiple facility location, location-allocation, quadratic assignment problems, covering problems, median problems, centre problems, hierarchical facility location problem, hub location problem, competitive facility location, warehouse location problems, dynamic facility location problems, location-routing, location-inventory, location-reliability and especially location in supply chain (Farahani *et al.* 2010). This section explores the literatures of the MADM especially in AHP and TOPSIS.

Figure 3.1 The classification of MCDM location problems



Source: Farahani *et al.* (2010), Torfi *et al.* (2010)

3.3.2.1 Multiple-Objective Decision Making (MODM)

MODM consists of a set of conflicting goals that cannot simultaneously be achieved (Torfi *et al.* 2010). MODM provides a mathematical framework for designing a set of decision alternatives. Each decision alternative, once identified, is judged by how close it satisfies a criterion or multi-criteria. In the MODM approach, the number of potential decision alternatives may be large. It concentrates invariably on the continuous decision spaces and can be solved by mathematical programming techniques (Torfi *et al.* 2010). MODM deals general with preferences relating to the decision maker's objectives and with the relationships between objectives and attributes (Torfi *et al.* 2010). The aim, broadly, is to restrict consideration to a (relatively small) set of solutions to the MODM problem that is explicitly not dominated by others (DCLG, 2009). However, a solution found by MODM approach solution cannot be proved to be optimal, the best that can be hoped for is that they are relatively good (DCLG, 2009). An alternative could be described either in terms of its attributes or in terms of the attainment of the decision maker's objectives (Yang and Hung, 2007). Farahani *et al*. (2010) has described the common characteristics of the MODM problems as follows:

- A set of quantifiable objectives;
- A set of well-defined constraints; and,
- A process of obtaining some trade-off information.

3.3.2.2 Multiple-Attribute Decision Making (MADM)

MADM deals with the problem of choosing an option from a set of alternatives, which are characterised in terms of their attributes (Torfi *et al.* 2010). Although different MCDM models have been applied to solve the location decision problems, most of them are basically mathematical and ignore qualitative and often subjective considerations (Önut and Soner, 2008). MADM is a qualitative approach due to the existence of the criteria subjectivity. (Torfi *et al.* 2010). Sometimes in location decision problems, numbers and mathematical findings are not dealt but decision based on human judgement is where MADM is an important part of location decision problems (Farahani *et al.* 2010). It requires information on the preferences among the instances of an attribute and on the preferences across the existing attributes (Torfi *et al.* 2010). The distinguishing feature of MADM is that it usually has a limited number of predetermined decision alternatives where each measures with respect to every criterion using a quantitative or qualitative judgment (Sen *et al.* 1999). The decision maker may express or define a ranking for the attributes in terms of importance or weights (Torfi *et al.* 2010). The aim of MADM is to obtain the optimum alternative that has the highest degree of satisfaction for all of the relevant attributes (Yang and Hung, 2007).

The main difference between MODM and MADM is that MODM concentrates on a continuous decision space, primarily based on mathematical programming with several objective functions and defined by constraints (Belton, 1986), whereas MADM focuses on problems with discrete decision spaces. In a discrete problem there is a choice between a numbers of discrete decision alternatives. Discrete problems can be usefully further categorised according to whether they involve few or many decision alternatives and few or many criteria. Therefore, the category of MCDM used for selection problem in this thesis will be MADM.

3.3.2.3 MCDM Techniques

The main purposes of the MCDM technique are: to identify a single most preferred option, to rank options, to short-list a limited number of options for subsequent detailed appraisal, or simply to distinguish acceptable from unacceptable possibilities (DCLG, 2009). The most popular techniques that are used in MCDM are listed below in Table 3.1.

Table 3.1 MCDM Techniques

MODM	MADM
Global criterion method	Dominant
Utility function	Maximin
Metric L-P methods	Maximax
Bounded objective method	Conjunctive method
Lexicographic method	Disjunctive method
Goal programming (GP)	Lexicographic method
Goal attainment method	Elimination by aspects
Method of Geoffrion	Permutation method
Interactive GP	Linear assignment method
Surrogate worth trade-off	Simple additive weighting (SAW)
Method of satisfactory goals	Hierarchical additive weighting
Method of Zints-Wallenius	Hierarchical tradeoffs
Step method (STEM)	Linear programming techniques for multidimensional analysis of preference (LINMAP)
Sequential multi-objective problem solving (SEMOPS)	MDS with the ideal point
Sequential generator for multi-objective problems	VlseKrtierijumska Optimizacija I Kompromisno Resenje (VIKOR)
Method of displaced ideal	Elimination and choice expressing reality (ELECTRE)
Goal programming STEM (GPSTEM)	Technique for order preference by similarity to ideal solution (TOPSIS)
Method of Steuer	Analytic hierarchical/network process (AHP/ANP)
Parametric method	Multi-Attribute Utility Theory (MAUT)
C-constant method	Stochastic Multi-criteria Acceptability Analysis (SMAA)
Adaptive search method	

Key: MODM – Multi-Objective Decision-Making, MADM: Multi-Attribute Decision-Making

Source: Farahani *et al*. (2010), Hwang and Lin (1987), Hwang and Masud (1979), Szidarovsaky *et al.* (1986), Zionts (1979)

MODM techniques try to design the best alternative by considering the various interactions within the design constraints which best satisfy the decision maker by way of attaining some acceptable levels of a set of objectives (Farahani *et al*. 2010). Meanwhile, in the MADM, there are usually a limited number of predetermined alternatives which satisfy each objective in a specified level and the decision maker selects the best solution among all alternatives, according to the priority of each objective and the interaction between them (Farahani *et al.* 2010). Most of the conventional decision-making models (such as Linear Programming (LM), Mixed Integer Programming (MIP), and Goal Programming (GP)) have limitations to enlighten the interrelations among the sub-criteria of the given context by the validity of the additively and independent assumptions. Moreover, the application costs are very high in terms of limited data handling capabilities of the approaches (Kayikci, 2010).

3.4 MADM Location Problems

Among the MADM methods, Elimination and Choice Expressing Reality (ELECTRE), Multi-Attribute Utility Theory (MAUT), Stochastic Multi-criteria Acceptability Analysis (SMAA), Analytic Network Process (ANP), AHP, and TOPSIS are well known for solving location problems (Farahani *et al*. 2010). Barda *et al.* (1990) modelled their thermal plant location problem in a hierarchical decision process in which they have utilised ELECTRE III to choose the best sites for each region they were studying. Norese (2006) also presented an ELECTRE III method to select the best sites for a waste-disposal plant and for the incinerator. Canbolat *et al.* (2007) incorporated the MAUT model to evaluate the alternative countries for the international location problem of a manufacturing facility. Tuzkaya *et al.*(2008) used the ANP technique, which includes qualitative and quantitative factors, and tangible and intangible criteria without sacrificing their dependence, to evaluate and select suitable undesirable facility location based on four main factors (benefits, cost, opportunities and risks). AHP has been widely used for location problem including Aras *et al*. (2004) in which considerable number of criteria were taken into account for a wind observation station location problem. Tzeng *et al*. (2002) also used AHP location problem with five aspects and eleven criteria for the location evaluation of a restaurant. Fernandez and Ruiz (2009) considered the selection of a location for an industrial park, where they proposed a three-level hierarchical decision process in which each level has its own geographical decision criteria. A comparison of fuzzy AHP and fuzzy TOPSIS methods was developed by Ertuğrul and Karakasoglu (2008), who implemented a facility location of a textile company. Yong (2006) introduced a new fuzzy TOPSIS for selecting a plant location under linguistic terms as triangular fuzzy numbers. More detailed literature search for AHP, TOPSIS, and fuzzy theory will be mentioned in the later section.

In the less recognised multi-attribute approaches, Lahdelma *et al*. (2002) applied an Environmental Impact Assessment (EIA) process to process the data and the Stochastic Multi-criteria Acceptability Analysis with Ordinal criteria (SMAA-O) to evaluate criteria in a location problem of a waste treatment.

Sometimes, different multi-attributes are combined together or combined with multi-objective approaches to gain better results. For example, Farahani and Asgari (2007) have presented a five-stage procedure where they used different tools and models (such as MADM, covering, distributing, MODM, binary programming and quadratic programming) to locate military warehouses.

3.4.1 Analytic Hierarchical Process (AHP)

One of the most outstanding MADM approaches is the AHP (Saaty, 1980), which was developed to obtain the relative weights among the factors and the total values of each alternative based on these weights (Torfi *et al.* 2010). In comparison with other MCDM methods, the AHP method has widely been used in multi-criteria decision-making and it has been applied successfully in many practical decision-making problems (Saaty, 1988). The AHP uses procedures for deriving the weights and the scores that are achieved by alternatives which are based, respectively, on pairwise comparisons between criteria and between options (DCLG, 2009; Rangone, 1996). The AHP process makes it possible to incorporate judgements on intangible qualitative criteria alongside tangible quantitative criteria (Badri, 2001).

3.4.1.1 AHP Applications

Vaidya and Kumar (2006) and Ho (2008) reviewed and organised the development of the AHP literature. They identified with the literature various themes with the areas of applications and incorporated of other research tools (see Table 3.2).

Table 3.2 Usage of AHP

Themes	Application Areas	Incorporated Research Tools	
· Location decision	· Personal	· Scaling models	· Fuzzy theory
· Evaluation	· Social	· Logic tables	· Linear Programming
· Benefit-cost	· Manufacturing	· ANP	· Cost benefit
· Allocation	· Political	· Probability	· Statistics
· Planning and development	· Engineering	· MAH	· Data envelopment analysis
· Priority and ranking	· Education	· Artificial	· Fuzzy set theory
· Decision making	· Industry	· MIP	· Fuzzy linguistic approach
· Forecasting	· Government	· Linear programming	· Goal Programming
· Medicine	· General management	· Linear goal programming	· Multi-objective programming
	· Project management	· Constraint method	· Simulation model
	· Stock Exchange	· PROMETHEE	· Accounting procedure
	· Sports	· Falure mode and criticality analysis	· Graph theory
	· Banking	· Simulation model	· Linguistic variable weight
	· Environmental management	· Cognitive maps, cause and effect diagrams	· Mixed integer linear program
		· Tree diagrams	· Tournament ranking
		· Dynamic programming	· Fuzzy logic
		· QFD	· Dempster-Shafer theory
		· DEMATEL	· Branch and bound theory
			· Dynamic programming
			· ELECTRE

Key: ANP – Analytic Network Process, DEMATEL – Decision-Making Trial and Evaluation Laborator, ELECTRE – Elimination and Choice Expressing Reality, MAH – Maximise-Agreement Heuristic, MIP – Mixed Integer Programming, PROMETHEE – Preference Ranking Organisation METHod for Enrichment Evaluation, QFD – Quality Function Deployment

Source: Vaidya and Kumar (2006) and Ho (2008)

3.4.1.2 AHP Location Decision Problems

There are certain strengths when using the AHP location decision methods. It is clear that users generally find the pairwise comparison form of data input straightforward and convenient (DCLG, 2009; Yoon and Hwang, 1995). In spite of AHP method popularity, this method is often criticised because of its inability in handling the uncertain and imprecise decision-making problems (Cheng, 1999).

One of the major applications of the AHP location selection is in the environmental sectors, such as municipal landfill sites (Aragones-Beltran *et al.* 2010; Bottero and Ferretti, 2011; Erkut and Moran, 1991; Mummolo, 1995), aquaculture development (Aguilar-Manjarrez and Ross, 1995), artificial reef location (Tseng *et al.* 2001), and wind observation (Aras *et al.* 2004; Lee *et al.* 2009). In the environmental sector, AHP is often incorporated with

Geographical Information System (GIS) for municipal landfill siting decisions (Charnpratheep *et al.* 1997; Gemitzi *et al.* 2007; Javaheri *et al.* 2006; Kashani, 1989; Kontos *et al.* 2003; Moeindannini *et al.* 2010; Sener *et al.* 2006, 2010, 2011; Siddiqui *et al.* 1996; Wang *et al.* 2009; Yahaya *et al.* 2010), and also in aquaculture (Aguilar-Manjarrez and Ross, 1995) and in artificial reefs (Tseng *et al.* 2001). It is interesting to note that only GIS tools are incorporated with AHP for their location selection problem. However, Ekmekçioğlu *et al.* (2010) and Önut and Soner (2008) approach different way to find the optimal location for landfill sites where they used fuzzy set theories of AHP and TOPSIS.

AHP earned its popularity in the application of plant site selection problems. For example, the AHP stand-alone method has been applied for the selection of electric power plants in Mexico (Akash *et al*. 2010), limestone quarry expansion in Barbados (Dey and Ramcharan, 2008), dual purpose nuclear power plant in Saudi Arabia (Hussein *et al.* 1987), mineral processing plant for iron ore mines in Pakistan (Moshen *et al.* 2010), and decision support system for overseas manufacturing plant location in the European countries (Yurimoto and Masui, 1995). Amiri (2010) combined fuzzy AHP with fuzzy TOPSIS for oil-field development. The multi-objective goal-programming was used to aid in location-allocation decision of evaluating potential plant location sites for a petrochemical company in Middle Eastern Asia (Badri, 1999). The application of fuzzy AHP approach has also been used for the selection of optimum underground mining method for Bauxite mine in Iran (Naghedehi *et al.* 2009) and by a motor factory company in Turkey (Kahraman *et al.* 2003).

The application of AHP in optimal store location studies can be found in the literature. Alphonce (1997) used AHP to find the optimal store in agricultural developing countries. Kuo *et al.* (1999) and Kuo *et al.* (2002) integrated fuzzy AHP with artificial neural network to locate a convenience store in Taiwan. Feed forward neural network with error back-propagation is applied to examine the relationship between the factors and the store performance. Decision support for locating port related facilities are studied through AHP as well. Min (1994) used AHP for location planning of airport facilities recognising the multiple and conflicting objective nature of the airport location problem. The AHP has also been used to help a state or regional airport authority to formulate viable location strategies in the volatile and complex public decision environment. For example, Van der Kleij *et al.* (2003) combined AHP and Monte Carlo to approach the problem of comparing uncertain alternatives for possible airport island location in the North Sea. The results found that with respect to morphology and ecology, it is most favourable to keep the Dutch national airport inland. Kuo and Liang (2011) combined fuzzy set theories of AHP, ANP with TOPSIS and DEMATEL to study the alternative port selection that could be served as an international distribution centres in order to increase production economies of scale and reduce transportation costs. Ugboma *et al.* (2006) approached solving a port selection with AHP in Nigeria.

The AHP is also popularly used to study the location problem of warehouses and logistics distribution centres. Selection of the location is the most important decision for international logistics managers owing to the need to consider various criteria that involve a complex decision process in which multiple requirements and uncertain condition have to be taken into consideration simultaneously (Kuo, 2011). Alberto (2000), Korpela and Tuominen (1996), and Min and Melachrinoudis (1999) applied AHP for warehouse (distribution centre) selection problem for their logistics management purposes. Demirel *et al.* (2010) propose a Choquet integral combined with AHP to locate warehouse location selection problem of a large Turkish logistic firm. Main criteria for their selection were costs, labour characteristics, infrastructure, and markets. Their paper included some sub-criteria due to the hierarchical structure of the problem, including: tax incentives and tax structures, availability of labour force, quality and reliability of modes of transportation, and proximity to customers. Özcan *et al.* (2011) integrated AHP with TOPSIS, ELECTRE and Grey theory for implementation of a warehouse location decision problem. Comparative analysis of multi-criteria decision making methodologies was made in their paper. Kayikci (2010) explored the applicability of the development of a conceptual model based on a combination of the fuzzy AHP and ANN methods in the decision-making process in order to select the most appropriate location of the intermodal freight logistics centres to ease the freight traffic problem. Kengpol (2004) designed a decision support system to evaluate the investment a new distribution centre with fuzzy AHP and capital investment model in Bangkok, Thailand. Kuo (2011) integrated fuzzy AHP with TOPSIS, fuzzy DEMATEL, and ANP for the selection of a location for an international distribution centre in the Asian-Pacific region. Sarkis and Sundarraj (2002) used ANP to study the location of a repair-parts warehouse for computer and electronics market. They considered not only the long-term strategic (or qualitative) perspective but also the freight-cost (or quantitative) perspective. Zheng *et al.* (2009) integrated AHP with TOPSIS to develop a decision-making model of distribution centres location for chain retail enterprises.

Other AHP location selection problem application can be found in site selection in the area of: hotels (Chou *et al.* 2008), banks (Cinar, 2009), service terminals (Hegde and Tadikamalla, 1990), hospitals (Lin and Tsai, 2010a, 2010b; Wu *et al.* 2007), ports (Lirn *et al.* 2004; Ugboma *et al.* 2006), shopping centres (Önut *et al.* 2010), markets (Suarez-Vega *et al.* 2011), railway stations (Mohajeri and Amin, 2010), and restaurants (Tzeng *et al.* 2002).

The research finding regarding AHP shows that it is flexible and incorporates other MCDM methods and research tools. It can be seen in the literature that the AHP determines the weight of the selection criteria in the first stage of the research. However, it is difficult to see whether the AHP method is used for humanitarian relief purposes. Therefore, a further search for the literature related to the humanitarian relief and especially for facility location selection of the pre-positioned warehouses for humanitarian relief is needed.

3.4.1.3 Categorisation of AHP Location Decision research

This section discusses the distribution of journal articles that are covered in the previous section into articles by journals, country/regional application, and distribution years of the journal papers.

Appendix D.2 provides the list of journals with the references published in different types of articles. The table demonstrates that most of the articles are well distributed and that there are no dominant journals. However, among these, six articles (10%) are published in *Expert Systems with Applications*. The next leading journal has four articles (6%) each in, *International Journal of Production Economics, Journal of Environmental Management,* and *Waste Management.* Looking at the articles published, it can be seen that, generally, the papers published in *Nuclear Technology* and *International Journal of Systems Sciences* represents the first publication of many analytical approaches (or combinations of them) in the context of facility location decision problem; such as, Hussein *et al.* (1987) and Kathawala and Gholamnezhad (1987) for AHP.

3.4.2 Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS)

TOPSIS developed by Hwang and Yoon (1981) is a distance-based MCDM method that is used for determining alternatives. TOPSIS is based on choosing the best alternative, which has the shortest distance from the positive-ideal alternative and the longest distance from the negative-ideal alternative (Hwang and Yoon, 1981; Karsak, 2002; Wu *et al.* 2010). The concept of distance measures, of the alternatives from positive-ideal solution (PIS) and the negative-ideal solution (NIS) proposed by Hwang and Yoon (1981), is the most straightforward technique in MADM (Shih *et al.* 2007). PIS maximises the benefit criteria and minimises the cost criteria, while the NIS maximises the cost criteria and minimises the benefit criteria (Wang and Elhag, 2006).

The concept of TOPSIS is rational and understandable, and the computation involved is uncomplicated. Moreover, the inherent difficulty of assigning reliable subjective preference to the criteria is worth noting (Shyur, 2006). Although TOPSIS is popularly used to solve MCDM problems, this approach also has some defects (Yu *et al.* 2011). TOPSIS is often criticised for its inability to deal with vague and uncertain problems (Yu *et al.* 2011). In many applications, it is difficult to handle ambiguous and vague issues for the method and mathematical models cannot cope with decision-makers' ambiguities, uncertainties and vagueness (Chan and Kumar, 2007). In addition, under many conditions crisp data is inadequate to model real-life decision problems. Meanwhile, perfect knowledge is not easily acquired (Kelemenis and Askounis, 2010). Unquantifiable, incomplete and non-obtainable information (Ölçer and Odabsi, 2005) makes precise judgement impossible (Kelemenis and Askounis, 2010).

3.4.2.1 TOPSIS Applications

TOPSIS is popularly used by lots of research for four reasons (Shih *et al.* 2007):

1. TOPSIS logic is rational and understandable;
2. The computation processes are straightforward;
3. The concept permits the pursuit of best alternatives for each criterion depicted in a simple mathematical form; and,
4. The importance weights are incorporated into the comparison procedures.

Table 3.3 TOPSIS applications

Author	Application areas	No. of attributes	No. of alternatives
Yoon and Hwang (1985)	Manufacturing plant location analysis	5 major (16 sub-attributes)	5
Parkan and Wu (1999)	Robot selection	4	27
Deng *et al* (2000)	Company financial ratios comparison	4	7
Chu (2002a)	Facility location selection	5	4
Cheng *et al.* (2002)	Solid waste management	12	11
Janic (2003)	High-speed transport system selection	15	3
Cheng and Tzeng (2004)	Expatriate host country selection	6 major (25 sub-attributes)	10
Srdjevic *et al.* (2004)	Water management	6	12
Byun and Lee (2005)	Rapid prototyping-process selection	6	6
Milani *et al.* (2005)	Gear material selection	5	9
Yang and Chou (2005)	Multiple response selection	2	18
Yong (2006)	Plant location selection	4	3
Kelemenis and Askounis (2010)	Personnel selection	11	4

Source: Adapted from Shih *et al.* (2007) and rearranged by author

Due to its logical reasoning, TOPSIS has been used to solve many real-world problems, especially in recent years in the Asian-Pacific region (Shih *et al.* 2007). Table 3.3 briefly illustrates the various application and the typical areas with the involved attributes and alternatives listed to the corresponding cases. TOPSIS location decision problem can be found in facility location selection (Chu, 2002a, 2002b), and plant location (Yong, 2006). The attributes and the alternatives vary as they are applied to real-life situation, which make them different due to the case-by-case problems. More detail of the TOPSIS application in location decision problem will be discussed in the next section.

3.4.2.2 TOPSIS Location Decision Problems

TOPSIS location decision problems has been successfully applied and implemented in site location problems in various fields of study (Chu, 2002a). In this section, the application of TOPSIS combined with AHP will not be mentioned as it already been discussed in Section 3.4.1.2. TOPSIS location decision problems literatures are listed in Appendix D.3.

Karimi *et al.* (2010) examined the location decision for foreign direct investment in South-East Asian countries using a TOPSIS approach that provides a relatively simple tool for the strategic decision making problem. Fuzzy set theory is widely used in TOPSIS applications, where it has been used to resolve the ambiguity of concepts that are associated with human being's judgments (Ertuğrul, 2010). Fuzzy TOPSIS is applicable in fuzzy group decision making for factory facility location selection problem (Ertuğrul, 2010) and in evaluating the location selection of railway passenger station (Liao, 2009). Kucas (2010) combined TOPSIS with Simple Additive Weighting (SAW) for location prioritisation in the case of forest fragmentation-based ranking of forest administrative areas. Bhattacharya *et al.* (1992, 1993), Boran (2011), and Kuo *et al.* (2007) studied the alternative location selection with in general with TOPSIS application. Gligorić *et al.* (2010) integrated fuzzy TOPSIS with Kruskal's algorithm and Steiner Points to locate a mine shaft at a deep multiple ore-body deposit. Meanwhile, Safari (2010) applied fuzzy TOPSIS method to locate mineral processing plant site selection in the case of the Sangan, Iran iron ore mine. Fuzzy TOPSIS is useful for manufacturing location selection problem (Chu, 2002a, 2002b; Yong, 2006). Cheng *et al.* (2002) and Cheng *et al.* (2003) studied the integration of MCDA and inexact mixed integer linear programming methods to support selection of an optimal landfill site and a waste-flow-allocation pattern such that the total system cost can be minimised. Different multi-objective programming models have been proposed to solve the problem which could minimise the weakness of the method where they are basically mathematical and ignore qualitative and often subjective considerations. Awasthi *et al.* (2011) presented a fuzzy multi-criteria decision making, TOPSIS, approach for location planning of urban distribution centres under uncertainty. This approach could practically applied by logistics operators in deciding on the location of new distribution centres considering the sustainable freight regulation proposed by municipal administrations. Li *et al.* (2011) studied the comprehensive method for the selection of logistic centre location. They studied fifteen regional logistics centre cities and thirteen criteria are studied and the numerical result show that the proposed evaluation framework is reasonable to identify logistics centre location, and it is effective to determine the optimal logistics centre location even with the interactive and interdependent criteria and attributes.

It can be seen that the TOPSIS method is applicable to various areas in studies of the location decision problem. TOPSIS is a practical and useful technique for ranking and selection of a number of externally determined alternatives through distance measures. Fuzzy set theory is often incorporated to TOPSIS in evaluating the suitability of alternatives. In the evaluation of the alternative location, quantitative and qualitative assessments are often required to deal with uncertainty, subjective and imprecise data, which are best represented with fuzzy data. This could result effective decision made on the basis of consistent evaluation results.

3.4.2.3 Categorisation of TOPSIS Location Decision Research

This section discusses the distribution of journal articles that are covered in the previous section into articles by journals, country/regional application, and distribution years of the journal papers relate to the research findings.

Appendix D.4 provides the list of journals with the references published in different types of articles. There are a total of seventeen different journals that published location selection related problems that includes TOPSIS. The table demonstrates that the vast majority of the articles (i.e. six articles or 22%) are published in *Expert Systems and Applications.* The rest are equally spread among the other journals. Looking at the articles published, it can be seen that, generally, the papers that are published in *Fuzzy Sets and Systems* which often represents the first publication of particular analytical approaches (or combinations of them) in the context of facility location decision problem; such as, Bhattacharya *et al.* (1992) for TOPSIS.

3.4.3 Integrated AHP and TOPSIS Location Decision Problems

The combination of AHP and TOPSIS has been used for many areas for location decision problems. TOPSIS is combined with other research tools, especially with AHP because the AHP can be used to acquire criteria weights and TOPSIS can be used to obtain the final suitable ranking order of the alternative locations (Amiri, 2010; Dagdeviren *et al.* 2009; Önut *et al.* 2010; Wang and Chang, 2007). The comparative analysis between AHP and TOPSIS was studied by Ertuğrul and Karakaşoğlu (2008), Özcan *et al.* (2011), and Shih *et al*. (2007) and the detailed context of this is mention in the methodology chapter. A brief literature review of location decision using the combination of AHP and TOPSIS is illustrated in Table 3.4.

Table 3.4 AHP and TOPSIS location decision literatures

Topic	Author	Major Attributes	Sub-attributes	Alternatives
Distribution centres	Kuo (2011)	4	10	6
	Kuo and Liang (2011)	3	10	6
	Özcan *et al.* (2011)	5		4
	Zheng *et al.* (2009)	-	-	-
Emergency facilities	Lin and Tsai (2010a)	4	14	14
	Lin and Tsai (2010b)	-	-	-
Solid waste	Ekmekçioğlu *et al* (2010)	8		4
	Önut and Soner (2008)	5		5
General	Kahraman *et al.* (2010)	-	-	-
Plant sites	Amiri (2010)	6		5
Bank branch	Cinar (2009)	-	-	-
Shopping centre	Önut *et al* (2010)	8		6

Source: Author

Kahraman *et al.* (2010) illustrated a combination of AHP and TOPSIS for location decision problem that could be applied to plants, warehouses, retail outlets, terminals, storage yards, and distribution centres. The selection of international distribution centres been studied by Kuo (2011), Kuo and Liang (2011), and Zheng *et al*. (2009). Kuo (2011) and Kuo and Liang (2011) had ten attributes and six alternatives locations under a fuzzy environment. Cinar (2009) presented the decision support model for bank branch location selection in South-Eastern Turkey to select the most appropriate city for opening a branch among six alternatives. The model consisted of five main criteria (demographic, socio-economic, sectoral employment, banking, and trade potential) and twenty-one sub-criteria which present the bank's mission and strategy. Lin and Tsai (2010a, 2010b) evaluated the optimal city in South China for new medical facilities using AHP to assess weights of the multi-interrelationships criteria. The values obtained for each city were determined using the TOPSIS using the weights from AHP. The optimal shopping centre site selection in Istanbul, Turkey was studied by Önut *et al.* (2010), who included eight attributes and six alternative sites in their study. Site selection of the appropriate solid waste facilities is also applicable for AHP and TOPSIS (Ekmekçioğlu *et al.* 2010). Project selection for oil-fields development by using the

AHP and fuzzy TOPSIS has been studied by Amiri (2010). They proposed a simple approach to assess alternative projects and help the decision-maker to select the best on for National Iranian Oil Company by using six criteria of comparing investment alternatives as criteria. All of the studies combining AHP and TOPSIS, not limiting to location decision problem, use AHP to analyse the structure of the location selection problem and to determine weights of the criteria, and TOPSIS method is used to obtain final ranking.

3.5 The Fuzzy TOPSIS Location Problem

In the primitive forms of the AHP and TOPSIS methods, experts' comparisons about the criteria, sub-criteria, and alternatives are represented in the form of exact numbers (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). In real-life decision problems, perfect knowledge is not easily acquired, unquantifiable, incomplete and may not even be obtainable under many conditions (Kelemenis and Askounis, 2010; Olçer and Odabasi, 2005). Qualitative criteria are often accompanied by ambiguities and vagueness (Önut *et al.* 2010). Fuzzy decision-making is a powerful tool for decision-making in a fuzzy environment (Önut *et al.* 2010; Torfi *et al.* 2010). Fuzzy sets are applied to describe vagueness with linguistic values and triangular fuzzy numbers (Shipley *et al*. 1991; Shyur and Shih, 2006). Classical decision–making methods work only with exact and ordinary data, so there is no place for fuzzy and vague data (Torfi *et al.* 2010).

Fuzzy TOPSIS has been proposed where criteria weights and alternative ratings are given by linguistic variables that are expressed by 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), although their fuzzy-TOPSIS algorithms are incomplete (Chu, 2002a). The AHP decision process can become impractical in some cases due to a large number of potential available alternatives in the literature. Therefore, to avoid an unreasonably large number of pairwise comparisons, the fuzzy TOPSIS is employed to achieve the final ranking results (Dagdeviren *et al.* 2009). A better approach may be to use linguistic value rather than numerical value, which means that the ratings and weights of the criteria in the problem are evaluated by linguistic variable (Yu *et al.* 2011). Linguistic values can deal with ambiguities, uncertainties and vagueness (Torfi *et al.* 2010). Fuzzy sets theory can be used to present linguistic value, which allows the decision-makers to incorporate unquantifiable information, incomplete information, non-obtainable information and partially ignorant facts into decision model (Kulak *et al*. 2005). Therefore, fuzzy-TOPSIS is proposed to solve ranking and evaluating problems (Ashtiani *et al.* 2009; Jahanshahloo *et al.* 2006; Wang and Elhag, 2006; Wang and Lee, 2009). The use of the fuzzy set theory for modelling and analysing decision systems is particularly interesting to researchers who are concerned with facility location selection problems (Awasthi *et al.* 2011; Bhattacharya *et al.* 1992; Bhattacharya *et al.* 1993; Boran, 2011; Chu, 2002a; Chung and Tcha, 1992; Darzentas, 1987; Ekmekçiouğlu *et al*. 2010; Ertuğrul, 2010; Gharakhlou *et al.* 20110; Gligorić *et al.* 2010; Kahraman *et al.* 2010; Kuo *et al.* 2007; Liang and Wang, 1991; Liao, 2009; Narasimhan, 1979; Önut *et al.* 2010; Safari *et al.* 2010; Tzeng and Lin, 1996; Yong, 2006). However, research on the application of fuzzy TOPSIS to location decision problem is still lacking (Chu, 2002b).

3.6 Location Decision Criteria

Warehouse location selection decision can be approached from both macro perspectives (Hoover, 1948) and micro perspectives (Freese, 1994; Miller, 1993, Pano, 1994). Schmenner (1982) also indicates the major locational determinants can be used with regional and specific site determinants. Table 3.5 presents the major location decision determinant attributes that decision-makers should consider for warehouse selection.

Table 3.5 Major location decision determinant attributes

Macro approaches	Micro approaches
Market positioned	Quality and variety of transportation carriers serving the site
Production positioned	Quality and quantity of available labour
Intermediately positioned	Labour rates
Von Thunen's Model	Cost and quality of industrial land
Webers' Model	Potential for expansion
Hoover's Model	Tax structure
Greenhut's Model	Building code
Centre-of-Gravity Model	Nature of the community environment
	Cost of construction
	Cost and availability of utilities
	Cost of money locally
	Local government tax allowances and inducements to build

Regional determinants	Specific site determinants
Favourable labour climate	Rail service
Proximity to markets	On expressway
Quality of life	Special provisions of utilities
Near supplies and resources	Rural area
Labour rates	Environmental permits
Environmental permits	Within metropolitan area
Facility/land already available	On water
Better transportation	Transportation (air and truck)
Taxes, financing	

Source: Freese (1994), Hoover (1948), Miller (1993), Pano (1994), Schmenner (1982)

In one of the best-known macro approaches to warehouse location, Hoover (1948) identified three types of location strategies: firstly, market positioned; secondly, production positioned; and thirdly, intermediately positioned. The *market-positioned strategy* locates warehouses nearest to the final customer, which maximises customer service levels and enables a firm to utilise transportation economies from plants source to each warehouse location. The factors that influence the placement of warehouses near the market areas served include transportation costs, order cycle time, the sensitivity of the product, order size, local transportation availability, and levels of customer service offered. The *production-positioned strategy* locates warehouses in close proximity to source of supply or production facilities. These warehouses generally cannot prove the same level of customer service as market-positioned warehouses; instead, they were used as collection points or mixing facilities for products manufactured at a number of different plants. The factors that influence the placement of warehouses close to the point of production include: perishability of raw materials, number of products of the firm's product mix, assortment of products ordered by customers, and transportation consolidation rates. The *intermediately positioned strategy* places warehouses at a midpoint location between the final customer and the producer. Customer service levels are typically higher for intermediately positioned warehouses than they are for the production-positioned facilities and lower than for market-positioned facilities.

Another macro approach includes the combined theories of a number of well–known economic geographers based on distance and cost considerations. Von Thunen (1966) developed a strategy of facility location based on cost minimisation when locating points of agricultural production, and argued that transportation costs should be minimised to result in maximum profits for farmers. *Von Thunen's model* assumed that market price and production costs would be identical for any point of production. *Weber's Model*, developed which was proposed by Alfred Weber (1929), also developed a model of facility location that is based on cost minimisation. According to Weber (1929), the optimal site is one that minimises "total transportation costs – the costs of transferring raw materials to the plant and finished goods to the market". He classified raw materials into two categories according to their effect on transportation costs: location characteristics and processing characteristics. *Hoover's model* includes the factors of demand and profitability in the location decision (Hoover, 1948). It considered both cost and demand elements, and stressed cost minimisation in determining an optimal location. Greenhut (1956) expanded upon the work of his predecessors by including factors specific to the company and profitability elements in the location choice. According to *Greenhut's Model*, the optimal facility location was one that maximised profits. The *Centre-of-gravity approach* is simplistic in scope, and locates facilities based on transportation costs. This approach locates a warehouse or distribution centre at a point that minimises transportation cost for products moving between a manufacturing plant and markets. Schemenner (1982) divided the selection factors of the macro and micro approaches into regional and specific site determinants.

3.6.1 MADM Decision Criteria

There are a large number of location factors that have influence on location decisions (Yang and Lee, 1997). Pardee (1969) suggested that a desirable list of attributes should:

1. *Be complete and exhaustive* – That is, all important performance attributes deemed relevant to the final decision should be represented by times on the list;
2. *Contain mutually exclusive items* – This would permit the decision maker to view listed attributes as independent entities among which appropriate trade-offs may later be made. This would also help prevent undesirable ‘double-counting’ in the worth of sense; and,
3. *Be restricted to performance attributes of the highest degree of importance* – The purpose is to provide a sound basis or starting point from which lower-level criteria my subsequently be derived.

Applying the desirable list of attributes, Farahani *et al.* (2010) organised decision criteria that is commonly used in MADM location problems (Table 3.6).

- Cost: including land, transportation, installation, and maintenance cost;
- Value and benefits: including revenue, land or asset value, or product value;
- Environmental risks: including health effects, sound and optical pollution, smells, air or water pollution, and waste collection;
- Resource accessibility and utilisation of the facility;
- Access to public facilities: including airports, motor or railways or recreation, resting, and accommodation;
- Political matters and regulation: including community consideration, country measures, and government regulations;
- Competitive environment and the presence of competitors;
- Economic criteria (beside cost and value): including labour availability, job opportunities, currency value, and business climate;
- Population is important in some location problems;
- Capacity and size of the facility;
- Distance: including closeness to markets or customers, suppliers and resources, closeness to forbidden or natural areas;
- Suitability: including qualitative, cultural and social issues, technical suitability, land use, natural threats, convenience to traffic system, and infrastructure;

These are the general common attributes that could be found in all of the MADM location problems. The following section will discuss the detail attributes that is found in warehouse, distribution/logistics centre, and general facility location selection problems in AHP and TOPSIS.

Table 3.6 Determinant attributes in multiple-attribute location problems

Criteria	**References**		
Cost	Alberto (2000)	Fernandez and Ruiz (2009)	Turetken (2008)
	Aras *et al*. (2004)	Farahani and Asgari (2007)	Tuzkaya *et al*. (2008)
	Chan and Chung (2004)	Guo and He (1999)	Tzeng *et al*. (2002)
	Chou *et al*. (2004)	Tabari *et al.* (2008)	Yong (2006)
Value and benefits	Guimaraes Pereira *et al*. (1994)	Lahdelma *et al*. (2002)	Tuzakaya *et al*. (2008)
	Guo and He (1999)	Norese (2006)	Farahani and Asgari (2007)
Environmental risks	Aras *et al*. (2004)	Lahdelma *et al*. (2002)	
	Barda *et al*. (1990)	Norese (2006)	
	Fernandez and Ruiz (2009)	Turetken (2008)	
	Guimaraes Pereira *et al*. (1994)	Tuzkaya *et al*. (2008)	
Resource accessibility and utilisation	Aras *et al*. (2004)	Chou *et al*. (2004)	
	Barda *et al*. (1990)	Kinara and Kotzab (2008)	
	Chan and Chung (2004)	Lahdelma *et al*. (2002)	
	Fernandez and Ruiz (2009)	Yong (2006)	
Public facility accessibility	Aras *et al*. (2004)	Kinara and Kotzab (2008)	
	Barda *et al*. (1990)	Lahdelma *et al*. (2002)	
	Chou *et al*. (2004)	Norese (2006)	
	Fernandez and Ruiz (2009)	Shen and Yu (2009)	
	Guimaraes Pereira *et al*. (1994)	Tzeng *et al*. (2002)	
Political matters and regulations	Badri (1999)	Kahraman *et al*. (2003)	Tabari *et al.* (2008)
	Canbolat *et al*. (2007)	Kinara and Kotzab (2008)	Turetken (2008)
	Chou *et al*. (2004)	Shen and Yu (2009)	
Competition	Badri (1999)	Kahraman *et al*. (2003)	
	Chou *et al*. (2004)	Tzeng *et al*. (2002)	
Economical (besides cost and benefits)	Badri (1999)	Kahraman *et al*. (2003)	Tabari *et al.* (2008)
	Barda *et al.* (1990)	Kinara and Kotzab (2008)	Turetken (2008)
	Canbolat *et al*. (2007)	Norese (2006)	Tuzkaya *et al*. (2008)
	Ertuğrul and Karakaşoğlu (2008)	Shen and Yu (2009)	Yong (2006)
	Fernandez and Ruiz (2009)		
Population	Canbolat *et al*. (2007)	Lahdelma *et al*. (2002)	Tzeng *et al*. (2002)
	Guimaraes Pereira *et al*. (1994)	Norese (2006)	
Capacity	Norese (2006)	Tuzkaya *et al*. (2008)	Tzeng *et al*. (2002)
Distance	Ertuğrul and Karakasoglu (2008)	Norese (2006)	
	Guimaraes Pereira *et al*. (1994)	Tuzkaya *et al*. (2008)	
Suitability	Aras *et al*. (2004)	Canbolat *et al*. (2007)	
	Barda *et al*. (1990)	Chou *et al*. (2004)	

Source: Farahani *et al*. (2010)

3.6.2 Warehouse Selection Attributes in AHP and TOPSIS

The attributes used for warehouse selection used in AHP and TOPSIS vary from case-to-case (e.g. by country or by industry type). Table D 5 in Appendix D illustrates the detail attributes with the major attributes and the sub-attributes applied for warehouse, distribution/logistics centre, and general facility selection. The attributes are derived from the literatures that apply at least one of the AHP or TOPSIS tools. It can be seen in the Appendix D that the sub-criteria of the attributes fit into different main criteria. It is difficult to determine which criteria are important because they are all assessed differently according to their research characteristics by decision-makers. The inconsistent grouping of the criteria depends on how the researcher looks at the problem and how the hierarchy structure of the attributes is determined.

For the warehouse selection problem, Alberto (2000) grouped attributes into seven main criteria, which are: 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) used cost, labour characteristics, infrastructure, markets and macro environment in their study of warehouse selection in Turkey. Korpela and Tuominen (1996) considered the reliability, flexibility, and strategic compatibility for their main criteria. Özcan *et al.* (2011) used only main criteria that consist of unit price, stock holding capacity, average distance to shops, average distance to main suppliers, and movement flexibility.

The key attributes for selecting distribution/logistics centre have lots of similarities with those of selecting a warehouse location selection. In the studies of selecting the distribution centre, Awasthi *et al.* (2011) used the main attributes of 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. Kengpol (2004) studied the distribution centre selection problem in Thailand with cost, comfort in truck management, preparation moving time, and comfort in product distribution as their main criteria. The distribution centre selection problem in Asia was studied by Kuo (2011) and Kuo and Liang (2011), who used cost, convenience, the condition of the port, operating capability, and service quality. They used similar sub-attributes by adding and eliminating in different main criteria. The distribution centre selection for Asia-Pacific region was studied by Sarkis and Sundarraj (2002). The attributes used for their main criteria were 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) researched a case in Austria using the main attributes of economical scale, national stability, intermodal operation and management, international market location, and environmental effect. Li *et al.* (2011) considered whether condition, 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

Chuang (2001) approached the facility location decision using the attributes of information technology of requirement, energy/utilities, labour conditions, community and working environment, political regulation and law, closeness to suppliers and customers, transportation conditions, initial and operating costs, and land features. Kahraman *et al*. (2003) studied the motor factory selection problem in Turkey using environmental regulations, host community, competitive advantage, and political risk. Levine (1991) organised the location factors that have been widely used in industrial location research into access to markets/distribution centres, access to supplies/resources, community/government access, competitive consideration, labour, taxes and financing, transportation, and utility services. Yang and Lee (1997) adapted the findings of Levine (1991) and applied market, transportation, labour and community as their attributes. They identified and eliminated the unimportant factors, including those which are not sensitive to location site and those where the difference in degree of factor achievement is insignificant.

3.7 Gaps in the Literature

In conducting the literature review, the author reviewed different papers related to the research topic in order to explore the previous contributions in this topic. The search revealed several gaps that the author aims to fill through this research. As a result of reviewing the literature, five research questions were formulated. These are discussed and presented below.

Firstly, the study facility location selection problem has been solved using different operations research techniques where the selection of logistics location has been long considered as one of the most important complex decision-making problems (Kayikci, 2010).

Location studies are conducted mainly with quantifiable methods dealing with mathematical solutions. MADM (AHP and TOPSIS) methods rarely deal with warehouse location selection problems, especially related with humanitarian logistics. Among the warehouse location selection problem, the attributes used varies according to the project characteristics and with the decision-makers preference. There are no standard must-have attributes for research; hence, the first question formulated in this thesis:

> **Research Question 1:** What are the humanitarian relief warehouse selection attributes?

Secondly, Table 2.5 shows that many humanitarian relief organisations are currently implementing a pre-positioning warehouse strategy for the global distribution of relief goods. The current research focuses on the case study of International Humanitarian Organisation A, which principally aids refugees. However, there has been little previous research of warehouse location selection for humanitarian relief, especially for refugee related operations. In addition, it is rarely discovered on what basis the criteria was selected for the selection problem; hence, this bring to extend Research Question 1 to the second question:

> **Research Question 2:** What are the priorities and the weights of the regional warehouse location selection determinant attributes?

Thirdly, International Humanitarian Organisation A operates five different pre-positioned stockpile locations around the world. This study aims to determine whether they have located the optimal warehouse location for their organisation. There is no indication or description from the literature review of how the criteria were selected. Furthermore, there is no qualitative location selection problem for humanitarian relief problem. This brings to the third research question:

> **Research Question 3:** Where is the optimal warehouse location using the evaluation of the regional determinant attributes?

Fourthly, there have been few previous studies of the decision criteria in the region of the Middle-East. Meanwhile, a pre-positioned warehouse of International Humanitarian Organisation A is based at Dubai, UAE. This current study shows that the decision criteria used for location selection problem differ due to the decision-makers opinions of the project. Since the author participated in the warehouse location selection project for International Humanitarian Organisation A, this brings to the fourth question:

> **Research Question 4:** What are the priorities and the weights of the specific site warehouse location selection determinant attributes?

Fifthly, the warehouse compound of International Humanitarian Organisation A is located in Dubai, UAE. At the time that this research was conducted they were running a project to move the warehouse to a new location within the country. Since there is no previous study, the author has participated in the project to seek the optimal warehouse location for the organisation with the decision criteria made by the decision-makers of the compound. This brings to the fifth question:

> **Research Question 5:** Where is the optimal warehouse location using the evaluation of the specific site determinant attributes?

These five research questions form the base of this thesis. Each research question once answered will provide insights into warehouse location selection problem of humanitarian relief organisation in particular, and provide better understanding of humanitarian relief warehouse location selection problem as a whole.

3.8 Chapter Summary

The importance of the application of supply chain management in humanitarian relief operation can be seen in many different aspects. One is the warehousing strategy question, where many humanitarian relief organisations are establishing or expanding new (pre-positioned) warehouses for their supply chain strategy. However, most of these are distributed in the mathematical programming models which have more of a focus on the quantifiable aspects of the problem. Multi-attribute decision-making process deals with selection and evaluation of locations, considering various criteria of the human factors of the qualitative approach to the decision making process. These methods have been widely used in various fields, such as information project selection, material selection, management decisions, strategy selection, and problems relating to decision-making. Among the MCDM location selection problem, the AHP and TOPSIS are found to be the most useful tools. The strength and the weakness among the multi-attribute decision making methods will be discussed in the next chapter. From the finding of the literature above, it can be concluded that there are no standard general attributes that are used for location selection decision problem for multi-attribute decision making method. The important attributes used by those methods for determining the location of a warehouse varies according to their need while the characteristics of the operation are determined by decision makers.

CHAPTER 4
RESEARCH METHODOLOGY

4.1 Chapter Overview

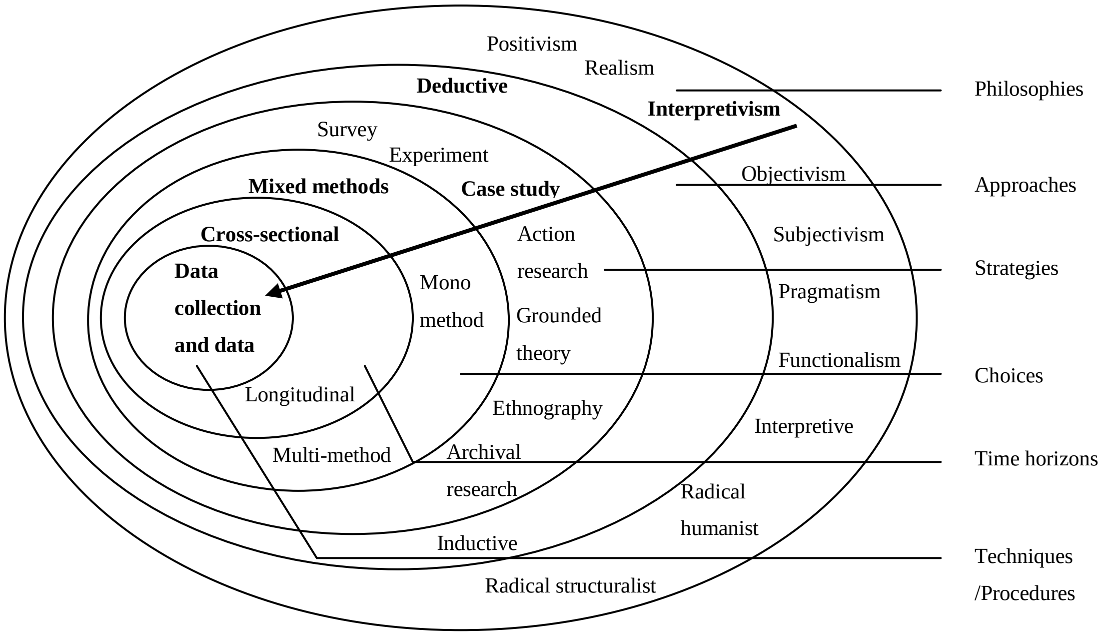
This chapter presents the research design and methodology that was used in this study. The main topics around the research methodology will be discussed, including: research paradigm, strategy, data collection methods and the data analysis methods. The framework for the study is then described in detail.

4.2 Research Design

The research design represents the plan to be followed to achieve the research objectives and address the hypotheses (McDaniel and Grates, 1999). In essence, research design can be conceived of as a structure or framework which guides the collection and analysis of data to answer a specific research problem or opportunity (Bryman and Bell, 2007). Since there is no single and best research design, the strategic choice of research design is highlighted in order to come up with an approach that enables problems to be answered in the best possible way within the given constraints (e.g. time, budgetary and skill constraints) (Ghauri and Grøhaug, 2002).

Kornhauser and Lazarsfeld (1995) compared research design to '*master techniques*', and the statistical analysis of the data collected to '*servant techniques*'. Consequently, it is crucial to develop a research design which allows the researcher to collect data effectively for achieving the research objectives and answering the questions being studied. As addressed in the previous chapters, the objective of the current study is to find the contributing attributes and optimal location in the humanitarian warehouse selection problem. The nature of this research objective is fundamental to deciding the appropriate research methodology. In order to accomplish this purpose, the research '*onion*' from Saunders *et al.* (2007) was adopted (Figure 4.1). The concept of the onion is that it has different layers depicting several issues to be considered before reaching the central point. The following subsections present the philosophical positions, the research approach, strategy and time horizon of the current study in detail.

Figure 4.1 The research '*onion*' for this study



Source: Saunders *et al.* (2007)

4.2.1 Research Philosophy

Research methodology indicates far more than the methods adopted in a particular study and it encompasses the rationale and the philosophical assumptions that underlie a particular study. A research philosophy is described as the logic of inquiry governing the research approaches or being '*the study of study'* which implies that it studies how each study issues (Maylor and Blackmon, 2005). In essence, it is a principle of how the data about a particular phenomenon should be collected, analysed and used. The philosophical approach associated with methodology has been explained in terms of ontology and epistemology from the perspective of several authors (Bryman and Bell, 2007; Guba and Lincoln, 1994; Näslund, 2002). In addition, Guba and Lincoln (1994) have distinguished four major research paradigms, which are: positivism, post-positivism, critical theory and constructivism. Table 4.1 explains the difference between paradigms based on their ontology, epistemology and methodology.

Ontological questions are concerned with the search for the reality underlying forms and nature, and what can be known about them. Bryman (2008) asserted that this is associated with what is treated as appropriate knowledge about the social world.

Table 4.1 Research paradigms

Orientation	Positivism	Post-Positivism (Realism)	Critical Theory	Interpretivism/ Constructivism
Ontology	"Naïve realism" in which an understandable reality is assumed to exist, driven by immutable natural laws. The true nature of reality can only be obtained by testing theories about actual objects, processes or structures in the real world.	Critical realism – "real" reality but only imperfectly and probabilistically apprehensible	Historical realism – social reality is historically constituted; human beings, organisations, and societies are not confined to existing in a particular state	Relativism – local and specifically constructed realities; the social world is produced and reinforced by humans through their action and interaction
Epistemology	Dualist/Objectivist; verification of hypotheses through rigours empirical testing; search for universal laws of principles; tight coupling among explanations, predictions and control	Modified dualist/objectivist; critical tradition/ community; findings probably true	Transactional/ Subjectivist; knowledge is grounded in social and historical practices; knowledge is generated/justified by critical evaluation of social systems I the context of the researcher's theoretical framework adopted to conduct research	Transactional/ Subjectivist; understanding of the social world from the participants' perspective; through interpretation of their meanings and actions; researchers' prior assumptions, beliefs, values, and interests always intervene to shape their investigations
Methodology	Hypothetical-deductive experiments0/ manipulative; verification of hypotheses; primarily quantitative methods	Modified experimental/ manipulative; falsification of hypotheses; many included quantitative methods	Dialogic/ dialectical; critical ethnography; interpretive case study; action research	Hermeneutical/ dialectical; interpretive case study; action research; holistic ethnography

Source: Guba and Lincoln (1994)

According to May (1993), ontological issues are concerned with '*being*'. Questions of ontology (such as '*What kinds of things really exist in the world*') are related to the nature of social entities (Bryman and Bell 2007; Hughes and Sharrock, 1997). A particular key issue around ontology is the question of whether social entities can be (or should be) viewed as objective entities in which a reality exists externally apart from social actors or whether they can be constructed socially from the perceptions and actions of social actors. These positions are associated with objectivism and constructionism, as demonstrated by Bryman and Bell (2007). On the other hand, epistemology is, to put if briefly, concerned with '*knowing'* (May, 1993). Hughes and Sharrock (1997) described it as evaluating claims on how the world can be known to us. In other words, this is to do with whether the social world is regarded as something external to social actors or as something that people are in the process of fashioning (Bryman, 2008); for example, '*How is it possible, if it is, for us to gain knowledge of the world?*', '*How can we know anything with certainty?*', '*How is knowledge to be distinguished from belief or opinion?*' and '*What methods can yield reliable knowledge?*'. These questions represent the issues of what is regarded as acceptable knowledge in a discipline (Bryman and Bell, 2007). Methodological questions are concerned with approaches in finding 'what we believe is known'. Ontology is the 'reality' that the research studies, epistemology is the relationship between the reality and the researcher, and methodology is the technique used by the researcher to investigate the reality (Healy and Perry, 2000).

Positivism is an epistemological position that applies the methods of the natural sciences to the study of social reality and beyond (Bryman and Bell, 2007). Easterby-Smieth *et al.* (2002) summarised the implications of positivism as follows:

1. (The observer) must be independent;
2. (Human interests) should be irrelevant;
3. (Explanations) must demonstrate causality;
4. (Concepts) need to be operationalised so that they can be measured;
5. (Units of analysis) should be reduced to the simplest terms;
6. (Generalisation through) statistical probability;
7. (Sampling requires) large numbers selected randomly.

In contrast to positivism, interpretivism is characterised as an epistemological position that requires the researchers to grasp the subjective meaning of social action (Bryman 2008). Interpretivists argue that human beings act according to their subjective understanding of the implications of phenomena and do not simply respond to external stimuli. Consequently, it is suggested that data should be interpreted. Crucial to the interpretivist epistemology is that the researcher has to adopt an empathetic stance in order to understand the research subjects' world from their point of view.

According to Mentzer and Kahn (1995), logistics research has been founded mainly on the positivist paradigm: "*Positivist researchers build a mountain of knowledge by systematically placing research findings on top of each other as study after study is completed*". Nevertheless, a new trend has emerged in logistics research stressing the importance of triangulation of quantitative and qualitative methods (Näslund, 2002). Accordingly, the research paradigm has shifted from rigid positivism to liberal phenomenology.

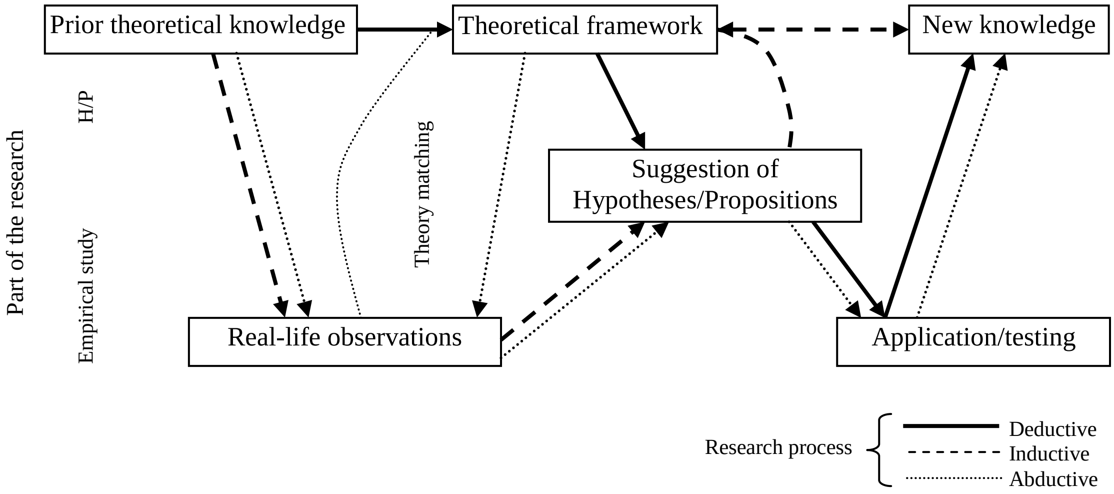
The ontological position of this present study tends towards the positivist paradigm. This research is based on the belief that there exist a real physical world beyond our knowledge and comprehension and that reality exists outside the researcher's mind. The epistemological position of this study is also positivist. Epistemology is much concerned with what is "known" and what "known" means, and the relationship between the researcher and the researched. This study is not concerned with knowledge creation for its own sake, but as an instrumental means of contributing to a better understanding of the impact of the determining factor for warehouse selection in the humanitarian relief logistics. The methodological position of this study rests on the use of multi methods, with the emphasis on both quantitative and qualitative methods; accordingly, it follows interpretivism paradigm in investigating the optimal warehouse selection in the humanitarian relief organisation. Triangulation of quantitative methods, in the form of empirical data collected from case studies and an exploratory and descriptive survey, semi-structured interviews with humanitarian relief organisation supply managers and (senior) officers, was used to verify and confirm findings derived from the different methods employed in this study.

4.2.2 Research Approach

A research approach is defined as the path of conscious scientific reasoning (Peirce, 1931). The choice research approach is derived from a researcher's philosophical position, which was explained in the previous section, and also based on the decision on what comes first: theory or data (i.e. empirical research). Spens and Kovács (2006) constructed the research process framework to differentiate between three different research approaches: deduction, induction and abduction (see Figure 4.2).

The deductive approach is characterised as a theory testing process, which begins with an existing theory or generalisation, and which then seeks to test whether the theory applies to specific cases. This approach is prevalent in positivism and employs a quantitative strategy. The inductive approach, on the other hand, is the mirror image of the deductive approach (Johnson, 1996).

Figure 4.2 Deductive, inductive and abductivve research approaches



Source: Spens and Kovács (2006)

Prior theoretical knowledge is not necessarily needed as a starting point in the inductive process. Instead, it is a process of developing theory, which commences empirical observations about the world, leading to the generation of hypotheses/propositions and their generalisation through logical argumentation (Danermark, 2001). The inductive approach is dominant in interpretivism and employs a qualitative strategy. However, Taylor *et al.* (2002) asserted that most great advances in science neither followed the pattern of pure deduction nor that of pure induction. The abductive approach stems from this insight. It commences with either a '*puzzling*' observation or an anomaly that cannot be explained by an established theory, or through the deliberate application of an alternative theory for explaining a phenomenon. It is notable that in the abductive research process, the empirical data collection and theory building phases overlap in a learning loop that is able to suggest new theories in the form of new hypotheses/propositions. In abduction, the generalisation only occurs after applying these hypotheses/propositions in further empirical studies (Spens and Kovács, 2006). The researcher should then consider whether the study should have an exploratory, explanatory, or descriptive approach according to different research purposes. Exploratory research aims to ask questions to gain new insights or evaluate phenomena in a new light in order to provide direction for any further research. Descriptive research seeks to provide an accurate profile of the situations, or persons being studied. Finally, explanatory research intends to explain the phenomenon being studied, often in the form of a causal relationship (Robson, 2002).

Since logistics does not have a rich history of theory development and empirical research, most concepts, principles, theories and methodologies are borrowed from different disciplines, such as: accounting, business/management, computing, economics, marketing, mathematics, philosophy, political science, psychology, and sociology (Stock, 1997). By adopting an interpretivist position, the present study focuses on identifying and evaluating the suitable humanitarian warehouse selection along with optimal location established through a logical abduction for the established theories and empirical studies. Given the nature of the objective of this study (i.e. to investigate the decision-making factors for pre-positioned warehouse locations in the humanitarian relief logistics context), positing a causal relationship between the key constructs for examination, the exploratory approach is deemed to be the most appropriate.

4.2.3 Theoretical Research Design

A design can be thought of as the logical steps that connect the empirical data to a study's initial research questions. The most important objective of any research design is to ensure that all of the pieces fit together. There are two basic research designs that are used by researchers when conducting social science research: experimental design and non-experimental design.

4.2.3.1 Experimental Design

Experimental research design is a design where the researcher actively manipulates aspects of a setting, either in the laboratory or in a field situation, and observes the effect of that manipulation on experimental subjects (Cohen and Manion, 1994). To manipulate a variable is to do something to it through treatment or intervention. Controlling an experiment means that the researcher controls the treatment of the study group while comparing and contrasting against a control group where there has been no treatment or intervention (Aaker *et al.* 1995). This type of research design is not appropriate in this study because there is no need to manipulate any aspect of the setting for the research.

4.2.3.2 Non-Experimental Design

Non-experimental design is popular among social scientist and it is used widely in the study of management. Unlike experimental research, variables cannot be manipulated because the study is carried out in its natural setting and relationships are observed as they occur. Both control and manipulation issues do no arise in this type of design. Non-experimental design can be divided into different categories which include case study and survey research, both of which will be employed in this study.

The first type of non-experimental design is case study research. According to Yin (1994), a case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and its context are not clearly evident. Goode and Halt (1952) stated that the case study is not specific technique, it is a way of organising social data so as to preserve the unitary character of the social object being studied. In other words, it is an approach which views any social unit as a whole. Moreover, case study research focuses on and observes the characteristics of an individual unit or organisation to refine knowledge (Nettleton and Taylor, 1990). However, there are some concerns about using this method, including: lack of rigour, validity and representativeness, the long time required to analyse extensive results, and finding are only generalisable to theoretical propositions not to populations or universe (Yin, 1994). Different approaches may be employed for data collection purposes when using the case study method. It is likely that a case research is most appropriate for humanitarian and emergency logistics studies because the individual circumstances are often largely unique with only limited commonalities with other emergencies. Table 4.2 summaries the strengths and weakness of these approaches.

Table 4.2 Sources for evidence for case study research

Source of Evidence	Strengths	Weaknesses
Documentation	· Stable – can be reviewed repeatedly · Unobtrusive – not created as a result of the case study · Exact – contains exact named, references, and detail of an event · Broad coverage – long span of time, many events, and many settings	· Retrievability – can be low · Biased selectivity, if collection is complete · Reporting bias-reflects (unknown) bias of author · Access – may be deliberately blocked
Archival records	· Same as above for documentation · Precise and quantitative	· Same as above for documentation · Accessibility due to privacy reasons
Interviews	· Targeted-focuses directly on case study topic and issues · Insightful-provides perceived casual inferences	· Bias due to poorly constructed questions · Response bias · Inaccurate due to poor recall · Reflexivity – interviewee given what interviewer wants to hear
Direct observation	· Reality – covers events in real time · Contextual – covers context of events	· Time consuming · Selectivity – unless broad coverage · Reflexivity – events may proceed differently because they are being observed · Cost – hours needed by human observers
Participant observation	· Same as above for direct observation · Insightful into interpersonal behaviour and motives	· Same as above for direct observation · Bias due to investigators' manipulation of events
Physical artefacts	· Insightful into cultural features · Insightful into technical operations	· Selectivity · Availability

Source: Yin (1994)

Survey research is appropriate for answering research questions about behaviours, attitudes, opinions, beliefs, knowledge and expectations (Neuman, 1997). It is most widely used data gathering method by researchers collecting primary data (Aaker *et al.* 1995). Additionally, according to Neuman (1997), survey research involves many respondents answering the same questions, it measures many variables, tests multiple hypotheses, and elicits information about past experience. It measures variables that represent alternative explanations and examines their effects, thereby ruling out any alternative explanations that do not belong. There are many advantages to survey research, such as the ability to generalise, versatility, standardisation, and suitability for statistical analysis. Some researchers call survey research co-relational since it uses control variables and correlations in statistical analysis (Neuman, 1997). Forza (2002) has distinguished three types of survey research:

1. *Exploratory survey*

   This type of survey takes place during the early stage of research. It helps in gaining preliminary insight into a phenomenon; in addition it provides a good foundation for a more in-depth survey.

2. *Confirmatory (or theory testing) survey research*

   This type of survey takes place when knowledge of a phenomenon has been articulated using well defined concepts, models and propositions.

3. *Descriptive survey research*

   This type of survey is aimed at understanding the relevance of certain phenomena and describing their distribution of the phenomenon in a population.

4.2.4 Quantitative Research, Qualitative Research and Triangulation

There are two main approaches to data collection: quantitative and qualitative methods.

Quantitative research follows the positivist paradigm, which implies application of a numerical approach to those issues under investigation, particularly with respect data collection and analysis (Denzin and Lincoln, 1994). According to Nachmias and Nachmias (1996), this research type relies on hypothesis derived from theory. These hypotheses contain variables that can be measured and analysed using statistical procedures. Nettleton and Taylor (1990) stated that, through statistical data analysis, quantitative methods provide accurate measurements for social action by explaining causal relationships between phenomena and measuring those using objective and systemic criteria.

Qualitative research follows the phenomenological approach to research, which is concerned with the means to increase data richness with regards to the social processes surrounding a problem under investigation (Van Maanen, 1979). According to Nachmias and Nachmias (1996), this method uses inductive reasoning to allow the researcher to generate theories. Consequently, the researcher poses questions rather than hypothesis, and the data are in the form of words. Bryman (1988) indicated that qualitative research is usually to provide in-depth insights about the phenomenon investigation.

While qualitative methods present a dynamic view of social life, quantitative methods provide a static account (Bryman, 1988). Therefore, triangulation, which combines both qualitative and quantitative methods, is able to overcome any deficiencies that might occur from either method (Denzin, 1978). Bryman (1989) suggests that social scientists are likely to show greater confidence in their findings when they are the product of more than one method of investigation. According to Denzin (1978), the integration of data collection methods in a single study opens up enormous opportunities for shared advantages in each of the major stages of design, data collection, and analysis. In addition, more information can be gathered and a new style of investigation can be developed from the marriage of two or more methods. Jick (1979) argues that more than one method should be used in the validation process to ensure that any variance reflected is that of the trait and not of the method. Therefore, convergence or agreement between two methods enhances the belief that the results are valid because of double testing. For example, since the quantitative method tests only the variables that it made enquiry into, this will make it difficult to find any unexpected relationships in the research. Since the research can achieve a closer relationship with the subject or informant through the qualitative method, this will allow more space for discovering factors that might not have been taken into account beforehand.

4.3 Research Framework

Triangulation of quantitative and qualitative methods was conducted in this study. As stated earlier, this study seeks to gain insight into determining factors for warehouse location selection in the humanitarian relief logistics, about which very little are known. This section briefly introduces the stages that the author took for the research. The detailed research method will be described in the next section.

The framework adopted in this study is essentially *the sequential approach* that was described by Mangan *et al.* (2004), who used both qualitative and quantitative methods are applied at different stages of the research. The findings of one stage are further refined to be used in the following stage. A similar framework is employed in this study. Silverman (2006) suggested that there could be three different ways of mixing quantitative and qualitative research. Firstly, using qualitative research to explore a particular topic in order to set up a quantitative study. For example, if you are designing a questionnaire on racial prejudice, it may be useful to begin by holding semi-structured interviews with community leaders and police officers together with focus groups composed of members of different ethnic communities. Secondly, beginning with a quantitative study in order to establish a simple of respondents and to establish the broad contours of the field. Qualitative research can then be used to look in depth at a key issue using some of the earlier sample. Thirdly, engaging in a qualitative study which uses quantitative data to locate the results in a broader context.

The research framework is summarised in Table 4.3. The first approach to combining methods as described above has been used in the current study. The qualitative method (i.e. a semi-structured interview with supply managers and officers) was employed in an exploratory stage in order to get a better understanding of the key issues of the determining factors for warehouse location selection in humanitarian relief logistics.

Table 4.3 Summary of the study framework

Stages	Research Questions	Methods	Findings
Stage One	- Humanitarian warehouse selection attributes (Q1)	- Literature Review - Exploratory Survey	- Identifying the major attributes for the warehouse selection - Priorities among the attributes being studied
Stage Two	- Regional and specific site determinant attributes in humanitarian warehouse selection (Q2, Q4) - Warehouse location sites for regional and specific site determinants (Q3, Q5)	- Two case studies with humanitarian relief organisations	- Identified the warehouse determinant for regional and specific site - Identified the optimal warehouse candidate locations - Hierarchical structure of the attributes being identified
Stage Three	- Priorities and weights of the attributes for warehouse location (Q2, Q4) - Humanitarian warehouse optimal location (Q3, Q5)	- Descriptive survey research	- Identifying the priorities among the factors - Priorities of the attributes are identified - Optimal warehouse location(s) is identified

Source: Author

The quantitative method (i.e. questionnaire survey) was used in this study to collect descriptive or explanatory data to seek the preferences of the factors used for the warehouse location selection and to evaluate the optimal warehouse sites. The combination of this method is expected to be an effective way to triangulate data collected by a questionnaire survey, which prevents delimiting the scope of the research by only using one research method. Further details about the research methodology are provided in relevant chapters.

Stage One:

- **Literature Review:** This sub-stage was the initial starting point of the study. An extensive review of literature on commercial warehouse selection and humanitarian pre-positioned warehouse was conducted. The use of key words when searching for literature helped to reduce time, as described by Bouma and Atkinson (1995). Keywords were very useful in narrowing the search efforts, namely: “pre-positioning”, “humanitarian”, “warehouse selection”, “MCDM”, “MADM”, “AHP”, and “TOPSIS”. Different sources were used during the literature review sub-stage, but mainly:

i. *On-Line Journal Databases:* These were primary sources of information mainly because of these of search and their wide coverage of databases. The main databases used for literature review were: ABI Inform/Proquest, Emerald Library and EBSCO Business Source Premier. The search included academic journals, professional magazines and industrial reports.

ii. *Cardiff University Library:* The library provided access to a large stock of books, academic journals and professional publications.

iii. *On-line Search:* An internet search provided an overview of different issues, nevertheless unlike journal information; data available on the internet is less creditable.

Although the literature review was more general when it started, a more focused literature review was undertaken during this stage. In particular, high-level academic journals (such as *International Journal of Production Economics, Expert Systems with Applications,* and *International Journal of Physical Distribution and Logistics Management*) were reviewed. The main goal of this specific literature review was to identify the determining factors used for warehouse selection which have been cited to date (especially in humanitarian relief logistics) and to find suitable research methods. The literature review resulted in identifying the suitable multi-criteria decision making research method for analysing the optimal site selection, which was conducted to further examine the strengths and weaknesses of the various research methods.

- **Exploratory Survey:** The determining factors for selection of the warehouse locations and the priorities of those factors have been used as the basis for the next research step of Case Study A and B. The author established contacts with supply chain managers and officers in a humanitarian organisation that operates pre-positioning warehouse strategy. The author conducted face-to-face and telephone interviews. Electronic mail and video calls were made to confirm the factors that were that were identified and the respondents were asked to give their opinions on the priorities of their warehouse strategy. Additionally, data obtained from the survey were refined and used for the case study survey conducted later in the research process. Further details about the exploratory survey are mentioned in the next section and its results can be found in Chapter 5.

Stage Two:

In order to gain further insights into international humanitarian organisations' pre-positioning warehouse strategy, the author undertook two case studies of the optimal warehouse selection with its own determining factors. The author conducted the cases during a two month internship in International Humanitarian Organisation A and other humanitarian organisations that are based in Dubai.

- **Case Study A:** The researcher undertook a case study of an international humanitarian organisation in order to gain more insight into regional (i.e. macro) determinant warehouse positioning strategy. This is an organisation that mainly operates with refugee related relief matters but which also becomes involved with providing relief of natural disasters. The humanitarian warehouse determining factors were studied with the managerial level decision-makers in the headquarters and in the field. The author participated in the weekly meetings and daily operational meetings in the organisation as an intern. The interviews were conducted with the senior and junior officers in order to verify the factors and to prioritise the factors that are used for their organisation. In addition, the study of optimal location for warehouse selection was conducted to see whether their decisions of locating the current warehouse locations were suitable.

- **Case Study B:** The second case study was conducted to seek the specific site determining attributes that were used in the humanitarian organisations based in Dubai, UAE. The author participated in a project where the international organisations were seeking to relocate the warehouse location for their operation. The alternative locations were identified with the determining factors that were used to access the locations.

Stage Three:

In this stage, the researcher employed a descriptive survey based on the outputs of the second stage in order to determine the extent of the weights/prioritisation, preferences, and to solve the location selection problem for the optimal site selection. Regional determinant attributes were evaluated for Case Study A and specific site attributes for humanitarian organisations based on Dubai, UAE were identified and analysed. A group decision-making technique of the decision-making level managers are adapted to identify the alternative warehouse location and to determine the hierarchical structure of the factors that were identified in second stage of the research. Combinations of AHP and TOPSIS was employed to analyse the survey data; these are both qualitative and quantitative analysis methods. Fuzzy set theory is adapted to ensure more robust results for the warehouse selection. Fuzzy set theory is used in many decision making problems because it deals with vagueness of human thought (Zadeh, 1965). Sensitivity analysis were carried out for getting accurate results. The idea of sensitivity analysis is to exchange each criterion's weight with another criterion's weight (Önut *et al.* 2010). The detailed calculations of the use of AHP, TOPSIS, and fuzzy set theory are explained in next sections.

4.3.1 Semi-Structured Interview

This section is divided into two categories: the first category is the justification for choosing a semi-structured interview and the second describes the sampling and administration of the interview.

1) Selection of the semi-structured interview

Depending on the level of formality and structure, interviews can either be: structured interviews; semi-structured interviews; and unstructured or in-depth interviews (Saunders *et al.* 2007). A structured interview employs a standardised set of questions that have an emphasis on fixed response categories. It uses systematic sampling and loading procedures combined with quantitative measures and statistical methods (Ghauri and Grønhaug, 2002). This method is highly likely to be straightforward and provides precise and reliable data. Unlike the other two qualitative interview techniques (i.e. the semi-structured interview and unstructured interview) which rely on the use of a questionnaire. The interviewer for structured interviews should be neutral and should ask identical questions in the same way to avoid any variations. Since the same questions are asked to all interviewees, the interview can be replicated and standardised. Most of all, this will allow the interviewer to contact a large number of people in an economical way. Nonetheless, if the sample size is too large it can become time consuming and the quality of data will depend highly upon the questions. Consequently, a considerable amount of time is required to prepare the questions. In addition, the interviewer cannot supplement additional questions, which makes it difficult to examine more complex issues further. However, there is a natural limit to answering questions in any depth.

In a semi-structured interview the interviewer generally has a framework of theme to be explored and prepares a formalised and limited set of questions on specific topics, which are often referred to as an interview guide (Bryman, 2008). This method is more flexible and conversational than a structured interview in that it allows new questions to be brought up as a result of the interviewee's response during the interview (Saunders *et al.* 2007). The questions may not follow on exactly in the way outlined on the guide and the interviewer can ask them in different ways from interviewee to interviewee; however, a similar wording will be used throughout all of the interviews (Ghauri and Grønhaug, 2002). Although the interviewer may encourage and facilitate the interviewees to discuss their own points of view and experiences, they would not personally become involved. The context of the interview is a key aspect of the process in comparison to a structured interview, which is assumed to elicit information untainted by the context of the interview (May, 1993). The interviewer is able to gain both factual information and the personal experiences of a particular domain from the interviewees' perspective and, therefore, this will produce rich and detailed data. The prepared themes and questions will make the interviews with a number of different persons more systematic and comprehensive, and they will also make the data more comparable. However, this technique can be time consuming, not only in terms of collecting the data but also in analysing it. The flexible wording and order of questions may result in substantial differences between different interviewees; consequently, making comparison difficult. In addition, the interviewer could influence the interviewee by suggesting leading questions. In order to prevent these problems, the interviewer needs to be trained to avoid asking leading or perspective questions.

An unstructured interview is a method of interview where the respondent is given almost full liberty to discuss behaviours, opinions and reactions on particular topics (Ghauri and

Grønhaug, 2002). This method aims to investigate the subjective interpretations and understanding of social phenomena in an exploratory manner and also seeks to generate data which probes deeper into the lives of the interviewees. It emphasises the interviewees' world-view and its process tends to be more flexible than a structured interview. Although there is no need to prepare specific questions, the interviewer should have a clear idea about the aspects that they wish to explore. In this case, the interviewer's ontological assumption is that people's knowledge, views and understandings are meaningful properties of the social reality that the research questions are designed to explore. The epistemological assumption is that it is important to have a conversation interactively with interviewees and to analyse their use of language and construction of discourse (Rubin and Rubin, 2005). This philosophical perspective will guide the way that the interview is conducted and how the data is analysed. In structured interviews, the interviewer can elicit a more accurate and clear picture from an interviewee's position because the questions to be asked are not leading questions. Unlike structured interviews, the questions of unstructured interviews can give valuable information which had not been discovered before the interview. Consequently, the interviewer could go further into a new topic and enrich the data beyond the answers alone. However, it should be noted that these questions can take much more time and the interviewee response could be affected by the interviewer. In order to overcome these weaknesses, leading questions and any non-verbal gestures which indicate any bias should be avoided. The findings from these questions may not be generalised because usually only a small number of people can be interviewed in a specific context; however, the results are not necessarily intended to be generalised since they reflect the reality and may be subject to change (Saunders *et al.* 2000). To analyse the data from unstructured interviews, grounded analysis which tends to offer a more open approach and is closely linked to the concept of grounded theory (Easterby-Smith *et al.* 2002).

By considering the characteristics of each interview type, as well as the purpose of the interview, the semi-structured interview technique was selected for use in the current study. The qualitative interview is more flexible and conversational than quantitative methods in that it allows new questions to be brought up as a result of the interviewee's response during the interview. A semi-structured interview may be used in relation to both an exploratory and explanatory study. In the current study, it was used in order to explore the research issues from the managerial level of decision making process from the humanitarian relief organisations because of the lack of previous studies on this topic. Specifically, the objectives of the interviews are: firstly, to better understand the application of the pre-positioning strategy for the humanitarian relief organisation broadly; secondly, to verify the attributes of determining factors for the pre-positioning warehouse location selection problem and their priorities; and thirdly, to identify the unforeseen issues and opinions of operating or planning the pre-positioning warehouse strategy for humanitarian relief supply chain. In the interviews the logistics officers and managers (who actually have the influence in decision making process of the pre-positioning warehouse location selection problem) participated to give the opinion of the different pre-positioning supply chain strategies, the determining factors for location selection, and their priorities of the factors.

2) Sampling and administration of the interview

It is as vital to sample appropriately for qualitative research as it is for quantitative research because getting data on a whole population is impossible and also because different designs are better at producing representative samples for different research objectives and populations. Among the different sampling techniques, purposive sampling and snowball sampling were deemed to be the best way to acquire data for this interview. Purposive sampling allows the researchers to use their judgement to select cases based on the knowledge and experience of a researcher. In snowball sampling, the researcher contacts a small number of people initially and then uses these to establish contacts with other people (Saunders *et al.* 2007).

Table 4.4 shows the information on the participants in the semi-structured interviews that have been conducted in the present study. The interviews were conducted in almost every region around the world because of the unique characteristics of the warehouse locations scattered around the world (as discussed in Chapter 2). They were conducted in Africa (i.e. Sudan, Uganda, and Zimbabwe), America (i.e. Canada, Panama, and United States of America), Asia (i.e. China, Iraq, Korea, Nepal, Philippines, and UAE), and Europe (i.e. Norway and United Kingdom) over two months in June and August 2010. Some of the respondents were first asked to participate in the interview by face-to-face, email or telephone.

Table 4.4 Participants in the semi-structured interviews conducted in June and August 2010

No.	Participant	Position	Method	Location operating base
1	United Nations 1	Senior Supply Officer	Face-to-Face	UAE
2	United Nations 2	Senior Supply Officer	Face-to-Face	UAE
3	United Nations 3	Logistics Officer	Email	Iraq
4	United Nations 4	Supply Officer	Email	Philippines
5	United Nations 5	General Manager	Email	Panama
6	United Nations 6	Logistics Manager	Email	Canada
7	United Nations 7	Fund Manager	Email	Ethiopia
8	United Nations 8	Supply Division Officer	Telephone	China
9	Int'l NGOs 1	Logistician	Face-to-Face	Korea
10	Int'l NGOs 2	Associate Supply-Chain Director	Face-to-Face	United Kingdom
11	Int'l NGOs 3	Supply and Logistics Manager	Email	Ireland
12	Int'l NGOs 4	Supply and Logistics Manager	Email	Zimbabwe
13	Int'l NGOs 5	Logistician	Email	Nepal
14	Int'l NGOs 6	Logistician	Email	Uganda
15	Int'l NGOs 7	Logistics Manager	Email	USA
16	Int'l NGOs 8	Senior Logistics Officer	Email	Zimbabwe
17	Int'l NGOs 9	Logistician	Email	Norway
18	Int'l NGOs 10	Logistician	Email	Zimbabwe
19	National NGOs 1	Logistician	Face-to-Face	Korea
20	National NGOs 2	Logistics Manager	Face-to-Face	Korea
21	National NGOs 3	Logistics Manager	Face-to-Face	Korea
22	National NGOs 4	Logistician	Email	Uganda
23	National NGOs 5	Logistician	Email	Zimbabwe
24	Governmental	Assistant Administrator	Face-to-Face	Korea
25	Governmental	Counsellor	Email	Sudan

Source: Author

Most of the participants replied through email where they were based in remote countries from the researcher or when they were not able to spare the time for telephone interview. During the interviews, other potential interviewees were suggested by the initial participants. Even though the characteristics of these organisations varies depending on whether they are NGOs, international organisation or government support organisations, they are all posted in the managerial level of their organisation that have influence in decision making process. This demonstrates that they have sufficient knowledge of this industry. Eight of the respondents were interviewed using the face-to-face method, one was interviewed on the telephone, and sixteen were interviewed via email due to the physical remoteness. A total of twenty-five people participated in the interviews. Most of them are logistics related managers that worked in the field and only a few were general and administration managers.

Brief information was provided before conducting interviews concerning the subject area to which the research relates, the purpose of the research, and the reason why they were asked to participate, as well as the anticipated benefits of the research. The date for the interview was then decided. Those respondents who were physically remote from the researcher kindly accepted the email version of the questions and replied back. To maintain the confidentially and anonymity of participants, private information about the participants has been removed and their personal identifiers have been changed into code (for example United Nations 1 and International NGOs). Debriefing took place immediately after the interview in order to ensure clarity between the interviewer and interviewee. The interview method and the contents of questions were examined by the Research Ethics Committee of Cardiff Business School in advance (see Appendix A.3). Each interview was conducted separately and had different durations. However, thanks to the supportive attitude of the respondents, most interviews lasted more than an hour. With the interviewees' permission, the interviews were recorded and noted. This record was transcribed shortly after the interview. The interview questions were prepared in advance in order to guide the interviewee during the interview (see Appendix A.1). There were eight main questions that were commonly asked in the interview. On the basis of the feedback from the interviewee, the flow of questions was adjusted but the sequence of the sections tended to be kept because this can play important role in the success of the interview.

4.3.2 AHP and TOPSIS Survey Design

The survey was designed after reviewing the literature on humanitarian pre-positioning warehouse selection problem and through the results that resulted from the exploratory studies. Two different sets of survey questions (including the AHP and TOPSIS) were constructed for two different case studies. The first survey questions mainly deal with the macro perspective approach (i.e. regional determinant attributes) of the humanitarian pre-positioning warehouse location selection problem in refugee related humanitarian relief organisation. The second survey mainly deals with a micro perspective approach (i.e. specific site determinant attributes) of the warehouse location selection problem for humanitarian relief organisations in Dubai, UAE. The first question survey for both case studies consists of five major criteria which propose to find the priorities (preferences) and their weights. Each of the major criteria has a list of sub-criteria preference measurements. The alternative site locations were selected to determine the optimal warehouse location in the following process for both cases. The detailed background of the case study will be introduced in Chapter 6.

Major considerations when designing questions are their content, structure, format and sequence (Nachmias and Nachmias, 1996). The questions in the present study were designed in a manner to help respondents complete the questionnaire thoughtfully but not at high cost of time and effort. Generally, the first survey consisted of sixty-five questions for preference measurement with five alternative warehouse locations that were set by the management level officers of the International Humanitarian Organisation A. AHP is used for preference measurement and TOPSIS is incorporated with fuzzy theory in order to find the alternative warehouse locations. In the second survey, ninety-two questions were asked for preference measurements for five alternative warehouse locations.

Bourque and Fielder (1995) advise that motivation is important when using a survey to collect data, motivation. Consequently, in this study a covering letter was attached with the survey to establish the credentials of the author and to encourage responses as well as to minimise the problem of a low response. The letter was prepared by the author and signed by both of his supervisors. The letter stated the general purpose and objectives of the study and encouraged respondents' cooperation by promising an executive copy of the study findings. Most importantly, the survey was designed to signal to the respondents the fact that the research project was important and would be undertaken professionally. The inside cover of the survey booklet contained a note to the respondents that explained the significance of the research and thanked them in advance for their cooperation. The survey respondents were encouraged to return the survey even if the survey questions were not completed in full. The author collected the data by all face-to-face interview with the officers stationed in Dubai, UAE while the author worked as an intern with International Humanitarian Organisation A.

4.4 Data Analysis Method

The empirical analysis for the current study aims to examine the preference of choice of the regional and specific site determining factors for the humanitarian pre-positioning warehouse selection of International Humanitarian Organisation A and International Humanitarian City (IHC) based in Dubai. This research further analyses the optimal selection of the warehouse site. There are several possible techniques to assist with this kind of analysis in the MCDM location problem. For example, comparing the usefulness of each technique (i.e. AHP and

TOPSIS) is a well-known technique for solving location problems (see, for example, Farahani *et al.* 2010). AHP and TOPSIS are also incorporated with each other to solve the location problem which have been used by many researchers. In addition, fuzzy set theory is applied to incorporate unquantifiable information, incomplete information, non-obtainable information, and partially ignorant facts into the decision model (Kulak *et al.* 2005). In this section, a brief introduction of the various research methods used in MCDM will be introduced, then the fundamental of AHP and TOPSIS are discussed along with the fuzzy set theory. Following this, the key issue related to their applications is considered. The procedural steps in incorporated AHP-TOPSIS are then briefly explained to demonstrate the AHP-TOPSIS practice adopted in the present study. The results of the empirical analysis will be provided in Chapters 7 and 8.

4.4.1 Fundamentals of AHP

One of the most outstanding MCDM approaches is the AHP (Saaty, 1980), which has its roots in obtaining the relative weights among the factors and the total values of each alternative based on these weights (Torfi *et al.* 2010). In comparison with other MCDM methods, the AHP method has widely been used in MCDM and it has been applied successfully in many practical decision-making problems (Alphonce 1997; Saaty, 1988). AHP, developed by Saaty (1980), addresses how to determine the relative importance of a set of activities in a multi-criteria decision problem. AHP has its roots in obtaining the relative weights among the factors and the total values of each alternative based on these weights (Torfi *et al.* 2010). The AHP makes it possible to incorporate judgments on intangible qualitative criteria alongside tangible quantitative criteria (Badri 2001). The AHP method is based on three principles:

1. Structure of the model;
2. Comparative judgment of the alternatives and the criteria; and,
3. Synthesis of the priorities (Amiri 2010).

The AHP uses procedures for deriving the weights and the scores achieved by alternatives which are based on pairwise comparisons between criteria and between options (DCLG, 2009; Rangone, 1996). The AHP technique was chosen in this study to analyse the location decision problem since this methodology is particularly effective for multi-attribute decision that involve both tangible and intangible factors (Alberto, 2000).

4.4.1.1 Strengths and Weaknesses of AHP

There are certain strengths for using the AHP location decision method. For example, the users generally find the pairwise comparison form of data input straightforward and convenient (Yoon and Hwang, 1995). The great advantage of the AHP lies in its ability to handle complex real life problems and in its ease of use (Alphonce, 1997). Narasimhan (1983) and Alberto (2000) identified advantages of using the AHP. Firstly, it is versatile, which is proved by its wide range of applications. Recent applications have extended the use of AHP to forecasting due to the fact that the AHP also allows judgments about the relative likelihood of events to be made. Secondly, its formal structuring of a problem allows complex decisions to be decomposed into sets of simpler judgments and provides a documented rationale for the choice of a particular option. Thirdly, it is simple because the use of pairwise comparisons implies that the decision-maker can focus, in turn, on each small part of the problem.

Another advantage of using AHP is that it results in better communication, leading to a clearer understanding and consensus among members of decision-making groups so that they are likely to become more committed to the alternatives selected (Harker and Vargas, 1987). AHP also has the ability to identify and take into consideration the decision maker’s personal inconsistencies. Decision-makers are rarely consistent in their judgements with respect to qualitative aspects. The AHP method incorporates such inconsistencies into the model and provides the decision maker with a measure of these inconsistencies (Alphonce, 1997).

On the other hand, since the AHP was first introduced there has been widespread criticism of its empirical effectiveness and theoretical validity (Belton and Gear, 1983; Dyer, 1990a, 1990b), including:

· *The axiomatic foundation:* The clarity and intuitive meaning of the axioms, that is the set of rules which are intended to provide the basis for rational decision-making, are not founded on testable descriptions of rational behaviour. Saaty (1980) has given a sound but incomplete axiomatic foundation for the AHP because it focuses mostly on paired comparisons among alternatives within criteria while the interdependence between alternatives and criteria and among criteria across levels remains ambiguous.

· *Inconsistencies imposed by scale of 1 – 9:* This problem has been overcome in this study by introducing the consistency index.

· *The rank reversal problem due to addition or deletion of alternatives:* The rank reversal problem arises from the way in which the AHP normalises the weights to sum to 1.

Lai (1995) demonstrated that the rank reversal problem in AHP results from the addition or deletion of alternatives and is caused by multiplying inappropriate criteria priorities with local priorities for alternatives. The author has, therefore, introduced a new scaling method in this study which is able to treat judgments from pairwise comparisons among criteria into values scales. A new integrated approach is, therefore, made available, which combines the main advantages of the data collection and treatment of the AHP with the axiomatic foundation and the elimination of the rank reversal problem. It has been shown that the rank reversal will not be a troublesome issue in real world applications because it is very rare to encounter two alternatives with very similar characteristics. In addition, special precautions (e.g. grouping similar alternatives) can easily be taken to avoid any rank reversal (Saaty, 1994b). Saaty (1994a) further argued that the AHP avoids the rank reversal by dealing directly with paired comparisons of the priority of importance, preference, or likelihood of pairs of elements in the decision hierarchy that is just the natural method that people follow in making actual decisions. Specifically, three steps have been identified in terms of ranking preservation (Saaty, 1994a):

1. Allow rank to reverse by using the distributive model of the relative measurement;
2. Preserve rank by using the ideal mode (in case of irrelevant alternatives); and,
3. Preserve rank absolutely by using the absolute measurement mode.

4.4.1.2 AHP Analysis Procedures

The AHP procedure involves six essential steps (Lee *et al.* 2009), which are:

(1) Defining the unstructured problem;

(2) Developing the AHP hierarchy;

(3) Pairwise comparison;

(4) Estimating the relative weights;

(5) Checking the consistency; and,

(6) Obtaining the overall rating.

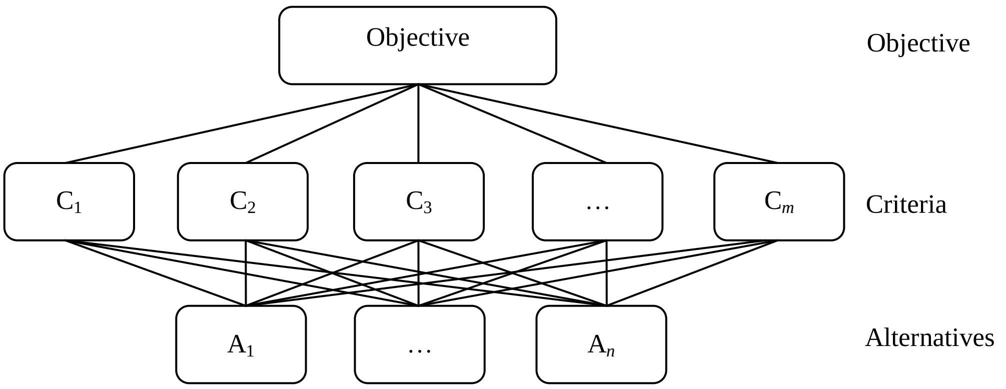
(1) Define the unstructured problem

In this step the unstructured problem and its characteristics should be recognised and the objectives and outcomes stated clearly (Moshen *et al.* 2010).

(2) Developing the AHP hierarchy

The first step in the AHP procedure is to decompose the decision problem into a hierarchy that consists of the most important elements of the decision problem, as illustrated below in Figure 4.3:

Figure 4.3 Hierarchical structure of the decision problem



Source: Moshen *et al.* (2010)

AHP initially breaks down a complex multi-criteria decision-making problem into a hierarchy of interrelated decision criteria, decision alternatives. A hierarchy has at least three levels: overall goal of the problem at the top, multiple criteria that define alternatives in the middle and decision alternatives at the bottom (Albayrak and Erensal 2004; Amiri, 2010). Figure 4.3 represents the structure of AHP.

(3) Pairwise comparison

Once the problem has been decomposed and the hierarchy is constructed, the prioritisation procedure starts in order to determine the relative importance of the criteria within each level. The pairwise judgment starts from the second level and finishes in the lowest level. In each level, the criteria are compared pairwise according to their levels of influence and based on the specified criteria in the higher level (Albayrak and Ersensal 2004). In AHP, multiple pairwise comparisons are based on a standardised comparison scale of nine levels (Table 4.5).

Table 4.5 Nine-point intensity important scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the aim fulfilment
3	Moderate importance	The experience and the judgement favour slightly to an activity
5	Strong importance	The experience and the judgement favour strongly to an activity
7	Very strong importance	An activity is more favoured that other one; its predominance was demonstrated in the practice
9	Extreme importance	The evidence favours an activity absolutely and clearly
2, 4, 6, 8	Intermediate values between adjacent scale values	When the parts need a commitment between adjacent values
Reciprocals	If the activity *i* has a number that is different of zero when this is compared with the activity *j*, then *j* has a reciprocal value when it is compared with ($a_{ij} = 1/a_{ji}$)	

Source: Saaty (1980)

Let C = {c_j | j = 1, 2, …. , *n*} be the set of criteria. The result of the pairwise comparison on *n* criteria can be summarised in an (*n_n*) evaluation matrix *A* in which every element a_{ij} (*ij* = 1, 2, …. , *n*) is the quotient of weights of the criteria, as shown below:

$$A = \begin{pmatrix} a_{11} & \cdots & a_{12} & \cdots & a_{1n} \\ \vdots & & \vdots & & \vdots \\ a_{21} & \cdots & a_{22} & \cdots & a_{2n} \\ \vdots & & \vdots & & \vdots \\ a_{n1} & \cdots & a_{n2} & \cdots & a_{nn} \end{pmatrix} \qquad a_{ii} = 1,\ a_{ji} = 1/a_{ij},\ a_{ij} \neq 0.$$

(4) Estimating the relative weights

In this step, the mathematical process commences to normalize and find the relative weights for each matrix. The relative weights are given by the right eigenvector (*w*) corresponding to the largest Eigen value (λ_{max}) as:

$$A_w = \lambda_{max} w.$$

(5) Consistency checking

If the pairwise comparisons are completely consistent then the matrix *A* has rank 1 and $\lambda_{max} = n$. In this case, weights can be obtained by normalising any of the rows or columns of *A* (Wang and Yang 2007). AHP must meet the requirement that matrix *A* is consistent. The consistency is defined by the relation between the entries of *A*: $a_{ij} \times a_{jk} = a_{ik}$. The Consistency Index (CI) is:

$$CI = (\lambda_{max} - n)/(n - 1).$$

The final Consistency Ratio (CR), the usage which lets someone to conclude whether the evaluations are sufficiently consistent, is calculated as the ratio of the CI and the Random Index (RI), as indicated. Table 4.6 shows the random inconsistency index for matrices of the order from 1 to 10 (Saaty and Kearns 1985).

$$CR = CI/RI.$$

Table 4.6 Random inconsistency indices

No. of Criteria	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: Saaty and Keams (1985)

Generally, if CR is less than 0.1 then the judgments are considered to be consistent; therefore, the weights are consistent and can be used in the ranking process (Saaty, 1980). If the final consistency ratio exceeds this value, the evaluation procedure has to be repeated to improve consistency (Saaty 1980). The measurement of consistency can be used to evaluate the consistency of decision-maker as well as the consistency of overall hierarchy (Wang and Yang 2007).

(6) Obtaining the overall rating

In the last step the relative weights of the decision elements are aggregated to obtain an overall rating for the alternatives (Moshen *et al.* 2010), as follows:

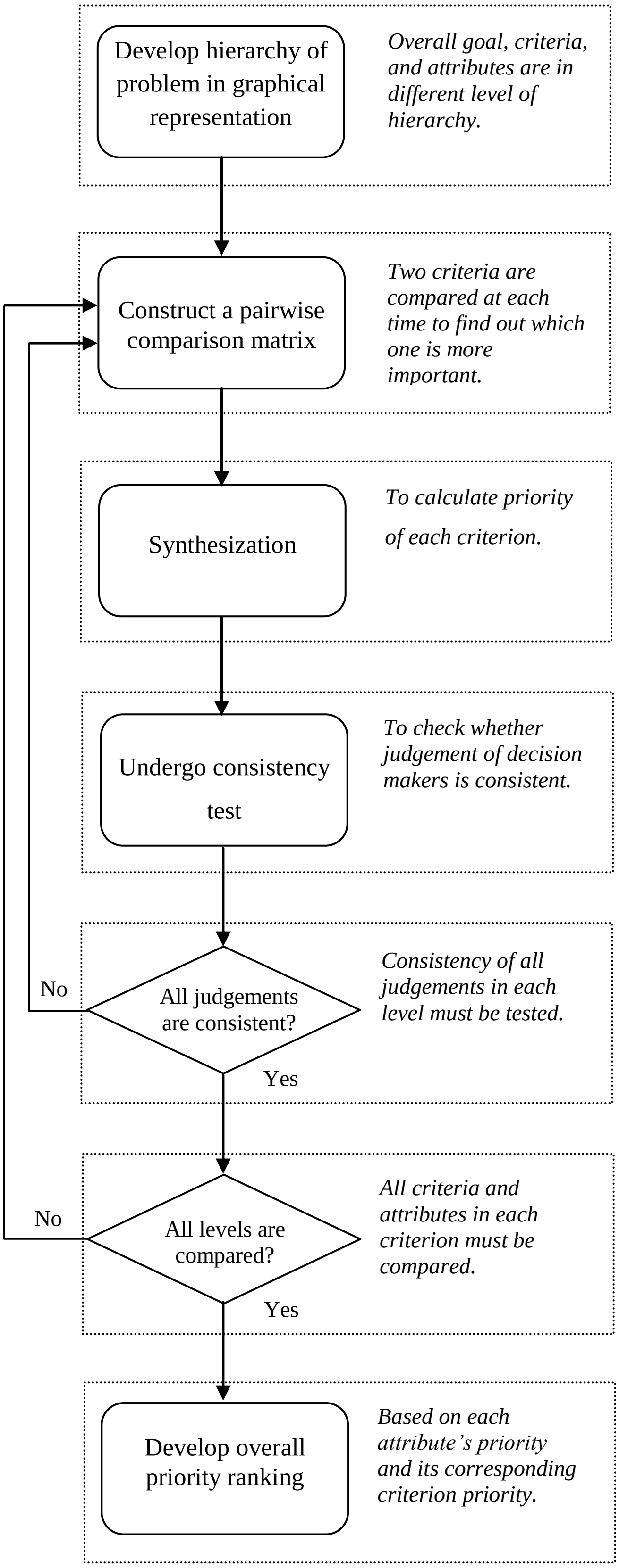
$$W_i^s = \sum_{j=1}^{m} W_{ij}^s \; W_j^a \quad (i = 1, 2, \ldots, m)$$

Where is the total weights of alternative *i*; W_{ij}^s the weight of alternative *i* associated to attribute *j*; W_j^a the weight of the attribute *j*; *m* the number of attributes and *n* the number of alternatives.

4.4.1.3 AHP Flowchart

For greater clarity, Figure 4.4 shows the flowchart of the AHP procedure that was explained by Ho *et al.* (2006). The AHP consists of three main operations, including hierarchy construction, priority analysis, and consistency verification. Firstly, the decision makers need to break down complex multiple criteria decision problems into its component parts. Every possible attribute is then arranged into multiple hierarchical levels. The decision-makers must then compare each cluster in the same level in a pairwise fashion based on their own experience and knowledge. For instance, every two criteria in the second level are compared at each time with respect to the goal, whereas every two attributes of the same criteria in the third level are compared at a time with respect to the corresponding criterion. Since the comparisons are carried out through personal or subjective judgements, some degree of inconsistency may occur. To guarantee that the judgements are consistent, the final operation is called consistency verification. This is regarded as one of the most advantages of the AHP and is incorporated in order to measure the degree of consistency among the pairwise comparisons by computing the consistency ratio. If it is found that the consistency ratio exceeds its limit, the decision makers should review and revise the pairwise comparisons. Once all pairwise comparisons are carried out at every level, and are proved to be consistent, the judgements can then be synthesised to find out the priority ranking of each criterion and its attributes.

Figure 4.4 The flowchart of AHP



Source: Ho *et al.* (2006)

4.4.1.4 Group decision-making in the AHP

The increasing complexity of socio-economic environments makes it less and less possible for decision-makers to consider all of the relevant aspects of a problem. Consequently, many organisations employ groups in 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 MADM analysis.

The AHP allows group decision-making, where a group of decision-makers can 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. Once the group is satisfied with the problem structure, pairwise comparisons are elicited for each level of the hierarchy in order to obtain the weights for each level with respect to one element in the next highest level in the hierarchy (Harker and Vargas, 1987).

The problem of group decision-making with MADM shares some common characteristics, which are outlined below (Kim and Ahn, 1997):

1. *Multi-criteria/objectives/alternatives:* The decision-makers may share some, none or all of the criteria/objectives/alternatives.
2. *Conflict among criteria:* Multi-criteria usually conflict with each other. For example, in designing a car, the objective of low fuel consumption might reduce the passengers' comfort by providing less space.
3. *Committee:* A group of decision-makers whose decisions agree with certain rules that further their interests.
4. *Alternatives:* There are finite numbers of decision alternatives that each group of decision-makers wants to choose from.

Where the individual preference judgements of the group of decision-makers are available, or can be collected, a method of combining or aggregating the opinions is required. Two of the models that have been found to be the most useful to aggregate information when more than one (perhaps many) individuals participate in a decision process, are: firstly, the collection of each separate individual's hierarchies and aggregation of the resulting weight values (Kim and Ahn, 1997; Forman and Peniwati, 1998; Bolloju, 2001), namely "aggregating individual weight values" (Forman and Peniwati, 1998; Zahir, 1999); or secondly, the compilation of the pairwise comparison matrices at each level of a hierarchy, by aggregating all the decision-makers individual judgements (Bolloju, 2001), namely "aggregating individual judgements" (Forman and Peniwati, 1998; Zahir, 1999).

There are two main methods for generating group priorities with the AHP. The first is the geometric mean method that was introduced by Saaty (1989). The second is the arithmetic mean for synthesising the individual judgements, for a single-issue problem that this results in efficient decision-making (Ramanathan and Ganesh, 1995).

The advantage of using the geometric mean method for generating the elements of the matrix is that it preserves the reciprocal property n of the combined pairwise comparison matrix, as is shown by Aczel and Saaty (1983), and Chwolka and Raith (2001). However, the geometric mean method has the disadvantage of not automatically guaranteeing Pareto optimality when there are more than two levels in the decision hierarchy (Chwolka and Raith, 2001). It is well known that the arithmetic mean method generates a Pareto optimal agreement for one issue, independent of the specific weights attached to the individual preferences (*ibid.*). Both the geometric mean method and the arithmetic mean method (Aczel and Saaty, 1983) are also widely used to determine group judgement by aggregating individual priorities for ratio scale measurements (Forman and Peniwati, 1998; Bolloju, 2001). Saaty (1989) suggest the method of taking the geometric mean of the individual judgements in order to obtain a group judgement for each pairwise comparison over the elements in the matrix.

4.4.2 Fundamentals of TOPSIS

Hwang and Yoon (1981) proposed the TOPSIS as an approach for dealing with complex systems related to making a preferred choice among several alternatives and which provides a comparison of the considered options. This technique is based on the concept that an alternative to be evaluated by n attributes can be represented as a point in n-dimensional space. Geometrical relationships can be constructed among m points (locations). The ideal alternative will have the best values for all attributes considered, while the negative-ideal will have the worst attribute values. TOPSIS defines solutions as the points which are simultaneously farthest from the negative-ideal point and closest to the ideal point (Chu, 2002b). According to the theory, the best alternative should have two features: the first is nearest to PIS while the second is farthest from the NIS (Ertuğrul and Karakaşoğlu 2007; Hsieh *et al.* 2006; Lin *et al*. 2008).

4.4.2.1 Strength and Weakness of TOPSIS

According to Kim *et al.* (1997) and Shih *et al.* (2007), the advantages of TOPSIS are:

(1) A sound logic that represents the rationale of human choice;
(2) A scalar value that accounts for both the best and worst alternatives simultaneously;
(3) A simple computation process that can be easily programmed into a spreadsheet; and,
(4) The performance measures of all alternatives on attributes can be visualised on a polyhedron, at least for any two dimensions.

These advantages make TOPSIS a major MADM technique as compared with other related techniques, such as AHP and ELECTRE (Shih *et al.* 2007). In fact TOPSIS is a utility-based method that compares each alternative directly depending on data in the evaluation matrices and weights (Cheng *et al.* 2002). According to the simulation comparison from Zanakis *et al.* (1998), TOPSIS has the fewest rank reversals among the methods used for their research. Therefore, TOPSIS is chosen as the main body of development.

The major weaknesses of TOPSIS are in not providing for weight elicitation and consistency checking for judgements (Özcan *et al.* 2011). However, AHP's employment has been significantly restrained by the human capacity for information processing and, therefore, the number seven plus or minus two would be the ceiling in comparison (Saaty and Ozdemir, 2003). From this viewpoint, TOPSIS alleviates the requirement of paired comparisons and the capacity limitation might not significantly dominate the process (Shih *et al.* 2007). Yoon and Hwang (1985) applied the TOPSIS technique to select the optimal alternative location for manufacturing plantj. However, the measurement of weights and use of qualitative attributes did not account for the uncertainty associated with human judgement. Moreover, the evaluation data of the facility location under different subjective attributes and the weights of the attributes are often expressed linguistically (Liang and Wang, 1991), making the application of fuzzy set theory necessary to reflect the uncertainty in human cognitive process when using TOPSIS to evaluate facility location selection problems (Chu, 2002a). The detail procedure of fuzzy set theory will be introduced in the next section.

4.4.2.2 TOPSIS Analysis Procedure

For the current study, the TOPSIS process approach suggested by Shyur and Shih (2006) is applied to the data analysis and the procedures are shown as follows:

Step 1: Construct a decision matrix.

If the count of criteria is n and the number of alterative is m, decision matrix with m rows and n columns will be obtained as following:

Table 4.7 A typical multiple attribute decision problem

	Criterion 1	Criterion 2	…	Criterion *j*	...	Criterion *n*
Alternative 1	f_{11}	f_{12}	…	f_{1j}	…	f_{1n}
Alternative 2	f_{21}	f_{22}	…	f_{2j}	…	f_{2n}
…	…	…	…	…	…	…
Alternative *i*	f_{i1}	f_{i2}	…	fij	…	f_{in}
…	…	…	…	…	…	…
Alternative *m*	f_{m1}	f_{m2}	…	f_{mj}	…	f_{mm}

In the Table 4.7, f_{ij} (i = 1, 2 … m; j = 1, 2 … n) is a value indicating the performance rating of each alternative ith with respect to each criterion jth.

Step 2: Calculate the normalized decision matrix.

The normalised value f_{ij} is calculated as:

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{n} f_{ij}^2}} \qquad i = 1, 2, \dots m; \quad j = 1, 2, \dots n.$$

Step 3: Calculate the weighted normalised decision matrix.

The matrix is from multiplying the normalized decision matrix by its associated weights as:

$$v_{ij} = w_j * r_{ij} \qquad i = 1, 2 \dots m; \quad j = 1, 2 \dots n,$$

Where w_j is the weight of the jth attribute of criterion, and $\sum_{j=1}^{n} w_j = 1$.

Step 4: Determine the positive-ideal and negative-ideal solutions.

$$A^* = \{v_1^*,\ v_2^*, \dots,\ v_2^*\} = \{(\max_j v_{ij} | i \in I'), (\min_j v_{ij} | i \in I'')\}$$

$$i = 1, 2 \dots m; \quad j = 1, 2 \dots n,$$

$$A^- = \{v_1^-,\ v_2^-, \dots,\ v_2^-\} = \{(\min_j v_{ij} | i \in I'), (\max_j v_{ij} | i \in I'')\}$$

$$i = 1, 2 \dots m; \quad j = 1, 2 \dots n,$$

Where I' is associated with positive factors, and I'' is associated with negative factors.

Step 5: Calculation of the distance of all alternatives (possible improvements) to the positive-ideal solution (D_i^*) and the negative-ideal solution (D_i^-).

$$D_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}, \qquad i = 1, \dots, m.$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, \qquad i = 1, \dots, m.$$

Step 6: Calculate the relative closeness of each alternative to the ideal solution and conducting the outranking of alternatives (improvement) in descending order. The relative closeness of the alternative A_i with respect to the A^* can be expressed as:

$$CC_i = \frac{D_i^-}{D_i^* + D_i^-}$$

Step 7: Rank the preference order. The index value of CC_i lies between 0 and 1. The larger the index value CC_i is, the better the alternative A_i is.

4.4.2.3 AHP and TOPSIS Comparison

The comparative analysis between AHP and TOPSIS location decision problem is shown in Table 4.8.

Table 4.8 Comparison of characteristics between AHP and TOPSIS

	Characteristics	AHP	TOPSIS
1	Category	Cardinal information, information on attribute, MADM	Cardinal information, information on attribute, MADM
2	Core process	Creating hierarchical structure Pairwise comparison (cardinal ratio measurement)	The distance from PIS and NIS (cardinal absolute measurement)
3	Attribute	Given	Given
4	Weight elicitation	Pairwise comparison	Given
5	Consistency check	Provided	None
6	No. of attributes accommodated	7 ±2 or hierarchical decomposition	Many more
7	Number and type of outranking relations	N (N -1) / 2	1
8	Problem structure	Little number of alternative and criteria, quantitative or qualitative data	Large number of alternative and criteria, objective and quantitative data
9	Others	Compensatory operation	Compensatory operation

Source: Ertuğrul (2010), Hwang and Yoon (1981), Özcan *et al.* (2011), Saaty (1990), Saaty and Ozdemir (2003), Shih *et al.* (2007).

The core (main) process: Decision making methodologies are separated from each other through different calculation methods. The steps are separative from other decision making methods and important in the solution algorithm are named as the core process (Özcan *et al.*, 2011). The core process in AHP is to create hierarchy and pairwise comparison matrices in all the levels of hierarchy (Saaty, 1980). In the TOPSIS method the calculation of each alternative distance from the positive ideal and the negative ideal solution draws attention.

The methodology of determining the weight of criteria: In multi-criteria decision making methodologies, for the rank among the alternatives and the determination of their preferences, the necessity is to determine the relative importance of criteria reveals (Özcan *et al.* 2011). AHP and TOPSIS methods are required to measure the relative importance of criteria in the solution of the decision problem. In the determination of the weight of criteria the AHP methodology puts forward a specific method while the TOPSIS suggest a solution which determines the importance of the decision maker based on the number of criteria. AHP presents a specific method which separates from the TOPSIS method using pairwise comparison matrix in order to determine the importance of criteria (Saaty, 1980). However, pairwise comparison matrices, the 1 – 9 scale, and the limitation caused by this principle are important disadvantages of the AHP (Özcan *et al.* 2011). For example, if *A* criterion is five times more important than *B* criterion and *B* criterion is five times more important than *C* criterion, the condition that *A* criterion is twenty-five times more important than *C* criterion cannot be explained with AHP. However, this problem has been solved by introducing the CI that was discussed in the earlier section. The TOPSIS methodology does not put forward a specific method about weight determination where in some decision making problems criterion weights are given without using any calculation (Özcan *et al.* 2011). On the other hand, while determining the weight in TOPSIS, linear and vector normalisations are commonly used (Shih *et al.* 2007).

The type and number of outranking relationship: In AHP, all of the factors in the all the levels of hierarchy are paired and then compared. Therefore, the pairwise comparison number determining the outranking relations in an *N*-dimensional comparison matrix is $N\ (N - 1)/2$. An important disadvantage of the AHP is that the number of pairwise comparison matrix can be too many. In addition, in situations when there are a large number of alternatives and criteria, the opportunity of carrying out the methodology is substantially curtailed (Özcan *et al.* 2011). Meanwhile, a TOPSIS methodology needs less input compared to AHP and it can eliminate the necessity of comparisons of pairs. Only one outranking relation is put forward while evaluating the criteria and alternatives in TOPSIS (Özcan *et al.* 2011).

The control of consistency: It is important to be able to measure the consistency of the judgements of the decision makers. In AHP, the consistency of judgements and decision maker while creating pairwise comparison matrices is measured through calculating the CI (Saaty, 1980). While the limitation of consistency is one of the most important advantages of AHP (Özcan *et al.* 2011), the consistency is not controlled in TOPSIS.

Problem structure: The selection of the correct methodology related to the structure decision making problems is important for the decision maker. The AHP is preferred in situations when the decision making problem can be dissociated as criteria, sub-criteria and alternatives, and the effect of each subject is demanded for measurement (Özcan *et al.* 2011). Furthermore, since it is necessary to make pairwise comparisons in all the levels of hierarchy, it becomes harder to perform AHP as the number of alternatives increases (Özcan *et al.* 2011). On the other hand, AHP can be performed easily by disregarding the data applying evaluation of alternatives based on whether the criteria are quantitative or qualitative. TOPSIS draws attention because of its simplicity in perception and use (Ertuğrul, 2010). In addition, TOPSIS can be performed easily when the number of alternatives and criteria is too large (Chu, 2002b; Özcan *et al.* 2011). In addition, these methods are more suitable in cases when the data is provided as objective and quantitative (Kuo *et al.* 2007; Özcan *et al.* 2011).

Final results: Global and net ranking is attained among alternatives for both methodologies (Özcan *et al.* 2011).

4.4.3 Fuzzy Set Theory

Fuzzy set theory is composed of an organised body of mathematical tools that are particularly well-suited for handling incomplete information and the un-sharpness of classes of objects or situations in a flexible way (Chiclana *et al.* 1998; Dubois and Prade, 2000). It offers a unifying framework for modelling various types of information, ranging from precise numerical, interval-valued data, to linguistic knowledge with a stress on semantics. The fuzzy linguistic approach has produced significant results in the modelling of qualitative information (Delgado *et al.* 1997). The fuzzy linguistic approach is an approximate technique which represents qualitative aspects as linguistic values by means of linguistic variables; that is, variables whose values are not numbers but words or sentences.

Zadeh (1965) defined a fuzzy set as ‘a class of objects with a continuum of grades of membership’. In other words, a set is described as fuzzy if there is no sharp boundary between those elements (or objects) which belong to the associated class and those which do not (Bellman and Zadeh, 1970). A crisp set allows only full membership or no membership at all, whereas fuzzy sets allow for partial membership.

4.4.3.1 Mathematics of Fuzzy Numbers

The concept of fuzzy numbers is contained in the theory of fuzzy sets. Fuzzy numbers are used to describe variables that are uncertain. A fuzzy number represents a range of possible values instead of the single (precise or discrete) value that a crisp number represents. Each possible value in the fuzzy number range has a possibility level (also called a confidence level or a presumption level) or belief attached to it (Kaufmann and Gupta, 1991). This section will examine the fundamental concept of a fuzzy number and the algebraic operations on fuzzy numbers. The principle functions in the fuzzy logic are illustrated in Appendix D.6.

Linear functions: These functions express their belonging to the set by means of a function of degree one. They are used in evaluation models to evaluate distances, and percentages. The triangular and trapezoidal functions are an extension of the linear functions. These functions are used to define intervals of temperature, and distance.

The *triangular* function is defined by the lower limit a, the modal value m and the top limit b. The *trapezoidal* functions have the top limit d, the lower limit a, and the support limits b and c.

Gamma functions: These functions have a rapid growth from a. This growth will be bigger if the value of k increases.

S functions: These functions are defined by its lower limit a and its top limit b, and by its inflection point m.

Gaussian functions: The average value m and the value k ($k > 0$) defined these functions, it is the Gauss bell. If k increases the bell will be narrower.

Pseudo-exponential functions: These functions are defined by average value m and the value k, $k > 1$. As the Gaussian function, if k increases the bell will be narrower

4.4.3.2 Algebraic Operations on Fuzzy Numbers

The normal algebraic operations such as addition, subtraction, multiplication, and division can be extended to fuzzy numbers, which are based on the extension principle (Zadeh, 1965).

The extension principle states that examination of the similarities and differences between the realm of crisp sets and that of fuzzy sets naturally leads to the consideration that in order to develop computation with fuzzy sets it is necessary to find a way to take traditional, crisp functions and fuzzify them. A principle for fuzzifying crisp functions is called the extension principle (Klir *et al.* 1997). The extension principle is one of the most basic ideas in fuzzy set theory (Zadeh, 1965). It provides a method for extending non-fuzzy mathematical operations to deal with fuzzy sets and fuzzy numbers.

Fuzzy operations do not necessarily possess the usual properties of commutativity associativity, and distributivity that characterise their non-fuzzy counterparts. The rules for conducting many fuzzy operations differ for positive and negative fuzzy numbers (Cummins and Derrig, 1997). The extension principle can be systematically applied to real algebra and to the operation of fuzzy numbers (Dubois and Prade, 1980).

Although membership functions of have variety of possibility for the representation of fuzzy numbers, the most common are trapezoidal and triangular shapes. In applications it is often convenient to work with Triangular Fuzzy Numbers (TFNs) because of their computational simplicity (Giachetti and Young, 1997; Abdel-Kader and Dugdale, 2001; Moon and Kang, 2001). They are also useful in promoting representation and information-processing in a fuzzy environment (Liang and Wang, 2003). TFNs are used most in the Fuzzy-TOPSIS location selection problems (Awasthi *et al.* 2011; Boran, 2011; Chu, 2002a; Ekmekçiouğlu *et al.* 2010; Ertuğrul, 2010; Fernandez and Ruiz, 2009; Gligorić *et al.* 2010; Karimi *et al.* 2010; Kuo *et al.* 2007; Liao, 2009; Önut *et al.* 2010; Önut and Soner, 2008; Yong, 2006). This thesis will adopt TFNs in the fuzzy-TOPSIS.

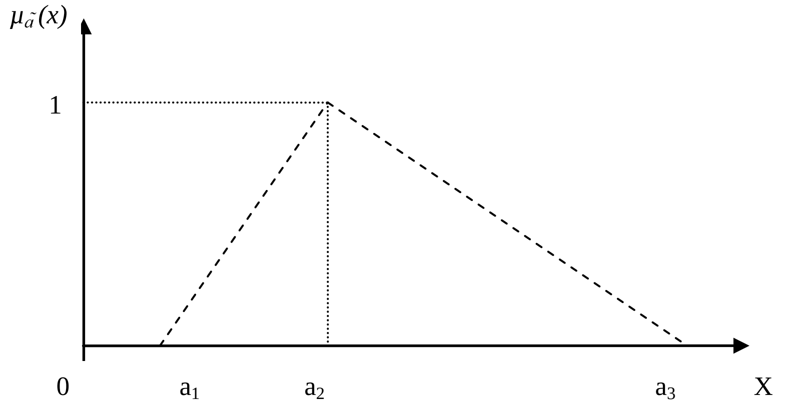
The definition of fuzzy sets using triangular function are discussed and presented in many papers (Buckley 1985, Chen *et al.* 2006, Kaufmann and Gupta 1985, Yang and Hung 2007, Yu *et al.* 2011, Zadeh 1965, Zimmermann 1991). Two definitions are given below:

Definition 1. A fuzzy set $\tilde{A}$ in a universe of discourse X is characterised by a membership function $\mu_{\tilde{a}}(x)$. It connects with each element x in X, a real number in the interval [0,1]. The function value $\mu_a(x)$ is termed the grade of membership of x in $\tilde{A}$.

A triangular fuzzy number $\tilde{A}$ can be defined by a triplet (a_1, a_2, a_3), where a_3 is greater than a_2 and a_2 is greater than a_1. Mathematical form of triangular fuzzy is displayed in the following equation and Figure 4.5 (Yu *et al*. 2011).

Figure 4.5 Triangular fuzzy numbers

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



Source: Yu *et al.* (2011)

Definition 2. Suppose $a = (a_1, a_2, a_3)$ and $b = (b_1, b_2, b_3)$ are two TFNs, the distance between them is calculated as follows:

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

The operational laws of these two TFNs are shown in Table 4.9.

Table 4.9 Operational laws of these two triangular fuzzy numbers

Operational law	Expression
Addition	$a + b = (a_1, a_2, a_3) + (b_1, b_2, b_3) = (a_1 + b_1, a_2 + b_2, a_3 + b_3)$
Subtraction	$a - b = (a_1, a_2, a_3) - (b_1, b_2, b_3) = (a_1 - b_3, a_2 - b_2, a_3 - b_1)$
Multiplication	$a \times b = (a_1, a_2, a_3) \times (b_1, b_2, b_3) = (a_1 \times b_1, a_2 \times b_2, a_3 \times b_3)$
Division	$a \div b = (a_1, a_2, a_3) \div (b_1, b_2, b_3) = (a_1 \div b_3, a_2 \div b_2, a_3 \div b_1)$
Inverse	$a^{-1} = (a_1, a_2, a_3)^{-1} = (\frac{1}{a_3}, \frac{1}{a_2}, \frac{1}{a_1})$

4.4.3.3 Exposition of Linguistic Variables

The concept of linguistic variables is very useful in dealing with situations which are too complex or too ill-defined to be reasonably described in conventional quantitative expressions (Zadeh, 1975). The idea behind this is to allow verbal inputs into a decision problem. This is then to convert these into fuzzy sets that can be manipulated according to fuzzy sets operations. The output is then converted back into verbal form (Zadeh, 1973). The linguistic means for characterising complex or ill-defined phenomena. Zadeh (1973) states that:

> *By moving away from the use of quantified variables and toward the use of a type of linguistic description employed by humans, we acquire a capability to deal with systems which are much too complex to be susceptible to analysis in conventional mathematical terms.*

The main applications of the linguistic approach lies in the realm of humanistic systems, especially in the fields of artificial intelligence, linguistics human decision process, pattern recognition, psychology, law, medical diagnosis, information retrieval, economics and related areas (Zadeh, 1975; Herrera and Martinez, 2000).

As noted in the literature, a key benefit of fuzzy set theory analysis is its ability to describe human subjective judgements, which are expressed in linguistic terms. In brief, the linguistic approach is appropriate for many problems, since it allows a representation of the information in a more direct and adequate way when we are unable to express it with precision (Delgado *et al*. 1997). Fuzzy set theory can provide a good result in the modelling of qualitative information (*ibid*.). Therefore, this section deals with the concept of a linguistic variable whose values are fuzzy variables and the connection between linguistics statements and their representation in fuzzy set theory and then the computational of linguistic variables will be discussed.

A linguistic variable is a variable whose values are words or sentences in a natural or artificial language. Since words, in general, are less precise than numbers, the concept of a linguistic variable serves the purpose of providing a means of approximate characterisation of phenomena which are too complex or tool ill-defined to be amenable to description in conventional quantitative terms. More specifically, the fuzzy sets which represent the restrictions associated with the values of a linguistic variable may be viewed as summaries of various subclasses of elements in a universe of discourse. This is analogous to the role played by words and sentences in a natural language. For example, the adjective *beautiful* is a summary of a complex of characteristics of the appearance of an individual. It may also be viewed as a label for a fuzzy set which represents a restriction imposed by a fuzzy variable named *beautiful*. From this point of view, then, the terms *very beautiful*, *not beautiful, extremely beautiful*, and *quite beautiful* are means of fuzzy sets which result from operating on the fuzzy set named *beautiful* with the modifiers named *very, not, extremely*, and *quite*. In effect, these fuzzy sets, together with the fuzzy set labelled *beautiful*, play the role of values of the linguistic variable *appearance* (Zadeh, 1975).

When a problem is solved using linguistic information, it implies the need for computing with words. The use of the fuzzy linguistic approach (Zadeh, 1975) has provided very good results (Herrera and Martinez, 2000). It deals with qualitative aspects that are represented in qualitative terms by mans of linguistic variables.

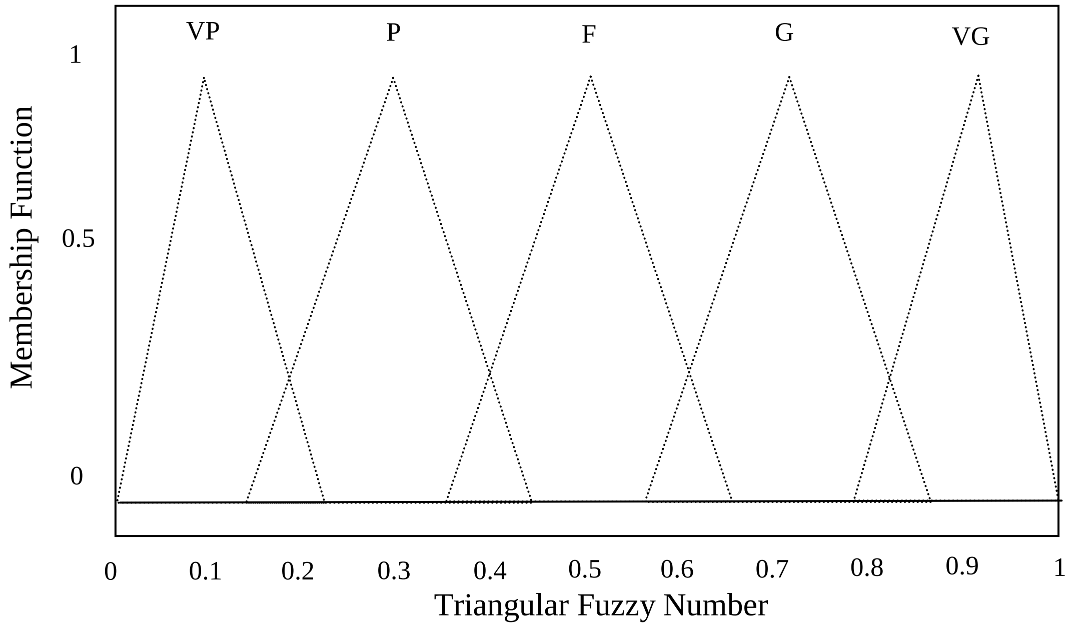
Many aspects of different activities in the real world cannot be assessed in a quantitative form, they can only be assessed in a qualitative form (i.e., with vague or imprecise knowledge) (Herrera and Martinez, 2000). Consequently, it may be better to use linguistic assessments instead of numerical values (*ibid.*). Attempts to qualify phenomena related to human perception have often led to the study of the use of words in natural language (Torfi *et al.* 2010). The use of linguistic assessments implies the use of computations to study them. Foundations and applications providing the current status of theoretical and empirical developments in computing with words can be found in Zadeh and Kacprzyk (1999). The semantics of these linguistic expressions are given by fuzzy numbers, which are described by membership functions (Herrera *et al*. 2001).

Experts use linguistic variables to evaluate the importance of the criteria and to rate the alternatives (Torfi *et al.* 2010). The present study has adopted the transformation for fuzzy membership functions of Torfi *et al.* (2010) because it uses only precise values for the performance ratings and for the criteria weights. In order to illustrate the idea of fuzzy TOPSIS, the author has deliberately transformed the existing precise values to five levels, which are: fuzzy linguistic variables very poor (VP), poor (P), fair (F), good (G), and very good (VG). The purpose of the transformation process is to illustrate the proposed Fuzzy TOPSIS method (Torfi *et al*. 2010).

Among the commonly used fuzzy numbers, triangular and trapezoidal fuzzy numbers are likely to be the adoptive numbers due to their simplicity in modelling and their ease of interpretation (Torfi *et al.* 2010). Both triangular and trapezoidal fuzzy numbers are applicable to the present study. It can be assumed that a triangular fuzzy number can adequately represent the five-level fuzzy linguistic variables; therefore, they are used for the analysis hereafter.

Based on the research study of Torfi *et al.* (2010), as a rule of thumb, each rank is assigned an evenly spread membership function that has in interval of 0.30 or 0.25. Based on these assumptions, a transformation figure can be found as illustrated in Figure 4.6, which shows the relationship between linguistic ratings and triangular fuzzy numbers for five sub-criteria grades (Torfi *et al*. 2010; Yang and Hung, 2007). For example, the fuzzy variable very poor has its associated triangular fuzzy number with the minimum of 0.00 mode of 0.10 and maximum of 0.25. The same definition is then applied to another fuzzy variable poor, fair, good and very good.

Figure 4.6 Fuzzy triangular membership functions



KEY: VP – Very Poor, P – Poor, F – Fair, G – Good, VG – Very Good

Source: Yang and Hung (2007)

4.4.4 Fuzzy Set Theory Procedure in TOPSIS

The general procedure for making location decisions usually consists of the following steps (Stevenson, 1993)

1. Decide on the criteria that will be used to evaluate location alternatives;
2. Identify factors that are important;
3. Develop location alternatives; and,
4. Evaluate the alternatives and make a selection.

The conventional approaches for facility location problems (e.g. locational cost volume analysis, factor rating, and centre of gravity method (Stevenson, 1993) tend to be less effective in dealing with the imprecise or vague nature of the linguistic assessment (Ertuğrul, 2010). In multi-criteria problems, data are very often imprecise and fuzzy (Ekmekçioğlu *et al.* 2010). In decision-making practice, individual preferences are often expressed by way of linguistic terms which reflect imprecise values (Ertuğrul, 2010). In addition, the experts' preferences are uncertain and they are reluctant or unable to make numerical comparisons (Torfi *et al.* 2010). Consequently, precise mathematical models are not able to tackle such decision situations. To deal with the fuzziness of decision makers' preferences in decision-making, fuzzy group decision making approaches have been proposed (Zhang and Lu, 2003) because they are a powerful tool for decision-making in a fuzzy environment (Torfi *et al.* 2010). Classical decision-making methods work only with exact and ordinary data, so there is no place for fuzzy and vague data (Torfi *et al*., 2010). Humans have a good ability for qualitative data processing, which helps them to make decisions in a fuzzy environment (Torfi *et al.* 2010).

Although TOPSIS is very popular to solve MCDM problems, there are some defects to this approach. For example, in many real applications it is difficult to handle ambiguous and vague issues and mathematical models cannot cope with decision-makers' ambiguities, uncertainties and vagueness (Chan and Kumar, 2007). A better approach may be to use a linguistic value rather than numerical value, which means that the ratings and weights of the criteria in the problem are evaluated by linguistic variables (Farahani *et al.* 2010, Yu *et al.* 2011). Linguistic values can deal with ambiguities, uncertainties, and vagueness and, therefore, fuzzy sets theory can be used to present linguistic value, which allows the decision-makers to incorporate unquantifiable information, incomplete information, non-obtainable information, and partially ignorant facts into decision model (Kulak *et al.* 2005). Consequently, fuzzy TOPSIS is proposed to solve ranking and evaluating problems (Ashtiani *et al.* 2009, Jahanshahloo *et al.* 2006, Wang and Elhag 2006, Wang and Lee 2009).

Decision makers use the linguistic variable to evaluate the importance of the criteria and to rate the alternatives with respect to various criteria. The merit of using a fuzzy approach is to assign the relative importance of attributes using fuzzy values rather than mathematical values in which criteria or their weights are inaccurate (Farahani *et al.* 2010, Yu *et al.* 2011).

The concept of applying fuzzy numbers to TOPSIS was first suggested by Negi (1989). The current study develops a fuzzy TOPSIS model under group decisions for selecting facility location, where the ratings of various alternative locations under different subjective attributes are assessed in linguistic values represented by fuzzy numbers. To ensure compatibility with the linguistic ratings of the subjective attributes, the objective attributes are transformed into a comparable scale.

Fuzzy-TOPSIS can be outlined as follows (Yu *et al.* 2011):

Step 1: Choose the linguistic values (x_{ij}; i = 1, 2 … *m*; *j* = 1, 2 … *n*) for alternatives with respect to criteria.

The fuzzy linguistic rating x_{ij} preserves the property that the ranges of normalised triangular fuzzy numbers belong to [0, 1], which is applied after the normalised scale.

Step 2: Construct the weighted normalised fuzzy decision matrix. The weighted normalised value v_{ij} is calculated as:

$$v_{ij} = x_{ij} \times w_{ij} \qquad i = 1, 2 \ldots m; \qquad j = 1, 2 \ldots n,$$

Where w_j can be obtained from AHP (Wang and Yang, 2007).

Step 3: Identify positive-ideal (A^*) and negative-ideal (A^-) solutions.

The fuzzy positive-ideal solution (FPIS, A^*) and the fuzzy negative-ideal solution (FNIS, A^-) are demonstrated in the following equations:

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

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

Where I' is associated with positive factors, and I'' is associated with negative factors.

Step 4: Calculate the distance of each alternative from A^* and A^- using the following equations.

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

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

Step 5: Calculate similarities to ideal solution by the following equations.

$$CC_{\mathrm{i}} = \frac{D_i^-}{D_i^* + D_i^-}$$

Step 6: Rank order.

Rank alternatives according to CC_{i} in descending order.

4.4.5 Motivation to Integrate AHP-TOPSIS

The location decision problem is both a MCDM problem where many criteria should be considered in decision-making, and a problem containing subjectivity, uncertainty and ambiguity in assessment process (Dagdeviren *et al.* 2009). Therefore, in this study AHP, fuzzy sets, and TOPSIS are combined to rank the optimal pre-positioned warehouses location for humanitarian organisation which utilises AHP to acquire criteria weights, fuzzy sets to describe vagueness with linguistic values and triangular fuzzy number, and TOPSIS is used to obtain the final ranking order of the pre-positioned warehouses (Önut *et al.* 2010). This approach was employed for four reasons: firstly, TOPSIS logic is rational and understandable; secondly, the computation processes are straight forward; thirdly, the concept permits the pursuit of best alternatives for each criterion depicted in a simple mathematical form; and fourthly, the importance weights are incorporated into the comparison procedures (Wang and Chang, 2007). TOPSIS can combined with other research tools, especially with AHP, because the AHP is used to acquire criteria weights and TOPSIS is used to obtain the final suitable ranking order of the alternative locations (Amiri 2010, Dagdeviren *et al.* 2009, Önut *et al.* 2010, Wang and Chang 2007). Hsieh *et al.* (2006) justified the use of TOPSIS after AHP and argued that it can avoid the predicament that the units under evaluation are of the same value and cannot be appropriately ranked (Joshi *et al.* 2011). Joshi *et al.* (2011) explained the approach of the use of AHP-TOPSIS integrated method.

4.4.6 Proposed Method

The proposed model for the humanitarian warehouse location selection problem, composed of AHP and fuzzy TOPSIS methods, consists of three basic stages:

1. Identify the criteria to be used in the model;
2. Identify the AHP computations; and,
3. Evaluate the alternatives with fuzzy-TOPSIS and determine the final rank (Amiri 2010, Yu *et al*. 2011).

A schematic diagram of the proposed model for the integration of AHP and fuzzy TOPSIS for humanitarian pre-positioning warehouse selection problem for the current study is provided in Figure 4.7. The stages of the integration of AHP-TOPSIS are in parallel to that of the analysis process of AHP and TOPSIS that were explained earlier.

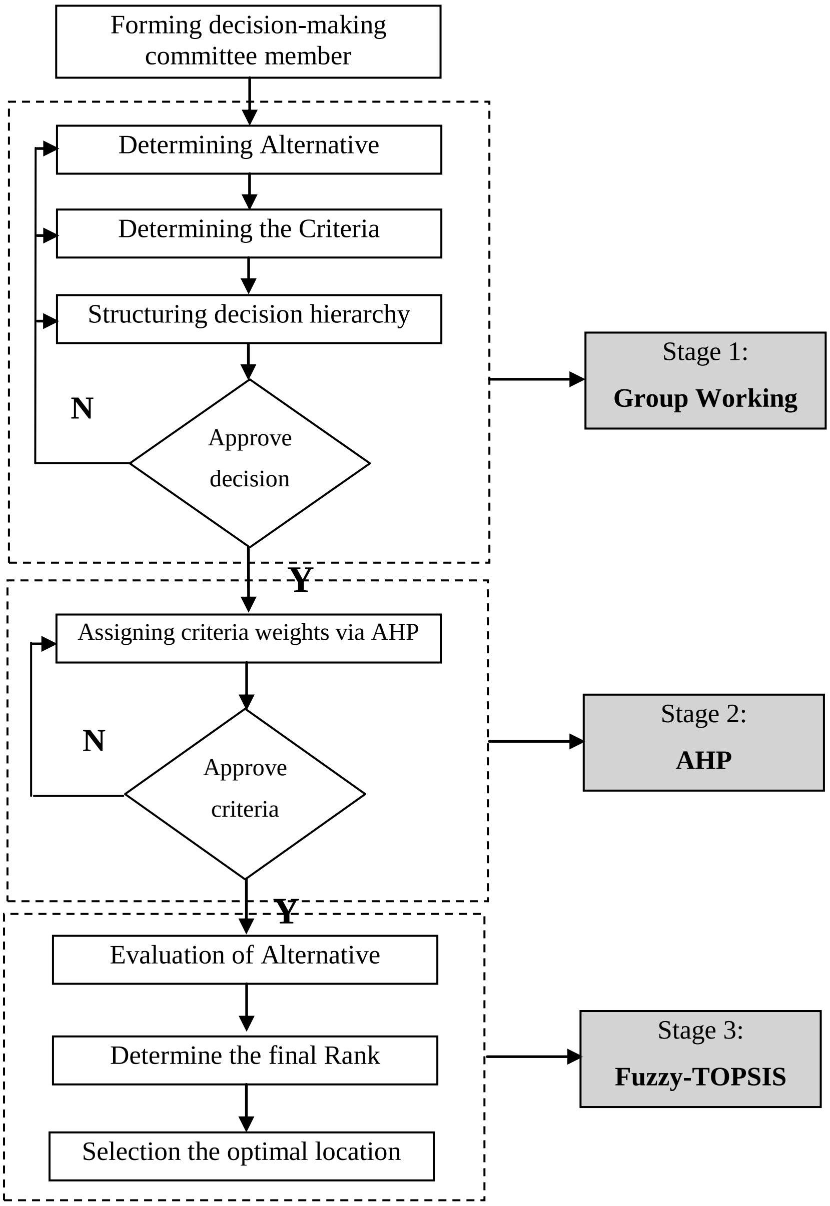
Stage 1:

In the first stages, alternative location and the criteria which will be used for the evaluation are determined and the decision hierarchy is formed. The main goal in this stage is the identification of the criteria. The AHP model is structured so that objective is in the first level, criteria are in the second level and alternative locations are on the third level. In the last step of the first stage, the decision hierarchy is approved by the decision-making team. Site selection is usually a team effort, and AHP is one available method for forming a systematic framework for group interaction and group decision-making (Saaty, 1980). The group decision-making method is widely adapted in the studies of AHP-TOPSIS studies where the participants are in the managerial level and have better insights of the problem and have actual influence in the decision making process (Amiri, 2010; Kuo *et al.* 2007). This process is repeated until the decision-makers finally approve the hierarchical structure of the decision criteria.

Stage 2:

After the approval of decision hierarchy, criteria used in selection projects are assigned weights using AHP in the second stage. In this stage, pairwise matrixes are formed to determine the criteria weights. The officers from decision-making team make individual evaluations using the scale provided in Table 4.5 to determine the values of the elements of pairwise comparison matrixes. Computing the geometric mean of the values obtained from individual evaluations, a final pairwise comparison matrix on which there is a consensus is found. Geometric means of these values are found to avoid error and to obtain the pairwise comparison matrix on which there is a consensus (Saaty, 1980).

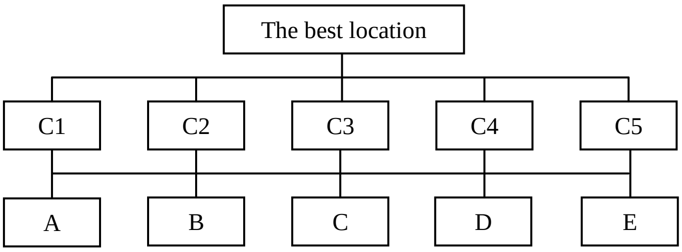
Figure 4.7 Schematic diagram of the proposed model for selection



Source: Amiri (2010) and Yu *et al*. (2011)

When the consistency ratio is below 0.1, the judgement would be used in the ranking process because it is regarded as consistent (*ibid*). The measurement of consistency can be used to evaluate the consistency of decision-maker as well as the consistency of overall hierarchy (Wang and Yang, 2007). If the final consistency ration exceeds this value then the evaluation procedure has to be repeated to improve consistency (Saaty, 1980). Decision hierarchy structured with the determined alternative locations and criteria is provided in Figure 4.8.

Figure 4.8 Example of visual representation for an optimal warehouse selection



Source: Author

Stage 3:

In the last step of this phase, calculated weights of the criteria are approved by decision-making-making team and they were asked to build the decision matrix by comparing the alternatives. To deal with the fuzziness of decision makers' preferences in decision–making, fuzzy group decision making approaches have been proposed (Zhang and Lu, 2003). Ranking the alternative location is determined by using fuzzy TOPSIS in the third phase. Linguistic ratings are used for evaluation of the locations. The alternative warehouse selection having the maximum relative closes to ideal solution (CC_i) values is determined as the optimal location according to the calculations by TOPSIS. Ranking of the other alternative location is determined according to CC_i in descending order schematic.

One of the limitations of the framework can be viewed as the subjectivity of the rating and the evaluation standard of the measuring system. Sensitivity analysis addresses this issue of variation in judgment from person to person or for the same person over time. Since the selection of the best alternative depends upon the pairwise comparison of factors set by experts, a thorough sensitivity analysis is important to foresee the impact of changes in these in comprehensible way. Sensitivity analysis sees the robustness of proposed framework due to variation in the expert's opinion in assigning the influence during comparison (Bottero and Ferretti, 2011).

After obtaining a ranking of the alternatives and despite the coherence obtained in the results, it was considered useful to perform a sensitivity analysis on the final outcome of the model to test its robustness. In addition, sensitivity analysis was conducted to analyse the manner of the warehouse sites under different criteria weights. The sensitivity analysis is concerned with a 'what if' kind of question to see if the final answer is stable when the inputs, which can be either judgements or priorities, are changed (Bottero and Ferretti, 2011; Min, 1994). It is of particular interest to see whether these changes modify the order of the alternatives. The idea of sensitivity analysis is to exchange each criterion's weight with another criterion's weight with each combination stated as a condition. Sensitivity analysis allows a composite view of the analysis to be developed by providing overall priority to changes in the significance of each criterion relative to others. Meanwhile, sensitivity analysis demonstrates the evaluation to obtain more rationality (Kuo, 2011) and allows accurate results to be achieved (Önut *et al.* 2010). The testing of the sensitivity analysis is widely used in AHP-TOPSIS warehouse location selection problems (Awasthi *et al.* 2011; Badri, 1999; Bottero and Ferretti, 2011; Ekmekcioglu *et al.* 2010; Gumus, 2009; Kuo and Liang, 2011; Önut and Soner, 2008; Önut *et al.* 2010).

4.5 Chapter Summary

This chapter has described the methodology that is used in this study. The theoretical approach to the research methodology has been described. The research design adopted in the study is a similar to the location selection solving problem with the combination of AHP-TOPSIS (Amiri 2000; Yu *et al.* 2011). This research is based on three stages, each of which was illustrated and discussed. In addition, this chapter described the concepts of fundamental fuzzy sets in order to understand the methodology used for TOPSIS. It includes the basic concepts of classical sets, fuzzy sets, fuzzy numbers and linguistic variables, and demonstrated the operation of TFNs. The extension principle based on Zadeh (1975) has also been discussed. Three key mathematical concepts have been emphasized, they are: fuzzy numbers, the operation s of TFNs and linguistics variables. These concepts will be used in order to apply the fuzzy TOPSIS to group decision-making. Since the evaluation data of the facility location under different subjective attributes and the weights of the attributes are often expressed linguistically (Liang and Wang, 1991), this makes the application of fuzzy set theory necessary to reflect the uncertainty in human cognitive process when using TOPSIS to evaluate facility location selection problems (Chu, 2002a).

CHAPTER 5
EXPLORATORY STUDY OF HUMANITARIAN RELIEF PRE-POSITIONED WAREHOUSES

5.1 Chapter Overview

This chapter will outline the exploratory survey, which was conducted with the supply managers of several humanitarian organisations. The aim was to provide further information concerning their priorities during the decision-making process in locating pre-positioning warehouses. This study also investigates the reasons for operating the pre-positioning warehouse strategy and the difficulties that are encountered with various types of pre-positioning.

5.2 An Exploratory Study on Humanitarian Relief Pre-positioning Strategy

The author attempted to search for the determining attributes for humanitarian warehouse location selection through an exploratory study. Logistics managers in twenty-five different international humanitarian organisations were contacted for the exploratory study. Several reasons were behind the use of this approach. Firstly, the author wanted the sample to show experience of a pre-positioning strategy within their organisations (i.e. whether their organisation operates pre-positioning warehouses). Secondly, the interviewees are in a position in their organisation where they are directly responsible for the supply chain management of their organisation; therefore, they were felt to be the best people to respond to questions. Lastly, the interviewees have taken part in decision-making process or in the position where their opinions have influence on the operation.

The majority of the survey was conducted through email due to the fact that their on-going humanitarian aid operations are operated around the globe. Despite the environmental fact of geographical limitation, the author was fortunate to make contact with some of the respondents to conduct fact-to-face and telephone interviews. Semi-structured interviews were conducted with logistics managers and officers to focus on the level of development of pre-positioning warehouse strategies. The survey was designed to be completed within a specific amount of time (i.e. 30 minutes) due to the limited time was given to the author for the interview. The survey (shown in appendix A.1) covers four areas, which are:

1. *The background of pre-positioning strategy*

   The survey respondents were asked to provide the background of implementing the pre-positioning warehouse strategy for their organisations. Questions about the development of the pre-positioning warehouse strategy were asked in the face-to-face and telephone interviews.

2. *Determining factors*

   The survey respondents were asked to list the determining factors for pre-positioning warehouse selection. There was no limit to the number of factors to be listed. The question was asked in order to find the determining factors that were used in the decision-making process.

3. *Priority of the determining factors*

   These questions were asked to gain further insights into the prioritisation of the determining factors. The survey respondents were asked to give their opinion on the relative importance of the factors when they choose a pre-positioning warehouse.

4. *Difficulties and limitations*

   The main aim of the last exploratory question is to find the difficulties that the humanitarian relief organisations face when operating a pre-positioning warehouse. Again, more specific reasons were demanded from face-to-face and telephone respondents to guide the future study of humanitarian relief pre-positioning warehouse.

In the last part of the survey the humanitarian organisations were asked if they were interested to participate in a case study of their organisation to examine the warehouse location selection problem using multi-criteria decision-making methods. The author's aim was to take the study a step-further and apply multi-criteria decision making method in real case studies for the decision-making process in humanitarian relief organisation.

Prior to the survey distribution, the author gave a brief introduction to the survey and explained its objectives. A total of 27% of the international humanitarian relief organisations responded to the email survey. Four respondents were questioned in face-to-face interviews and one was interviewed by telephone. All of the respondents of Korean humanitarian organisations were questioned through face-to-face interviews. From the eighty-six humanitarian organisations provided by KCOC, only ten (12%) of them had a supply chain division in the organisation that participates in emergency relief. From these ten, only five (6% of the total) of them operates pre-positioning warehouse.

5.3 Implementing a Pre-Positioning Warehouse Strategy

From the exploratory study, several reasons emerged why humanitarian organisations implement a pre-positioning warehouse strategy. The ultimate goal of humanitarian relief logistics is “to deliver the right supplies in the right quantities to the right locations at the right time to save lives and reduce human suffering in given financial constraints” (Beamon and Balcik, 2008, pp. 101). Not surprisingly, all of the respondents replied that the main reason for operating pre-positioned warehouses is to reduce response time. One of the strategies that could allow responding quickly is to locate the pre-positioned warehouse near to disaster-prone areas (cited by 28% of the respondent) and near to the potential beneficiaries (cited by 16% of the respondents). The pre-positioning warehouse maintains the stockpiles of items that would be required at short notice to respond to emergencies could eliminate challenges of procurement and deployment delays by such stocks being already established. The pre-positioned items enable the organisation to standardise the specification of the relief goods (cited by 20% of the respondents).

> *Before adapting the pre-positioning warehouse strategy, it was difficult to find a place to store the goods and deliver the goods to the beneficiaries efficiently.* (Respondent 19)

The respondents suggested that they experience a lot of time being wasted in organising the relief items in the field. Also by holding the pre-positioning stocks, it is possible for them to sort the priority of the goods to the needed in advanced (cited by 10% of the respondents). This allows eliminating the waste of time organising the items in the field (cited by 10% of the respondents). Pre-positioning warehouses could reduce cost by purchasing in bulk which allows for better price and quality (cited by 24% of the respondents) and by locating near to the beneficiaries (cited by 16% of the respondents). Specific comments were made as follows:

> *The price of the relief item increases dramatically during the event of the crisis since all the humanitarian organisations are trying to buy them. So by purchasing them in advance before the disaster event, the price is lower and we don't face difficulty to buy them because there are enough of them in the market.* (Respondent 20)

> *Pre-purchase of the stock could avoid the maverick and casual purchase at the last minute of emergency.* (Respondent 3)

Pre-positioning warehouse is implemented to support relief logistics service for large disasters (cited by 32% of the respondents) and for preparedness purposes (cited by 12% of the respondents).

> *A pre-positioned warehouse strategy is implemented to prepare the "preparedness" to maintain availability of emergency relief items which could be distributed in response to urgent needs related to their situations of violence or natural disasters.* (Respondent 13)

Table 5.1 summarises the critical reasons for implementing the pre-positioning warehouse strategy.

Table 5.1 Reasons for implementing the pre-positioning strategy

Reasons	No. of respondents	Percentage (%)
To reduce response time	25	100
To support relief logistics service for large disasters	8	32
Closer to disaster frequent areas	7	28
Reduce in cost by purchasing in bulk	6	24
Standardise the specifications of relief items	5	20
Closer to beneficiaries	4	16
For preparedness purpose	3	12
Sort the priority of goods in advanced	3	12
Eliminate the waste of time organising the items in the field	3	12

Source: Author

5.4 Determining Attributes

Analysis of the determining factors for humanitarian relief warehouse selection for MADM research methods is lacking in the literature. Even the existing factors for commercial field vary a lot due to the different environment of the case and view of the decision-makers. In this section, the results of findings from the exploratory survey involving by logistics experts at managerial level are explained.

Findings in Exploratory Survey

The results of exploratory survey (to find out the determining factors for humanitarian relief pre-positioning warehouse selection) provide several different possible attributes that could be used for the next-step of the research study. Altogether twenty-nine different attributes were drawn from the respondents. Most of them were mentioned by several respondents and some of them came from a single respondent. Table 5.2 summarises the results of the determining attributes for humanitarian relief pre-positioning warehouse selection. The table shows the number and percentage of respondents citing each of the factors.

Proximity to disaster prone areas

The most dominant factor that the respondents consider when locating a pre-positioning warehouse was that the warehouse should be located in close proximity to the disaster prone areas; twenty-on out of twenty-five (84%) respondents cited this factor. Balcik and Beamon (2008), Campbell and Jones (2011), Mete and Zabinsky (2010) and Rawls and Turnquist (2010) consider the potential disaster locations in their pre-positioning modelling. Facility location decision affects the performance of relief operations since the locations of the distribution centres directly affect the response time and cost incurred throughout the relief chain (Balcik and Beamon, 2008; Rawls and Turnquist, 2010).

Availability of logistics experts

The availability of the logistics experts is the next dominant factor that respondents think should be considered for the warehouse location selection problem (cited by 52% of the respondents). However, this factor links to the broader attributes of availability of *trained and qualified personnel* (cited by 16% of the respondents) and *labour availability* (cited by 8% of the respondents) where they all need the logisticians available in broader extent. In addition, the availability of these logisticians also affects the *logistics service* (cited by 8% of the respondents) of the country (Respondents 8 and 16). Availability of logistics experts are considered to warehouse location problem in Chuang (2001), Levine (1997), Sarkis and Sundarraj (2002), and Yang and Lee (1997).

Table 5.2 Determining factors for humanitarian relief pre-positioning warehouse locations cited by respondents

Factors	No. of respondents	% in total factors	% in total respondents
Proximity to disaster prone areas	21	17	84
Logistics experts availability	13	12	52
Warehouse security	12	11	48
Geographical location	9	8	36
Transport connectivity	8	7	32
Availability of seaport and airport	6	6	24
Near to (potential) beneficiaries	5	5	20
Adequate warehouse facilities	4	3	16
Adequate warehouse infrastructure	4	3	16
Warehouse accessibility	4	3	16
Storage cost	4	3	16
Stable government	4	3	16
Trained and qualified personnel	4	3	16
Flexible customs regulations	3	2	12
Proximity to urban facilities	2	1	8
Warehouse capacity	2	1	8
Labour availability	2	1	8
Logistics service	2	1	8
IT/Communication	2	1	8
Cost relate to logistics	2	1	8
Land cost	1	0.8	4
Climate	1	0.8	4
Replenishment cost	1	0.8	4
Donor’s opinion	1	0.8	4
Labour price	1	0.8	4
Existence of other agents (NGOs)	1	0.8	4
Cooperation with logistics agents	1	0.8	4
Closeness to other warehouses	1	0.8	4
Political and economical stability	1	0.8	4

Source: Author

Warehouse security

The safety and the security of the warehouse is one of the most important factors from the respondents’ replies (cited by 48% of the respondents). The respondents replied that the reason warehouse security is one of their determining factors is that it is important for the warehouse to be safe because they stock various valuable relief goods (i.e. medicines, foods, tents, and armoured-vehicles). The warehouse should also be protected with security facilities and guards. Consequently, they have to be sure that the location of the warehouse is safe to stock relief items and the security is guaranteed (Respondent 4 and 9). The security of the warehouse is considered in warehouse location problem in Awasthi *et al.* (2011).

Geographical location

This is also a location-related factor that many respondents (36%) cited as an important attribute for warehouse selection. This means that the geographical location around the globe can satisfy the general requirements of their relief operations. This can be a location which 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 (Respondents 3, 4, 9, 12, 13, 18 and 22).

Transport connectivity

About eight of the respondents (32%) responded that transportation connectivity should be reliable between different transport modes for the emergency relief operations. The location of the warehouse site should have reliable transport infrastructure that enables transhipment of the relief goods from one mode to another. *"The pre-positioning warehouse location will be useless if it does not have this ability"* or *"if it is going to function as the main distribution centre for the organisation"* (Respondents 5 and 24). The intermodal connectivity is included in many of warehouse location selection problems (Kayikci, 2010; Levine, 1999; Yang and Lee, 1997).

Availability of seaport and airport

This is one of the determining factors that the pre-positioning warehouse should acquire for the emergency relief operation, 24% of the respondents cited this. This result can be regarded as low in percentage; however, the respondents replied that transport connectivity, logistics service includes availability of seaport and airport which will increase the percentage of citation (Respondents 5, 7 and 15). To cite availability of seaport and airport separately is to emphasise the importance of those attributes (Respondents 14, 16, and 21). Since the goal of the humanitarian relief is to get the relief goods to the beneficiaries as soon as possible after the emergency, the availability of the airport is a very important factor for emergency operations. In addition, the seaports used to handle large quantities of replenishment goods, and they are also used to deliver relief goods for post-disaster operations and for regional warehouses (cited by Respondents 7, 14, 16 and 20). Warehouse location problem considering of the seaport and airport related factors are found in Alberto (2000), Korpela and Tuominen (1996), and Kuo (2011).

Near to (potential) beneficiaries

This is one of the factors that relates to the location factor of the pre-positioning warehouse, and a total of 20% of the respondents replied that this was important. This can be seen in the similar view of the proximity to disaster prone areas; however, the proximity of the beneficiaries is different for a refugee crisis where the refugees (beneficiaries) could leave from their home country to neighbouring countries which could be 1,000 miles away (Respondent 16, 19 and 21). Humanitarian organisations pre-positioned relief supplies near places available for many suffering people (Oloruntoba and Gray, 2006)

Adequate warehouse facilities and infrastructure

A total of 32% of the respondents replied this to be an important attribute. These replies are expressed in a broad terms. When the respondents reported that the warehouse should have enough space/capacity (cited by 8% of the respondents) and access to the warehouse should be easy (cited by 16% of the respondents) because they affect operating costs and quality of storage (Respondents 4, 5, 8, 14, and 18). This relates to the pre-positioning warehouse size could result minimising the expected cost (Rawls and Turnquist, 2010). Warehouse location problem regarding to facilities and infrastructure are found in Alberto (2000) and Korpela and Tuominen (1996).

Cost:

Cost is one of the important determining factors that many respondents replied that they should consider when selecting the warehouse location decision-making process. Four respondents (16%) replied that storage cost which can be categorised as the maintenance cost. Two respondents (8%) replied that cost relate to logistics factors should be considered for warehouse selection. Minimising the general logistics cost of the location/country is more important than lowering operating costs in isolation. *Land cost, replenishment cost* and *labour cost* were also mentioned by one respondent (0.8%) as important considerations for warehouse location. Pre-positioning problem regarding to cost are found in many researches (Balcik and Beamon, 2008; Campbell and Jones, 2011; Rawls and Turnquist, 2010; Soon 2007, Yang and Lee, 1997)

Flexible customs regulations

This is an important issue for some of the humanitarian organisations (cited by 2% of the respondents). A lack of support from the government with regard to flexible customs and quick customs clearance will delay the whole supply chain process if the relief items are caught up in the border of the country (Respondent 21). However, large international humanitarian organisations normally have their relief items cleared from the customs, which will smooth the process if they have the customs exemption document with them which has been agreed with the government in advance (Respondents 1, 2, and 4). Warehouse location problem considering the customs regulations are found in Kayikci (2010), Min and Melachrinoudia (1999), and Sarkis and Sundarraj (2002),

Proximity to urban facilities

It is important to have the pre-positioned warehouse located near to the urban facilities (cited by 1% of the respondents). The relief items should not be placed in a facility that has just storing function (Respondent 16). The warehouse should be equipped with proper facilities so that it can do its function. The warehouse should not be isolated by itself; it should be near to the urban facilities that can provide electricity, water, and vehicle maintenance service that can support the function of the pre-positioned warehouse (Respondent 23). Proximity to urban facilities was considered in warehouse location selection problem in Levine (1991), Li *et al.* (2011), and Yang and Lee (1997).

IT/communication infrastructures

The existence of IT and communication infrastructure is necessary for the establishment of pre-positioned warehouse (cited by 1% of the respondents). The basic communication process from pre-positioned warehouse to head/regional office is made by internet and telephone. This is the most basic and critical factor to consider for the pre-positioned warehouse location selection problem and places that do not have this facility will not be even considered (Respondent 8, 21). IT/Communication infrastructure requirement was considered in facility location problem in ACFID (2007) and Chuang (2001). IT/Communication infrastructure plays an important role in humanitarian logistics distribution especially in recovery phase (Choi *et al.* 2010).

Climate

The deterioration of the relief items in the pre-positioned warehouse depends on the climate and the environment (cited by 0.8% of the respondents). A very hot climate not only affects the relief items but also the labour force in the warehouse (Respondent 1). The climate factor is considered in the pre-positioning of medical and food supplies (Dessouky *et al.* 2006; Jia *et al.* 2007). The climate issue only becomes relevant in a very extreme cases and it is very rare likely in a real situation.

Donor's opinion

Some small humanitarian organisations that get large funding from a few donors have to depend on their donor's opinion where to locate the pre-positioned warehouse (cited by 0.8% of the respondents). Humanitarian organisations have to respect the donors/firms' opinion that supports them by contributing a large portion of the funding for their budget. Some donors insist on a certain location to pre-position the warehouse due to their politics and business relationship with certain governments (Respondent 19). Most relief organisations rely almost solely on donor funding, and so cannot imitate a disaster response before funding becomes available (Seamon, 1999). In this case, the humanitarian organisation has to consider the plan if it does not want to lose one of their largest contributors.

Closeness to other regional warehouses

Pre-positioned warehouse should consider the closeness to other regional warehouse (cited by 0.8% of the respondents). This is important for humanitarian organisations where the relief aid is focused in particular areas because it will reduce cost and time during the relief operation (Respondent 16). Normally, this is not an issue for large international humanitarian organisations because the relief items will be shipped via air transport and they operate more than one pre-positioned warehouse. The closeness to other warehouse is considered in the facility location selection problem in HRN (2006) and Partovi (2006).

Political, economic, and social stability

This includes the stability of the country/government (cited by 0.8% of the respondents). The stability of the country is important for the pre-positioned warehouse location because if the country is very fragile and unstable it will be very difficult for the humanitarian organisation to operate the supply chain in a risky and dangerous environment. The organisations want the country's future to be as predictable as it can be (Respondent 1). Kayikci (2010) and Sarkis and Sundarraj (2002) also included political, social, and economic stability for their warehouse location problem.

Existence/cooperation with other agents

The existence of the other relief agents in the location is also an important factor (cited by 0.8% of the respondents). However, existence is not enough; there must also be a form of cooperation with each other (Respondent 2). The relief agents do not only include humanitarian organisations but parties who are involved in relief aid, such as the host government, neighbour countries and logistics agents and operators. The importance of the coordination is emphasised especially in humanitarian logistics (Balcik *et al.* 2010; Kovács and Spens, 2009; Oloruntoba and Gray, 2006; Pettit and Beresford, 2005).

The facility location decisions affect the performance of relief operations since they directly affect the response time and cost incurred throughout the relief supply chain (Balcik and Beamon, 2008).

5.5 Priorities of the Attributes

The next exploratory survey question aimed to find out which attributes/factors the decision-makers see as the most important or preferable for the choice within their selection process. Some respondents replied with only one preference or they provided with priority of the factors they considered to be most important for warehouse selection. However, most of the respondents replied that the factors they provided are equally important.

Table 5.3 Priority of the factors

Most preferable to least	No. of respondents	Respondents
Equally important among the factors that respondents provided	18	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 14, 15, 16, 18, 19, 20, 24, 25
Accessibility, Communication, Security, Space	1	12
Location, Custom regulation, Cost, Proximity to disaster area, Logistics service	1	21
Proximity to beneficiaries	1	22
Warehouse accessibility, cost	1	17
Close to beneficiaries, labour availability	1	13
Close to beneficiaries, logistics agents, connectivity, urban facilities, airport and seaport, labours	1	23
Logistics infrastructure, connectivity, near to other warehouses, logistics service, security, cost of storage	1	4

Source: Author

Table 5.3 shows the results from the exploratory study of the priority of the factors that respondents provided for the humanitarian pre-positioning warehouse selection decision-making process. Table 5.3 shows that the dominant opinion (cited by 72% of the respondents) of the managers was that the factors should be treated equally or, at least, the manager cannot decide the priority of their importance among the factors they provided. They answered that the factors are hard to distinguish in terms of their priority. Lack of any priority could be detrimental and can break the entire supply chain, cause delays to deliver timely response to the beneficiaries (Respondent 3). Respondents 13, 17, and 22 replied that closeness to the beneficiaries is their first priority for locating the pre-positioned warehouse facility among the factors given. The purpose for this survey question was to grasp an idea of the priority factors for the warehouse location decision process. It can be drawn out from the result that most of the decision-makers consider all factors should be treated equally and they cannot decide the most important factor for warehouse location selection, as in this example:

> *When it comes to the real decision-making process, it is true that all of the factors are important, but there is always a debate among the decision-makers to decide which factors are the most important for evaluation.* (Respondent 3)

For this reason, it is important to categorise the factors weighted that so everyone can agree with the evaluation process (Respondent 3). Table 5.3 shows that the respondents cannot provide clear opinions on the dominant attributes for the factor weighting, which leads to a requirement to identify the main attributes from the humanitarian organisation decision-makers.

5.6 Limitations of Pre-positioning Warehouse

This part of the survey is to gain a better understanding of the limitations and the difficulties of the humanitarian pre-positioned warehouse strategy in managerial level decision-makers point of view. Table 5.4 summarises the findings of the limitation and difficulties in humanitarian pre-positioned warehouse.

The major concern regarding their pre-positioning warehouse strategy that decision-makers have is that the limited shelf-life of some relief items that could deteriorate while in the stockpile (cited by 44% of the respondents). However, this was a not a big issue for some of the organisations because of the different nature of relief operations that they were dealing with. For example, Respondent 1 replied that the limited shelf life was not their problem where they focus on relief operation for refugee related programmes. Most of the relief items they handle are tents, blankets, jugs, mosquito nets and other durable items. On the other hand, relief organisations that mainly operate with nutrition foods and medicines have to be very aware of the expiry date on the relief items because they directly affect the beneficiaries. Potentially, the most sensitive items of all are medical supplies.

Table 5.4 Limitation and difficulties for pre-positioning warehouse

Limitation and difficulties	No. of respondents
Limited shelf life	11
High maintenance cost	8
Uncertainty and unpredictable of disasters	5
Establishing maximum stock level amounts	5
Not confident what stocks to store	4
Transportation cost to warehouse	3
Justify funding (persuade donors)	2
Limited space	2
Security (Theft/Pilferage)	2
Not suitable for small operations	2
Difficulty of transportation access	2
Labour cost	1
Potential negative impacts for local economy	1
Climate issues	1
Complicate procedures of releasing stocks	1
Not suitable in the initial stage of response	1

Source: Author

One other problem of operating a pre-positioning warehouse was the high maintenance cost (cited by 32% of the respondents). Taking a broader view, cost includes the storage, transportation, labour and any other costs that relate to operating the warehouse system. Due to these high cost difficulties, small relief organisations with financial burdens could not dare to operate the pre-positioning warehouse system. To solve this problem some international humanitarian organisations have offered to share the burden of cost. Larger international organisation offers small relief organisations some free space to store relief items in their warehouse buildings. The strict standards of packaging of the relief items are to be required for the relief items should be stored and to be take care of. Transportation cost is to be paid separately and this could be shared among the small organisations if they are delivering the relief items to the same disaster area. This attracts many small organisations to use the large international humanitarian organisation's pre-positioning warehouse because it could save a huge amount of costs.

The next difficulty that the decision-makers face is the uncertainty and unpredictability of disasters (cited by 20% of the respondents). Not only the uncertainty of the natural disasters in terms of being very difficult to predict requirements for the relief operation, but also the uncertainty in man-made crises. The development of new technologies to predict weather and early warning system help to prepare for the natural disaster is now better than ever before. However, the problem is that *"the uncertainty of the impact that the disaster will bring no matter how well you are prepared for it, there will be always a harm done by disasters"* (Respondent 8). A man-made crisis is a very sensitive issue, especially for refugees. Preparing the relief items for the refugees in advance will be likely to motivate them to flee the country to certain area, which will mean that the organisation has had a negative impact for the relief operation (Respondent 1). Due to the limited funding, it is difficult to purchase a variety of items in large quantities and it is also not sensible to purchase a large quantity of a single item. The range of uncertainties in a given disaster greatly affects the needs of the beneficiaries and this is a challenge for the organisations to maintain the optimal level of stock. Consequently, it is difficult for them to establish optimum stock levels to hold in the warehouse (cited by 20% of the respondents). In addition, this lead to difficulties to stock what kind of relief items in advance and brings a lack of confidence to purchase those (cited by 20% of the respondents). However, large international humanitarian organisations that have sufficient funding to purchase the relief items always aim to maintain the maximum stock level possible. They also keep the range of the relief items as simple as possible so that they can focus on purchasing the major relief items that are most often needed during similar disaster events.

Other difficulties of operating the pre-positioning warehouse is the high transportation cost of the relief items (cited by 12% of the respondents). Normally, humanitarian organisations deliver relief items to the pre-positioned warehouse as far as possible via sea. This transportation mode could save cost but will take a long time; for example, averaging from four to six weeks from suppliers (China) to pre-positioned warehouse (UAE) (Respondent 21). In addition, there is an immediate situation when there is no choice but to send the relief items to the pre-positioned warehouse by air transportation. There is then a limitation of the volume of the cargo and the cost is extremely high compared to that of sea transport even though it will take only 24 – 48 hours delivery from loading (Respondent 21). To avoid this kind of incident, relief organisations must plan ahead by the purchasing of the relief items using shipping to reduce transportation cost with a positive effect of stockpiling large volume of items.

The next difficulty in operating a pre-positioning warehouse is to persuade the donors (cited by 8% of the respondents). The donors tend to see their contribution as visible when they donate the money, which is then used to purchase the relief items and deliver them to the beneficiaries. They are not happy with the money being spent for the relief organisation's "management purposes", especially for the warehouse management (Respondent 9). It takes time to convince and persuade the donors of the importance of having a pre-positioning warehouse strategy. However, if the donors are still not pleased with this system, they refuse to donate and will give funds to other relief organisations that will meet their fulfilment criteria (Respondent 19). Limited space (cited by 8% of the respondents) is another problem for the relief organisation to solve. One international humanitarian organisation shared their warehouse facility with other small organisations. In the first place, this was an ideal strategy that they all agreed with. However, this came to be a problem when all the small relief organisations wanted to stock more relief items for their own purposes. It was a hard decision to accept relief items from certain organisations and not accept others due to the limited space available to stock them (Respondent 2). The issue of security is also a factor to consider in a pre-positioning warehouse strategy (cited by 8% of the respondents). Some of the relief items stocked in the warehouse are very valuable items; for example, radio-telecommunication systems, medicines, armoured vehicles, etc. (Respondents 1 and 2). There is often a threat of theft or pilferage of these items. Delivering a small quantity of relief items will not be suitable or even possible for a pre-positioning warehouse strategy (cited by 8% of the respondents). The logistics managers prefer to dispatch large amounts of relief items for cost issue "just in case" rather than sending them in small amounts (Respondent 1 and 20). The philosophy is that it is better to have too much relief cargo than not enough. For these reasons, the pre-positioning warehouse strategy is mainly used for emergency relief purposes where they can dispatch in large quantities. As long as the initial need is satisfied through pre-positioned warehouse, the later relief items could be purchased in the neighbouring countries and local markets in the disaster affected area (Respondent 1). The difficulty of transport access to the warehouse (cited by 8% of the respondents) is also an issue, although the logistics managers do not consider that to be a big issue because normally the pre-positioned warehouse will be located in a well-equipped area, or at least one with transportation infrastructure (Respondent 10).

The other minor difficulties cited by the respondents are the considerations of labour cost (4%), potential negative impacts for the local economy (4%), climate issues (4%), complicated procedures for releasing stocks (4%), and goods not suitable in the initial stage of response (4%). Every logistics manager is aware of the potential negative impact for the local economy by purchasing the items outside the area because they do not want to harm the local market. They want to encourage and stimulate the local economy by purchasing the items even though the prices get higher just after the disaster event. Some of the pre-positioned warehouses are located in very hot climates which could affect the working environment of the labour and damage the quality of the relief items (Respondent 1). Complicated procedures for releasing of stock are one of the procedures that relief organisations need to experience and make the system adapt to theirs if they are aiming to establish a pre-positioning warehouse strategy (Respondent 21). Respondent 19 replied that pre-positioning of stocks is not suitable in the initial stage of emergency response because they believe it takes too long and is too complicated for the relief goods to be actually delivered to the beneficiaries compared to purchase the goods in the local area or in neighbouring countries through a conventional needs assessment.

The difficulty to initiate or to maintain the pre-positioned warehouse strategy due to the uncertainty of disaster occurrences, funding tendencies in the sector and the costs associated with operating centres are also found in Balcik and Beamon (2008), Balcik *et al.* (2010), and Oloruntoba and Gray (2006).

5.7 Chapter Summary

This exploratory study has provided insights into the humanitarian pre-positioning warehouse strategy. The pre-positioning warehouse strategy is of interest to many humanitarian relief organisations. There are various reasons for the humanitarian organisations to adapt the pre-positioning warehouse strategy. In this study the two main reasons to implement this strategy were that it reduces cost and response time.

The dominant factor that the decision-makers most considered was that the pre-positioned warehouse should be located in the proximity of disaster prone areas. The other factors related to logistics included cost and location. The percentage weighting of the factors was distributed almost equally with a few exceptions.

Most of the decision-makers could not decide which factor should be considered to be the most important for the location problem. They replied that the factors are all equally important when it comes to the real situations. In spite of this, they need a categorised structure of the importance of the factors that could show in percentage terms (priority weighting) the process of assessing the alternative warehouse location sites. Some respondents replied that a warehouse which is close to the beneficiaries is their first priority. The results explicitly show that it is difficult for the decision-makers to decide which factors should be in their priority list for locating pre-positioning warehouse facility. In addition, the results from other respondents who listed the importance among their factors do not clearly show particular preferences. Consequently, AHP is employed to obtain the weight of the attributes to show priority preferences.

There are some limitations for examining pre-positioning warehouse location. Most of the responses concerned cost-related difficulties. The operational cost is high for small humanitarian organisations to manage if they do not get enough support from the donors or from the country. Usually, large humanitarian organisations with good reputations and which are well-known receive enough funding from the donors and are able to operate a pre-positioning warehouse relief supply chain. For these reasons, different humanitarian organisations have their own relief supply chain strategy according to their capability and this capability is derived mainly from size. The exploratory study also found that there are different types of pre-positioning warehouse strategies, ranging from establishing the organisation’s own pre-positioned warehouse to sharing the facility with other organisations.

CHAPTER 6
CASE STUDIES OF INTERNATIONAL HUMANITARIAN ORGANISATION'S PRE-POSITIONED WAREHOUSE LOCATION PROBLEM

6.1 Chapter Overview

This chapter describes the two case studies that were conducted within international humanitarian organisations. The primary and secondary data that has been provided by the managerial level are analysed thoroughly in order to gain an insight into the pre-positioned warehouse location problem. The first case study was carried out to investigate the regional determining attributes that are suitable for international humanitarian organisation. It also examines how they are related to locate the pre-positioned warehouse locations from a macro point of view. The second case study was conducted to identify the pre-positioned warehouse location problem in a real situation for international humanitarian organisations that are based in Dubai, UAE. This approach is to investigate the specific site determining attributes from a micro point of view that is used in a project for moving a warehouse to an alternative location. Both of the case studies were conducted during 15th March 2011 – 15th May 2011 while the author worked in the international humanitarian organisation as an intern.

6.2 Case Study A: Regional Determinants, a Macro View

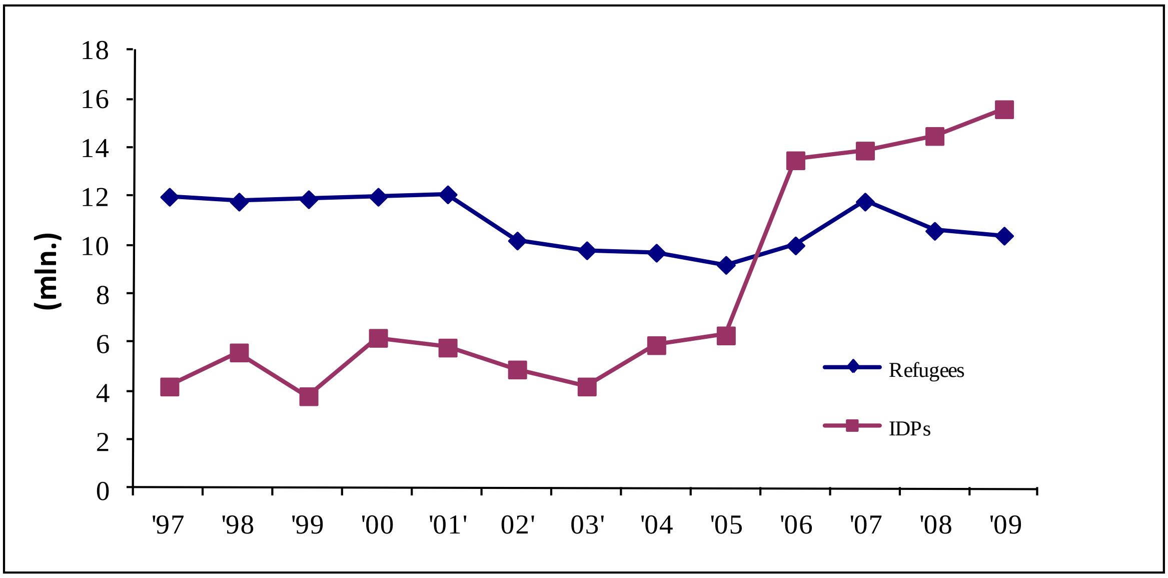
The objective of this case study is to understand the regional attributes affecting the warehouse location decision-making process for the International Humanitarian Organisation A. It also examines the important role of the pre-positioned warehouse in the relief supply chain within the organisation. This case study will also investigate the location of the sea-air pre-positioned warehouses in relation to the location decision attributes.

6.2.1 Organisation's Background

International Humanitarian Organisation A mainly focuses on aiding refugees, returnees, stateless persons and certain Internally Displaced Persons (IDPs), who are collectively referred to as "persons of concern" (Respondent A1). The organisation's Global Report (2009) states that the total population under the organisation's responsibility stands at 36.5 million. The definition of each population group is shown in Appendix D.7.

By the end of 2009 there were an estimated 10.4 million refugees under the organisation's responsibility, including some 1.6 million people in refugee-like situations (Respondent A7). The number of IDPs protected and/or assisted by the organisation at this point was the highest on record (Figure 6.1). A total of 15.6 million IDPs, including 129,000 people in IDP-like situations, were receiving humanitarian assistance under arrangements in which the organisation was either the lead agency or a key partner (Respondent A7).

Figure 6.1 Refugees and IDPs protected/assisted by International Humanitarian Organisation A



Source: Respondent A 7

Table 6.1 explains the population of concern to International Humanitarian Organisation A. It can be seen that there are a total of 3.6 million refugees in the Asian region and a total of 4.5 million IDPs. These are the largest numbers of refugees and IDPs of any global region. For example, Africa has 1.6 million refugees and 6.4 million IDPs. In particular, South-West Asia had the most refugees (2.1 million) and IDPs (57,580) in the Asian region. The numbers include the recognised Afghan refugees (2,800), registered Afghans in refugee villages who are assisted by the organisation (758,600), and registered Afghans outside refugee villages who are living in a “refugee-like” situation (981,300) (Respondent A 1). In Africa the Central Africa and the Great Lakes sub-regions have a total of 969,300 refugees, which is the largest number of refugees in Africa, while most African IDPs population are located in the East and Horn of Africa sub-region (3.4 million).

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 (Respondent A1). It has a global responsibility to provide basic relief items to persons of concern and it has accepted to be ready to provide basic Non-Food Items (NFI) for 500,000 people in case of emergencies (Respondent A1). Furthermore, the strategic orientation of the organisation is to become a lead global humanitarian agency for basic NFI and shelter items. The establishment of a global system to consolidate the management of the 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.

International Humanitarian Organisation A 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 International Committee of Red Cross (ICRC). Agreements with suppliers have been augmented to allow for the rapid replenishment of the CES and faster delivery to operations.

Table 6.1 Populations of concern to International Humanitarian Organisation A

Subregions	Refugees	Person in refugee-like situations	Total refugees	Of whom assisted	Asylum-seekers	Returned refugees	IDPs protected/ assisted	Returned IDPs	Stateless persons	Various	Total population of concern
Central Africa and the Great Lakes	945,190	24,100	969,300	626,830	19,900	99,190	2,520,210	99,630	-	155,060	3,863,280
East and Horn of Africa	779,230	33,920	813,140	718,620	64,630	33,770	3,429,440	579,600	100,000	-	5,020,550
West Africa	149,030	10	149,040	139,660	9,340	2,010	519,140	166,820	-	4,660	850,980
South Africa	143,420	-	143,420	62,280	325,690	2,500	-	-	-	14,480	486,090
North Africa	104,810	26,000	130,810	92,220	3,950	12,010	-	-	-	-	146,760
Middle East	1,857,640	17,490	1,875,140	522,340	30,240	38,040	1,802,000	167,740	694,260	-	4,607,420
South-West Asia	1,829,920	981,320	2,811,240	2,811,240	4,300	57,580	2,191,690	1,113,630	-	-	6,178,440
Central Asia	8,060	-	8,060	3,800	2,140	10	-	-	46,900	-	57,100
South Asia	320,320	202,300	522,620	127,190	6,760	1,490	434,900	94,600	800,000	480	1,860,850
East Asia and the Pacific	508,310	5,790	514,100	175,700	29,420	430	67,290	-	4,272,770	61,400	4,945,390
Eastern Europe	14,050	5,000	19,050	11,460	4,000	30	889,770	6,150	120,070	82,740	1,250,650
South-Eastern Europe	119,790	570	120,350	114,710	550	4,290	340,810	1,380	30,040	74,840	572,260
Central Europe and the Baltic States	44,920	-	44,920	16,960	17,400	30	-	-	461,940	370	524,670
Western Europe	1,463,130	-	1,463,130	-	271,430	-	-	-	33,500	17,680	1,785,700
North America and the Caribbean	448,700	-	448,700	70	125,190	10	-	-	-	-	573,900
Latin America	74,190	293,190	367,380	89,910	68,570	60	3,303,980	-	120	-	3,740,090
Various	-	-		-	-	30	-	-	-	-	30
Total	8,810,710	1,589,690	10,400,400	5,512,990	983,510	251,480	15,449,230	2,229,550	6,559,600	411,710	36,464,160

Source: Respondent A 1

6.2.2 Group Decision-Making

The current research implements an AHP and TOPSIS methodology, which are effective in eliciting judgment from the members of the facility-planning decision-making members in a systematic and consistent manner. It also helps to obtain group consensus in a highly political environment in a timely manner for a fairly complex planning problem (Badri, 1999). Site selection is usually a team effort, and AHP is one available method for forming a systematic framework for group interaction and group decision-making (Saaty, 1982). The group decision-making method is widely adapted in the studies of AHP-TOPSIS studies where the participants are from the managerial level who have better insights of the problem and who have actual influence in the decision making process (Amiri, 2010; Ertuğrul, 2010; Kuo *et al.* 2007). This process is repeated until the decision-makers finally approve the hierarchical structure of the decision criteria.

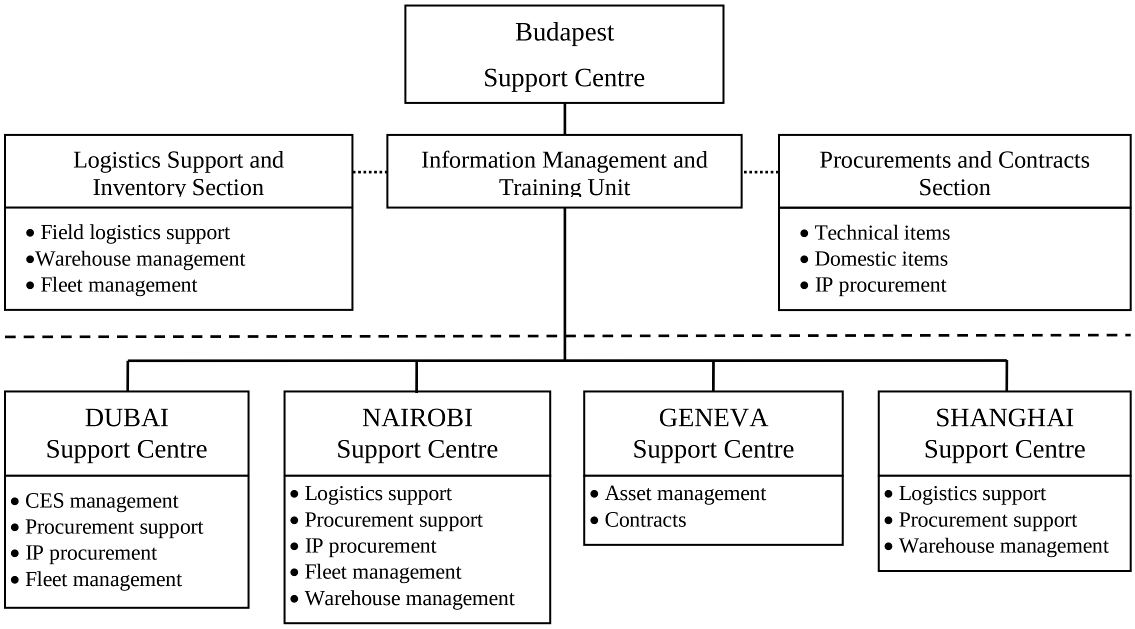
Supply Management Service (SMS)

International Humanitarian Organisation A has an independent supply management department, which is called Supply Management Service (SMS). The goal of SMS is to deliver efficient and cost-effective supply chain solutions at all levels, through in-house, outsourced, inter-agency and bilateral arrangements, in support of operations (Respondent A 1). Also, the role of SMS is to improve supply chain management business processes, enhance information and data management, and build support and surge capacity. The functional foci of SMS are:

1. Accountability framework;
2. Sourcing of Goods and Services;
3. Implementing Partner Procurement;
4. Logistics Support and Response Capacity;
5. Asset Management;
6. Fleet Management;
7. Warehouse and Stockpile Management;
8. Cluster Coordination and Support;
9. Training and Capacity Building; and,
10. Information Management Capacity.

The structure and capacities of SMS are illustrated in Figure 6.2. The SMS headquarters is based in Budapest, Hungary, which is called the Budapest Support Centre. In Budapest, the SMS is divided into three sections: a logistics support and inventory section, an information management and training unit, and a procurement and contracts section. The main function of the logistics support and inventory section is to support field logistics with warehouse, fleet and asset management. The responsibility of the procurement and contracts section is to make contracts with suppliers, set Implementing Partners (IPs) guidelines in procurement, and to provide support in technical and domestic items. The final role of the information management and training unit is to train logistics officers whenever required.

Figure 6.2 Structure and capacities of SMS



Source: Respondent A1

The Budapest headquarters is supported by four regional support centres, which are based in: Dubai (UAE), Geneva (Switzerland), Nairobi (Kenya), and Shanghai (China). The support centres usually provide procurement support. In addition, the Dubai and Nairobi support centres also have fleet management and IP procurement responsibilities. The only office that manages the CES is the Dubai support centre for emergency relief operations. The Dubai support centre runs the daily supply chain related operations, especially with pre-positioned warehouse (CES). Since the main beneficiaries of the aid are the refugees, most of who are in Africa, the Nairobi support centre plays an important role for post-disaster relief operation in the region. The Shanghai support centre does not get involved in emergency or in post-disaster relief operation, its main role is to procure and stock relief items that are purchased mainly via/from Chinese suppliers. When enough relief items are stocked in the warehouse, they dispatch them to the central and regional warehouses as they are requested.

In this case study, the officers in the logistics department are responsible for the decision-making process because they are the main logisticians in the field and their opinions are heavily converged. In this study, the officers were excluded from the panel when they replied 'no' or if their answers were not relevant to the study due to the fact they are not the experts in that area. For the current study, the field logistics officers based in Dubai support centre, and the headquarter logistics officers in Budapest and in Geneva were grouped for the purpose of the group work.

Group Working Members

Working group members for the decision-making process were formed within the logistics officers of the organisations. Table 6.2 illustrates the members that were involved in the study by their based locations and the position in the organisation.

Table 6.2 Working group members

Location	Respondent	Position
I	A 1	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)

Source: Author

Unfortunately, some of the officers could not participate in the study because they were on an emergency mission, holidays, or because of other personal issues. However, these participants have influence in the decision-making process within the organisation with regard to the facility location problem.

6.2.3 Regional Determining Attributes

The determining factors for the warehouse location problem that are given in Table 5.2 were shown to the panels (Table 6.2) and they were asked to add or eliminate any attributes from the organisation's perspective. Fortunately, the panels agreed with most of the determining factors. Due to the limited time given to the author, organising the attributes to related groups were made alongside the selection of the determining factors for the pre-positioned warehouse location decision problem. The final hierarchical structure of the factors will be illustrated in next sub-section, together with the feedback. A total of three rounds were made to determine the pre-positioned warehouse location factors for International Humanitarian Organisation A (Table 6.3).

Table 6.3 Forming of regional determinant warehouse location attributes

Rounds	1 ------------►	2 ------------►	3
Date	20-03-2011	23-03-2011	27-03-2011
Goal	Add or eliminate attributes	Add or eliminate attributes	Add or eliminate attributes
Result	Participants agreed with the attributes. Added more detail (minor) attributes. No attributes were eliminated.	New attributes were added. No attributes were eliminated	No new attributes added or eliminated. Participants agreed with the determining factors

Source: Author

6.2.3.1 Hierarchical Structure

After the pre-positioning warehouse location factors were determined and confirmed by the members, the factors that required their approval were structured on the decision hierarchy. The factors were initially grouped into related attributes for the first round. It became clear at this point that the attributes could be grouped and formed into a hierarchical structure. There was very little disagreement among the members and, fortunately, this took only two rounds to complete (see Table 6.4).

Table 6.4 Forming of hierarchical structure of regional determining location attributes

Rounds	1 →	2
Date	29-03-2011	31-03-2011
Goal	Form hierarchical structure	Form hierarchical structure
Result	Participants grouped the related attributes and structure them into hierarchical level. Had little disagreement in the first place but ended agreeing with the structure	Participants agreed with the decision hierarchical structure that was made in the previous round

Source: Author

The decision hierarchical structure for pre-positioning warehouse location attributes for International Humanitarian Organisation A is illustrated in Figure 6.3, along with their explanations.

Location (C_1)

All the respondents replied that one of the crucial factors for a pre-positioned warehouse is the location related attributes. The location related factors are:

1. Geographical location (SC_{11});
2. Proximity to beneficiaries (SC_{12});
3. Disaster free location (SC_{13});
4. Donor’s opinion (SC_{14});
5. Climate (SC_{15});
6. Closeness to other warehouses (SC_{16}); and,
7. Proximity to disaster prone areas (SC_{17}).

Disaster free location (SC_{13}) was brought up in the meeting. Locating the pre-positioned warehouse near to the beneficiaries and potential disaster location will reduce the delivery time and cost, however this will be useless if the warehouse get destroyed by disasters (Respondents A8 and A11). Campbell and Jones (2011), Rawls and Turnquist (2006), and Ukkusuri and Yushimoto (2008) modelled the pre-positioned warehouse considering the facility not being destroyed/damaged by the disasters.

National Stability (C_2)

The group members agreed to break the national stability factors into three sub-criteria, which are:

1. Political (SC_{21});
2. Economical (SC_{22}); and,
3. Social (SC_{23}).

The working members discussed how a stable political situation is important for the organisation to operate a pre-positioned warehouse. A government direction which is easier to predict will make it easier to negotiate and communicate with them so that a deal can be arrived at (Respondent A1). The first findings in the exploratory study (i.e. political, economic, and government stability) were grouped together. Later, Social stability (which means that there is less risk of riots or protest towards the government) was added under the government (national) stability along with political and economic stability as in Kayikci (2010).

Cost (C_3)

The attributes related to cost were rather easy for the group working members to organise. The cost related attributes were consisted of:

1. Storage (SC_{31});
2. Logistics (SC_{32});
3. Replenishment (SC_{33});
4. Labour (SC_{34}); and,
5. Land (SC_{35}).

The panels did not feel that land and labour costs are an issue for their organisation because most of the land that they use is provided to them to purchase free of charge from the government while most of the contractors who work in the warehouse are working for low wages. Meanwhile, they reported that the storage costs include the maintenance of some of the relief items (such as armoured-vehicles, cold storage items, and forklifts). They also described how replenishment costs arise from purchasing relief items due to competitive prices, productivity and accessibility in the local and neighbouring countries (Respondent A2). They added that logistics costs include supplying a pre-positioned warehouse to the aid recipients and supplying other regional warehouses.

Cooperation (C_4)

The cooperation of different actors was seen as a major issue for many members of the panel, which was initially triggered by discussing the existence and cooperation of other agents (e.g. NGOs and logistics companies). The panel discussed that locating a pre-positioned warehouse needs the help of many organisations that are involved in the humanitarian relief operation, including:

1. Host Government (SC_{41});
2. United Nations (SC_{42});
3. Neighbour Countries (SC_{43});
4. Logistics Agents (SC_{44});
5. International NGOs (SC_{45}); and,
6. Local NGOs (SC_{46}).

Logistics companies are important in providing trained and qualified logisticians who are capable of providing an efficient service (Respondents A7 and A9). However, the panel tended to emphasise the role of the host government because they are the body that will allow tax exemption of relief items and who will offer warehouse facilities (including land or a warehouse), prompt financial systems, and other benefits that could attract the organisation to contribute.

Logistics (C_5)

Logistics related factors are divided into:

1. Airport (SC_{51});
2. Seaport (SC_{52});
3. Road (SC_{53}); and,
4. Warehouse (SC_{54}).

The panel reported that the connectivity of the transport mode was a major concern when they approach the pre-positioned warehouse location decision-making problem. The existence of airports, seaports, warehouses, and roads are crucial to transport connectivity and they can enable an effective immediate response to be provided. In addition, the logistics services provided by these logistics agents are also crucial (Respondents A1 and A7). In the findings of the exploratory study the logistics services were exposed by various terms, including: trained and qualified personnel, labour availability, and logistics services. The panel decided to group these terms together into one major attribute (i.e. logistics). Therefore, the major attribute of 'logistics' includes the availability of transport connectivity and logistics services.

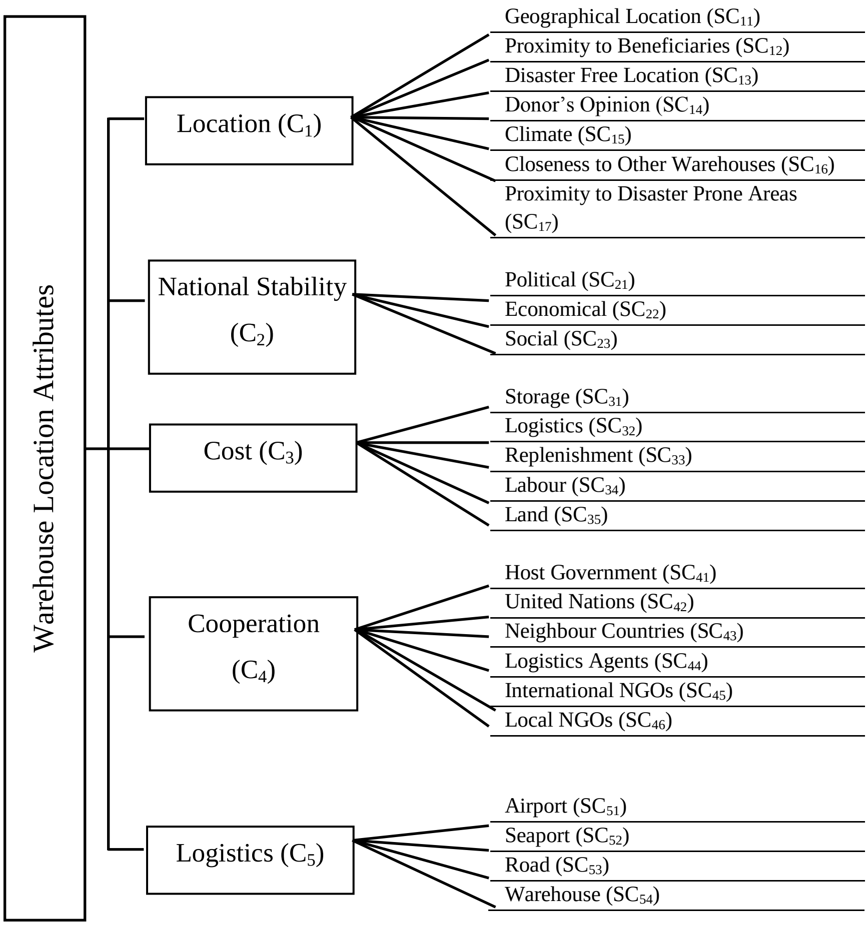
The panel also reported that an airport is an important factor for the organisation because most emergency relief items are delivered through air-chartered flights in order to provide a quick response. To enable this response, the airport needs to have suitable capacity to handle large aircraft up to B747. 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 national carrier connections will speed the delivery of emergency relief items while using less effort. In addition, an abundant availability of local air cargo companies can lower the burden of chartering aircraft when short of time (Respondents A3 and A4). The airport's operational ability should be capable of handling air cargo effectively and in a professional manner.

The panel reported that a seaport is another important logistics infrastructure attribute when making the pre-positioned warehouse location decision. Seaports are normally used to receive large quantities of relief items from suppliers for replenishment purpose and to deliver relief to regional warehouses for long-term post-disaster relief operations (Respondents A1 and A6). Seaports should have frequent departure schedules, which mean that if they miss a shipment they will not have to wait long for the next arrival (Respondents A1 and A5). The facilities of the seaport affect the operating cost, the quality of the storage, and the handling time. The handling capacity must be adequate for the organisation 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 (Respondents A1 and A8).

Warehouse related factors are importance in logistics. The capacity of the warehouse should have adequate space to store large amounts of relief items (Respondent A10). The relief items are highly valuable and are always in a target for theft (Respondent A2). For this reason, the expert panels are always concerned with security issues and safeness of the warehouse. Warehouse should be near to the urban facilities for electricity and water supplies.

In the interviews the panel reported that road-related attributes include the condition of the roads, the availability of trucking services, and the number of road connections. The road conditions can have a significant effect on: the delivery time from the warehouse to the airport, the safety of the drivers and on the number and types of relief items that can be carried (Respondent A1 and A7). Since the international emergency relief items are usually delivered via air charter, the number of road connections with neighbouring countries is less likely to be a concern (Respondent A3); however, there are cases in the African region where the relief items are delivered via road from pre-positioned warehouses considered to be important (Respondents A3 and A5).

Figure 6.3 Decision hierarchical structures for regional determining warehouse location attributes



Source: Author

6.2.3.2 Excluded Factors

There were some attributes that were brought up during the discussion but which were not involved in the hierarchical structure (e.g. the availability of rail networks and warehouses that are located in close proximity to the suppliers). In addition, the attribute of IT/communication infrastructure was eliminated in the hierarchy structure. Although the attribute of the rail network was brought up when the panel was discussing the transport connectivity, when compared to the other transport modes rail is rarely used for emergency response purposes. Hence, the loading and unloading process will take longer than it used to. Most importantly, it is difficult to access the warehouse from the airport because the relief items will be delivered through chartered aircraft for quick response. Adding a rail network to the transport connectivity will increase costs and time.

The proximity to the suppliers was another issue that was brought up during the discussion related to the location attribute. In the initial stage the panel thought about adding this factor to the hierarchical structure; however, they concluded that the strategic location of the pre-positioned warehouse is meant to deliver the relief item to the beneficiaries within 48 hours of a disaster. All of the deliveries are made through chartered aircraft while large amounts of relief items are delivered by sea directly from the suppliers. Consequently, the panel felt that the proximity to the suppliers is not a major issue for selecting the warehouse location.

The entire decision-making panel agreed that the IT/communication infrastructure is another of the essential and crucial attributes of a warehouse location. No matter how suitable the warehouse location is, or how well-equipped it is, it will be useless without a basic IT/communication infrastructure (Respondent 1). Nowadays, it will be natural for the country that houses the warehouse to have proper IT/communication infrastructure, so the panel decided not to include this in the hierarchical structure for their organisation. This is also shown in the case of Rwanda Genocide in 1994, where IT links were very high priority in the recovery phase (Choi *et al.* 2010). This observation therefore confirms findings elsewhere.

The excluded factors are applied only in the conducted case study of the organisation’s pre-positioned warehouse strategy purpose. This is because International Humanitarian Organisation A focuses on the distribution of the relief goods from the central warehouse to beneficiaries in the initial stage of the crisis. However, these excluded factors could be very high priority in other organisations' warehouse location selection where road, railways, and IT links played a major role in the recovery phase for 94/95 Rwanda crisis (Choi *et al.* 2010).

6.2.4 Warehouse Locations

International Humanitarian Organisation A operates five pre-positioned warehouses around the world. The main warehouses are called CES, where it operates only during emergency crisis. The organisation also operates regional stockpiles, where it normally assists in post-disaster aid operations. International Humanitarian Organisation A operates CES in Location A and Location B. The regional warehouses are operated in Location C, Location D, and Location E. The main purpose of this case study is to find out the regional determining attributes that were identified for the organisation and to identify the optimal location by applying those attributes. In this section, two CES warehouses will be compared since they are the largest warehouses for stockpiling emergency relief items for the organisations emergency operations. The main characteristics of Location A and Location B are compared in Table 6.5.

Table 6.5 The main characteristics of Location A and Location B

	Location A	**Location B**
Cost	Free of charge	Free of charge
Additional costs	Movement of stock (receipts and releases) Insurance based on average values of stock in the warehouse Kuhn & Nagel (K&N) under global frame agreement to deliver and collect stock to/from the warehouse	
Warehouse management	Khun & Nagel (K&N)	UNICEF
Holding capacity	5,000m^2 warehouse 3,000m^2 open capacity	5,000m^3 warehouse
Future holding capacity	20,000m^2	10,000m^3
No. of airports	5	1
No. of seaport	1	1
Aim response capacity	500,000 persons	100,000 persons
Main area of service	Global	West Africa Europe
Loading capacity per day	12 full charter aircraft	1 full charter aircraft
Flight take off time	Only in the night	Usually outside 'normal' office hours
No. of staffs	15	Managed by UNICEF under MOU

Source: Respondents A 1 and A 2

Location A

Location A was started in 2006 in order to take advantage of the strategic location. Location A's office and warehouse are located on the premises of the International Humanitarian City (IHC), along with several other UN agencies and international local NGOs. Location A saves approximately US$700,000 annually in storage costs by using government provided warehouse facilities (Respondent A1).

Location A enjoys unrivalled logistics facilities. A seamless supply chain by sea and air is ensured through proximity to Jebel Ali, the Middle East's biggest and busiest seaport. From Jebel Ali, cargo vessels sail weekly to ports worldwide, including remote destinations. 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 A's logistics services are renowned for their professionalism and cost-efficiency. (Respondents A1 and A 2).

The emergency stockpile in Location A is the largest of several organisations' global stockpiles. It can cater for basic relief items such as tents, blankets, plastic sheeting, mosquito nets, kitchen sets, and jerry cans for up to 500,000 people anywhere in the world. Pre-fabricated warehouses, staff-accommodation kits, generators, bullet-proof vests for staff, and office support are also available.

In 2010, Location A despatched ninety-six shipments of shelter relief items and vehicles to thirty-six countries. There was a significant increase from five charter flights in 2007 to fifty-three in 2010 and from four containers in 2006 to 444 containers in 2010. In 2010, twenty of the shipments were air charters, each carrying between forty to one-hundred metric tons of cargo exclusively for the organisation. About half of the flights left from Dubai while the others departed from Sharjah Airport. (Respondent A1). During 2010, 16,8000m^3 of relief items were handled with on average three incoming and outgoing shipments per week. Since February 2007, Location A has shipped approximately two-hundred vehicles to various emergency operations (Respondent A2).

Khun & Nagel is the current worldwide logistics partner for this organisation, providing warehouse management and equipment in Dubai on a free-of-charge basis. The current storage capacity of location A is about 8,000m^2; including 3,000m^2 open storage area to hold 150 vehicles, which is scheduled to increase to 20,000m^2 in the near future. Location A has fifteen staff who works in the SMS, telecommunications and IT staff. Several functions in the Dubai office are regional, such as fleet management, IP procurement and IT. A market research function has also recently been added to help the Head Quarter (HQ) buyer source from the region.

Location B

A total of 5,000m^3 of storage space is provided free of charge by the Government of Denmark through UNICEF, which will increase up to 10,000m^3 when UNICEF moves to the new fully-automated warehouse in 2012. Location B is managed by UNICEF under MOU. None of International Humanitarian Organisation A's staff are employed at this facility.

Location B aims to have a 15% to 20% response capacity (for 500,000 persons), for the following reasons:

1. West Africa and Europe have been faster, cheaper and easier serviced from location B by air and sea; and,
2. Charter aircraft are suitable to fly in the EU because they fall within the noise level restrictions, which is not the case with most aircraft kept in location A for chartered cargo flights.

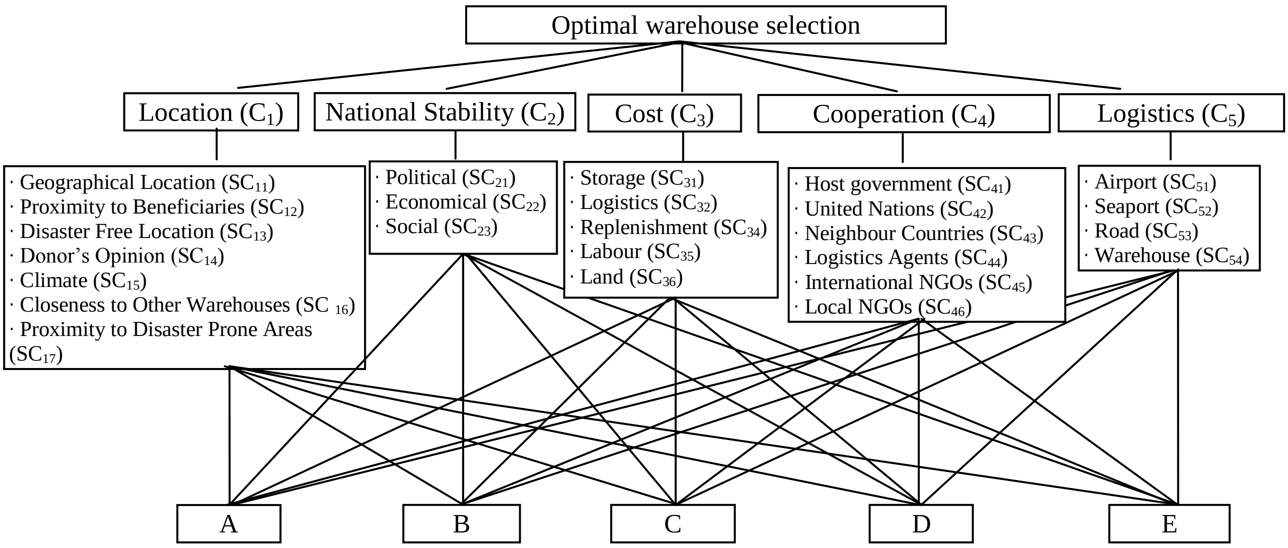
Costs directly relate to the movement of stock measured by receipts and releases. The tariffs per m^3 paid to UNICEF includes: "paperwork" relating to obtaining duty and tax exemptions, labour, record keeping, and reporting. In 2009 International Humanitarian Organisation A paid UNICEF US$78,551 for Location B, while in the first quarter of 2010 the cost was only US$16,000. In addition, UNICEF can load 300m^3 of cargo per day if required, which is the capacity of one full charter aircraft. This figure can be doubled if a subsequent overtime payment is additionally charged. Maintaining a second location for airlifts automatically doubles the organisation's response capacity, as opposed to a "put all our eggs in one basket" policy in one location. While cargo flights from Location A can only take off in the night due to the extreme day temperatures in Dubai (Respondent 7), there is no restriction in relation to this factor applicable in Location B. However, it should be noted that cargo flights in Location B are usually flown outside "normal" office hours because this is the cheapest time to have aircraft on the ground for loading and unloading.

In 2010, most relief items were sent from Location A instead of Location B, for the following reasons (Respondents A1 and A7):

1. A donated flight by Her Highness originated in Location A, which meant that the organisation managed to secure space for six hospital tents;
2. Shared UN flights (with WFP) and flights of IOM (the requester and recipient) originated in Dubai, therefore, plastic sheets and LWETs were sent from Dubai; and,
3. Some items were only stocked in Dubai (hospital tens, solar torches, and accommodation kits).

The decision hierarchy of International Humanitarian Organisation A is illustrated below in Figure 6.4:

Figure 6.4 Display of major criteria and sub-criteria for case study A



Source: Author

6.2.5 Case Study A: Discussion

The main goal in the first case study was to identify the regional attributes from a global perspective in the pre-positioned warehouse location problem that were used by International Humanitarian Organisation A. In addition, these attributes will be evaluated to find the optimal warehouse. The two central warehouse locations were discussed (i.e. Location A and Location B) because they are the main warehouses that are used for emergency response whereas the other warehouses are operated for long-term humanitarian relief purposes. During the study, the respondents strongly argued that all the warehouses are important because of their different purposes in the organisation's supply chain. Consequently, this study does not regard that any of the pre-positioned warehouses is more important or superior to the others. The alternative warehouse locations are there to provide comparative insight to explain the attributes that were used for the organisation for warehouse location problems.

6.3 Case Study B: Specific Site Determinants, a Micro View

The objective of Case Study B is to identify the specific site determinant attributes for the warehouse location problem that were applied in the humanitarian relief organisations that are based in Dubai, UAE. The case study will also investigate the location of the pre-positioned warehouses in relation to the location decision attributes.

6.3.1 Case Study Background

UN agencies and international and local NGOs are located in the premises of the IHC. The premises are provided free of charge to the organisation thanks to Her Royal Highness Princess Haya Bint Al Hussein[2]. The next sub-section briefly introduces the details of IHC's background and Dubai's commitment, mission and vision, services and facilities that were obtained by the organisation's source (IHC, 2006) and through casual meetings with the interviewees.

International Humanitarian City (IHC)

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 services specifically designed to meet their needs. The IHC is a non-religious, non-political and non-profit organisation.

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[2] Wife of His Highness Sheikh Mohammed Bin Rashid Al Maktoum, Vice-President and Prime Minister of the UAE and Ruler of Dubai

The IHC 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 proven Dubai free zone model the IHC is able to address the specific 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.

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.

Vision and Mission

The vision of IHC is to be a leading global humanitarian logistics hub that connects East and West, empowering those to create lasting change in the lives of people in need (Respondent B11).

The IHC is a non-profit independent free zone authority mandated by the government of Dubai to facilitate international humanitarian aid by:

1. Supplying leading humanitarian actors with a world-class logistics infrastructure, value-added services and administrative support;
2. Providing a platform for United Nations, non-profit organisations and regional staff to strengthen aid responses; and,
3. Facilitating coordination and collaboration among all aid providers

Dubai's Commitment to the Humanitarian Community

Dubai and its people have a history of giving and contributing to the society and the world they share. Consequently, IHC is a key emblem of Dubai's vision and the integral part of its strategy. Internationally recognised as one of the fastest growing economies in the world, Dubai has rapidly achieved its status as a hub for the region.

A key contributing factor to Dubai's dynamic growth is its location. Situated at the crossroads of Europe and Asia, the location grants this city unrivalled access to developed and emerging markets. This wider region, home to 1.8 billion people, encompasses Africa, the Levant, the Caspian Sea and former Soviet Union and South Asia (Respondent B 11).

Dubai's value to the global humanitarian community includes:

1. Logistical hub;
2. Strategic geographic location;
3. World class air and seaport facilities;
4. Cost effective procurement options;
5. Political stability and safety; and,
6. Excellent infrastructure.

Dubai is also a thriving cosmopolitan city, with a population made up of more than 150 nationalities; this brings with a sharp global awareness and outward look culture.

Facilities

At present, IHC operates out of its premises in Dubai, which are located behind Business Bay. The secure compound is designed to meet the specific needs of IHC members, and it includes:

Office space	: 4 office buildings
Warehouse	: 21,000 m^2 of warehouse floor space
Auditorium	: 50 seats, stage, speaker podium and comprehensive audiovisual equipment

Services

IHC provides its member organisations with a range of specialised services to facilitate their operations out of Dubai, including:

Facilitates management	: Maintenance, security and leasing
Government services	: Visa and government related series
Registration services	: Registration and licensing
Press office	: Publication of IHC members' latest news on the IHC website
IHC media watch	: Online news monitoring services, including daily e-mail alerts
Recruitment e-Portal	: Access to online CV database and posting job openings
Volunteer e-Portal	: Access to online volunteer database and posting volunteer Appeals
Pro Bono e-Portal	: Access to online Pro Bono database
Events e-Portal	: Promotion of IHC members' upcoming events through the IHC website

IHC Members

The total of 46 organisations use the facilities provided by the IHC. The characteristics of the IHC members are shown in Appendix D.8. The members are largely categorised into two groups: non-profit organisations and commercial companies. The non-profit organisations are the United Nations agencies, specialised agencies, non-governmental organisations, charities, foundations, news, research and educational institutions. The commercial companies include manufacturers as well as service providers (e.g. logistics, security, maintenance, and consulting), who supply aid related goods and services (e.g. shelters, medical equipment, food items, and vehicles). Specialised agencies include governmental and intergovernmental organisations. NGOs, in its broadest sense, are an organisation that is not part of any government. The purpose of NGOs is to cover the entire range of human interests, and they can be either domestic or international in scope. Charitable organisations comprise trusts, companies or unincorporated associations established for charitable purposes only. Trusts or bodies established partly for charitable purposes are sometimes considered as, or treated as, charities. A foundation is a type of philanthropic or charitable organisation set up by individuals or institutions as a legal entity (i.e. a corporation or trust) with the goals of the foundation, or as a charity entity that receives grants in order to support a specific activity or activities of charitable purposes.

The non-profit organisations and commercial companies of the IHC members must follow a code of ethics that are provided by IHC. The code of ethics is shown as follows:

Table 6.6 IHC's code of ethics

Non-Profit Organisations	Commercial companies
The 'humanitarian' imperative comes first	The 'humanitarian' imperative comes first
The organisations' activities do not aim to further a political or religious standpoint	The company demonstrates integrity, independence, transparency and accountability
The organisation is accountable to those it seeks to assist, and those from whom it accepts resources	The company does not tolerate forced or compulsory labour or the use of child labour
The organisation's major portion of funding is derived from contributions by affiliates, individuals or other non-governmental sources	The company supports and respects internationally accepted standards of human rights
The organisation follows a democratic decision making process	The company does not practice discrimination of any kind against employees
The organisations maintains integrity and independence	The company undertakes initiatives to promote environmental social responsibility

IHC's Innovative Concept

IHC has a unique value proposition that is a comprehensive combined with a strategic environment that capitalises on Dubai's incentives. There are several reasons that make IHC (Dubai) unique and which make it a strategic location. IHC is a community mix of local and international humanitarian non-profits and commercial suppliers. It is a fully integrated one-stop-shop, with access to procurers, suppliers and business partners and fast multi-modal logistics capabilities. In addition, IHC provides the office space, warehousing, and meeting facilities and a comprehensive set of value-added services. Consequently, IHC has increased the visibility and networking opportunities and become a platform for humanitarian information and knowledge exchange with a facilitated access to job seekers and volunteers.

The IHC believes that there are specific reasons for IHC Dubai to be a strategic location. For example, IHC is located at a crossroad between East, West, North and South. This is suitable for rapid disaster response because it has only 7 hours maximum flight time to many major crisis-prone areas. It has very good airport and seaport infrastructure that can support 10 minute sea-to-air logistics capabilities. Dubai is well known for its economic momentum with stable local currency, political stability and governmental support. It has minimal red tape to stock relief items. The existence of professional logistics companies forms a competitive fee structure. It offers a good environment for the staff because it is a cosmopolitan area and it has an attractive living environment. IHC offers free zone benefits, which includes 100% foreign ownership, repatriation of capital and profits, free tree transfer of funds, and exemption of import and export duties.

The movement of IHC

IHC is looking locally for an alternative compound location for its members; however, they are very keen on the UN agency officers' opinions because they are their largest partner (Respondents B2, B7 and B11).

6.3.2 Group Decision-Making

Among the IHC members, opinions were taken from the organisations that are already using the warehouse facility. The organisations that will soon need the warehouse facility were provided from the IHC staff. In these organisations, the opinions of the decision-making level managers were taken.

Decision-Making Committees

Table 6.7 represents the decision-making committee members for Case Study B. In total there were eleven members of the interview panel: eight came from UN agencies, one came from an NGO, one came from a company, and one came from the IHC. Three UN agencies participated in this case study.

Table 6.7 Group working members

Organisation	Respondent	Position
UN Agency 1	B 1	Senior Logistics Officer
UN Agency 2	B 2	Senior Supply Officer
	B 3	Assistant Supply Officer
	B 4	Supply Associate
	B 5	Supply Officer
	B 6	Consultant
UN Agency 3	B 7	Senior Supply Officer
	B 8	Assistant Supply Officer
NGO	B 9	Logistics Officer
Company	B 10	Supervisor Emergency & Relief
IHC	B 11	Logistics Manager

Source: Author

6.3.3 Specific Site Determining Attributes

The determining factors for warehouse location problem for IHC were discussed in the panel meeting. The panels brought up what were important factors for the choice of alternative warehouses for their organisation during the meeting. Due to the busy schedules of the panel members, only one meeting was organised by the IHC to discuss the determining factors. The panels were briefed in advance about the important factors that the organisation should consider. During the meeting, the panels discussed the factors that were important to them for the location of a new warehouse. The factors were grouped into a hierarchical structure according to the related areas that arose while discussing the factors. The meeting was concluded when the panels all agreed with the factors and the hierarchical structure. They were in agreement that the final structure will be used for analysing the alternative warehouse sites. The final hierarchical structure of the factors will be illustrated in next sub-section, together with feedback.

Hierarchical Structure

After the warehouse location factors were determined and confirmed by the panel members, they also agreed with the structuring of the decision hierarchy of the factors. The factors were initially grouped into related attributes, which was done while conducting the determining factors. They all agreed that the attributes should be grouped and formed into a hierarchical structure. The decision hierarchical structure for warehouse location attributes for IHC is illustrated in Figure 6.5.

Distance (C_a)

The sub-criteria for the distance attributes were formed in:

1. Jebel Ali Seaport (SC_{a1});
2. Dubai Airport (SC_{a2});
3. Al Maktoum Airport (SC_{a3});
4. Sharjah Airport (SC_{a4});
5. Abu Dhabi Airport (SC_{a5}); and,
6. Ministry of Foreign Affairs (MOFA) (SC_{a6}).

Seaports are used to handle large quantities of replenishment goods; they are also used to deliver relief goods for post-disaster operations. The distance from the warehouse to Jebel Ali seaport is used in this case for the evaluation. Closeness to an airport is an essential factor for emergency operations because the goal of humanitarian relief is to get the relief goods to the beneficiaries as soon as possible after the disaster strikes (Respondent B1, B2). Dubai has four international airports (i.e. Dubai, Al Maktoum, Sharjah, and Abu Dhabi) that are suitable for use by humanitarian organisations (Respondent B2). In addition, the document handling process is another aspect that should not be overlooked. Even though humanitarian goods are normally exempted from tax and customs, some goods are very sensitive (e.g. armoured vehicles and medicines) and the whole relief process can be delayed without the proper exemption documents from the right authorities (Respondents B1, B2, and B8). In the IHC the customs related process is handled in Ministry of Foreign Affairs (MOFA).

Security and Safety (C_b)

Humanitarian warehouses store various valuable goods for humanitarian relief operations. The committee conclude that the sub-criteria for the security and safety attributes should include:

1. Warehouse (SC_{b1});
2. Fire Fighting Stations (SC_{b2});
3. Police Stations (SC_{b3});
4. Hospitals (SC_{b4}); and,
5. Road Safety (SC_{b5}).

Warehouse security includes security facilities equipped with CCTV cameras in the compound, a fire alarm system in the warehouse and offices, and the use of security guards. It is important that the warehouse has a secured perimeter around the facilities (Respondent B8). The warehouse should also be close to emergency facilities (such as fire fighting and police stations and hospitals) in case any incidents occur in the warehouse (Respondent B 4). The warehouse should be located in a safe traffic area where there is less likelihood of traffic accidents (Respondents B3 and B5). The warehouse location problem considering the security and safety factors are found in ACFID (2007) and Yang and Lee (1997)

Office facilities (C_c)

The panel agreed that the office facilities of the compound should be included in the evaluation list. The sub-criteria for the office facilities are:

1. Suitable for Diplomatic Work (SC_{c1}) ;
2. IT/Communication Infrastructure (SC_{c2});
3. Warehouse Distance (SC_{c3}); and,
4. Modular Space (SC_{c4}).

One of the respondents added that the warehouse compound should not be isolated from the diplomatic work (Respondent B9). In addition, it should have a modular space with acceptable IT/communication infrastructure and it should be close to the warehouse (Respondent B7). ACFID (2007) and Chuang (2001) included the IT/communication factor for warehouse location selection problem.

Warehouse facilities (C_d)

There are many aspects to be taken into account when considering exactly which warehouse facilities are required for the humanitarian relief operations. The warehouse facilities attributes consists of:

1. Floor Capacity(SC_{d1});
2. Open Storage (SC_{d2});
3. Office Facility (SC_{d3});
4. Spill-Over Area (SC_{d4});
5. Ceiling Height (SC_{d5});
6. Loading Bays (SC_{d6});
7. Flood Lights (SC_{d7});
8. Openings (SC_{d8}); and,
9. Doors at Both Ends (SC_{d9}).

Floor capacity and the height of the ceiling of the warehouse are important in determining the volumetric capacity of the warehouse. Meanwhile, the availability of open storage is also important to stock the vehicles for relief operations. For the effective loading of relief goods, the warehouse should have: a general spill-over area to store surplus items, loading bays that are suitable for forty-feet high cube containers and flatbed trucks, flood lights for night operations, and doors at both ends of the warehouse to speed up loading time (Respondents B2, B5, and B9). The office facility for warehouse staff should also have sanitation facilities and air-conditioners to combat the heat (Respondent B2). Warehouse facilities related attributes can also be found in the warehouse location selection problems in the literature (ACFID, 2007; Özcan *et al.* 2011; Rawls and Turnquist, 2010).

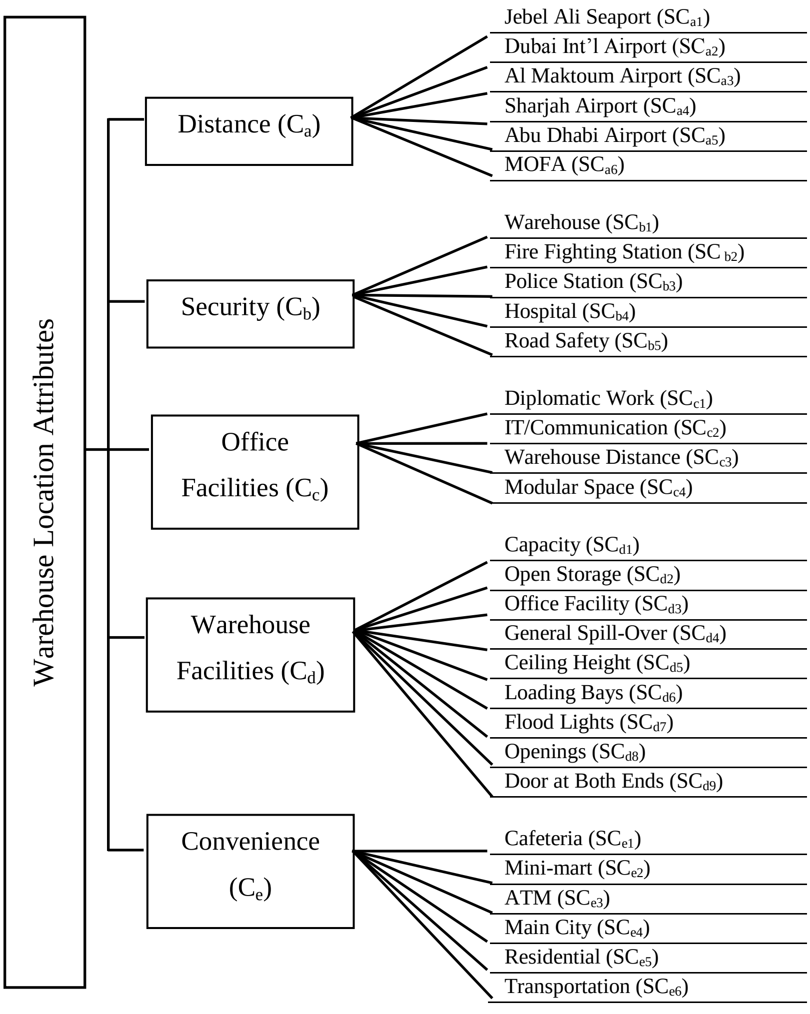
Convenience (C_e)

In the warehouse compound, the welfare of the staff is an important criterion. The attributes that the committee looked into for the convenience of the working environment were:

1. Cafeteria (SC_{e1});
2. Mini-mart (SC_{e2});
3. ATM (SC_{e3});
4. Main City (SC_{e4});
5. Residential Accommodation (SC_{e5}); and,
6. Public Transportation (SC_{e6}).

The 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 easy access (Respondent B7). Warehouse location selection problem regarding the quality of living (Alberto, 2000; Min and Melachrinoudia, 1999), residential accommodation (Levine, 1991; Yang and Lee, 1997), proximity to bank (Sarkis and Sundarraj, 2002), and public transportation (Min and Melachrinoudia, 1999) are also found in commercial sector.

Figure 6.5 Decision hierarchical structure for specific site determining attributes for IHC



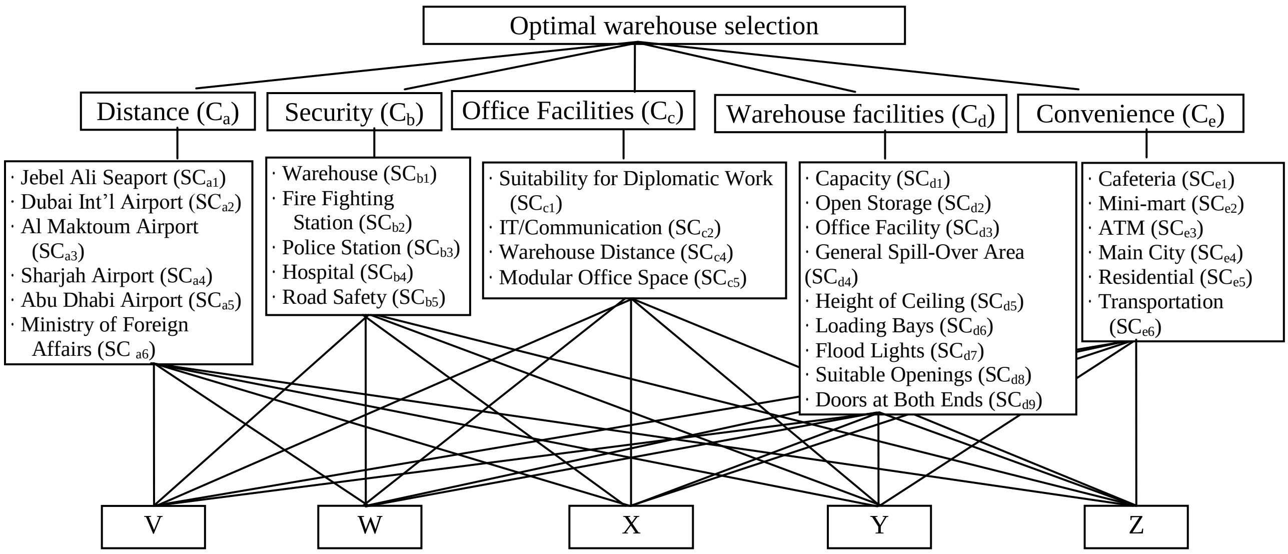
Source: Author

6.3.4 Warehouse Locations

The IHC have provided four alternative warehouse locations in Dubai for the members of IHC for evaluation. The four alternative warehouse locations have been indicated as Location W, Location X, Location Y, and Location Z. The evaluation criteria of the current warehouse compound (IHC), Location V, are given to compare with the alternative warehouse locations. Location W is located in Dubai Industrial City, Location X and Location Y are located in Jebel Ali industrial area and Location Z is located in Dubai Logistics City. Appendix D.9 describes a comparison of the alternative warehouse locations using the evaluation criteria that the panel agreed for the movement from the current compound. It can be seen that the evaluation of the criteria is a mixture of tangibles and intangibles.

The decision hierarchy, structured with the determined alternatives locations and criteria, is provided in Figure 6.6.

Figure 6.6 Display of major criteria and sub-criteria for case study B



Source: Author

6.3.5 Case Study B: Discussions

The main goal in the second case study was to identify the specific site determinant attributes that were used in humanitarian pre-positioned warehouse location problem from a micro perspective, in this case IHC which is located in Dubai, UAE. The IHC were planning to move from their current compound and were looking for alternative locations. The attributes were applied for the evaluation of the four alternative warehouse sites. The criteria were evaluated by the IHC members who currently use and who will need the warehouse facilities for their future supply chain operations. Due to the busy schedule of the panel members, only one meeting was arranged to determine the attributes and hierarchical structure. This section has provided a brief explanation of the criteria and alternative warehouse locations.

6.4 Chapter Summary

In this chapter, the attributes for regional and specific site determinants for humanitarian pre-positioned warehouse were identified from a macro and micro perspective of the two case studies. The first case study identified the macro attributes that were used in International Humanitarian Organisation A (which has pre-positioned warehouse locations that are based all around the world) from a macro perspective. The second case study identified the micro attributes that were used in IHC from a micro perspective. At that time, IHC were planning to move to new alternative warehouse locations. The identified attributes are a mixture of tangible and intangible factors for both case studies.

CHAPTER 7
SUMMARY OF FINDINGS I:
REGIONAL (MACRO) DETERMINANTS

7.1 Chapter Overview

In this chapter, the preference of the pre-positioned warehouse location attributes for humanitarian relief logistics operations are found from International Humanitarian Organisation A. This chapter aims to provide the regional (i.e. macro) determinant findings that were used to evaluate the warehouse. The ranking of alternatives warehouse locations were analysed using the evaluated attributes. The evaluation of the preference of the attribution has been analysed by AHP and the evaluation of alternative warehouse location and determination of the final rank has been assessed by TOPSIS and fuzzy-TOPSIS. Finally, the sensitivity analysis has been tested for robust results. Table 1.1 highlights the attributes that influence the warehouse location selection problem for their organisation from a global view (Q2) and evaluates the optimal warehouse location (Q3).

7.2 Case Study A Analysis

In this section of the analysis, the regional (i.e. macro) warehouse location attributes identified in the Chapter 6 are evaluated to obtain their weight. The pre-positioned warehouse locations are later evaluated to determine the final rank of those warehouses that were identified in Section 6.2.4. Finally, the sensitivity analysis is tested for accurate and robust results.

7.3 The Criteria Weights

The overall result of the reference of the attributes is analysed at the start of this section. The preferences of the attribution were calculated by geometric means to avoid error and to obtain the pairwise comparison matrix on which there is a consensus (see Chapter 4, Section 4.4.1.4). A detailed analysis of this group will follow. The groups will then be compared. The calculated results of the weights of criteria are determined based on the analysis procedure that is presented in Chapter 4, Section 4.4.1.2.

7.3.1 Evaluation of the Major Attributes

The result of the matrix for criteria for the pairwise comparison of the major attributes is shown in Appendix C.1. The results obtained from the computations based on the pairwise comparison matrix provided in Appendix C.1, are presented in Table 7.1, which includes the Eigen Value (λ_{max}), Consistency Index (CI), Random Consistency index (RI), and the Consistency Ratio (CR).

Table 7.1 Consistency checking of the matrix for Case Study A

Attributes	λ_{max}	CI	RI	CR
Major	5.3948	0.0987	1.12	0.0881
Location (C_1)	7.2358	0.0393	1.32	0.0298
National Stability (C_2)	3.1032	0.0516	0.58	0.0890
Cost (C_3)	5.0864	0.0216	1.12	0.0193
Cooperation (C_4)	6.2325	0.0465	1.24	0.0375
Logistics (C_5)	4.0681	0.0227	0.90	0.0252

Source: Author

Based on the consistency checking obtained in above table, the entire CR of the pairwise matrix for all attributes is calculated less than 0.1. This shows that the weights are shown to be consistent and they acceptable to be used in the selection process (Saaty, 1980). The CR shows less than 0.1 in the result of the group comparison as well (Appendix C.2).

7.3.1.1 Overall Results

Table 7.2 presents the preference order of importance of the major attributes. The Cooperation (C_4) attribute turned out to be the most important factor for the consideration of the warehouse location selection with a normalised weight of 0.2908. The National Stability (C_2) attribute follows with a normalised weight of 0.2282, which makes it the next important attribute. The first two attributes accumulate a weight of 0.5190 (51.90%), which is more than half of the whole percentage. The third important attribute is Cost (C_3), which has a normalised weight of 0.2270. The accumulated weight now rises to 0.7460 (74.60%). The Logistics (C_5) attribute was ranked fourth in the table, with a normalised weight of 0.1525. The last attribute, which was considered as the least important, is the Location (C_1) attribute, which has a normalised weight of 0.1015. Hence, Table 7.2 demonstrates that the decision-makers consider the cooperation attributes to be the most important among the major attributes for pre-positioning warehouse location selection.

Table 7.2 Preference order of the major attributes for Case Study A

Rank	Criteria	Normalised Weight	Accumulated Weight
1	Cooperation (C_4)	0.2908	0.2908
2	National Stability (C_2)	0.2282	0.5190
3	Cost (C_3)	0.2270	0.7460
4	Logistics (C_5)	0.1525	0.8985
5	Location (C_1)	0.1015	1.0000
	Total Weight	1.0000	

Source: Author

7.3.1.2 Group Comparison

Table 7.3 compares the preference order of the major criteria of each group.

Table 7.3 Preference order of the major attributes for Case Study A (Group)

Rank	Geneva	NW	AW	Budapest	NW	AW	Dubai	Weight	AW
1	C_4	0.2869	0.2869	C_4	0.3286	0.3286	C_4	0.2975	0.2975
2	C_2	0.2394	0.5263	C_2	0.2564	0.5850	C_2	0.2564	0.5539
3	C_3	0.2166	0.7429	C_5	0.1823	0.7673	C_3	0.2114	0.7653
4	C_5	0.1883	0.9312	C_3	0.1481	0.9154	C_5	0.1523	0.9176
5	C_1	0.0688	1.0000	C_1	0.0846	1.0000	C_1	0.0824	1.0000
Total Weight		1.0000			1.0000			1.0000	

C_1 – Location, C_2 – National Stability, C_3 – Cost, C_4 – Cooperation, C_5 – Logistics, NW – Normalised Weight, AW – Accumulated Weight

Source: Author

Table 7.3 shows that Cooperation (C_4) is the most important attribute and Location (C_1) is the least important attribute. The results of the ranking order in Geneva and Dubai are same as those in Table 7.2. The preference order from Budapest shows Logistics (C_5) to be slightly more important than Cost (C_3). Consequently, the decision-makers considered that Cooperation (C_4) and National Stability (C_2) are their most important attributes when selecting the warehouse location, while Location (C_1) is the least important. This happens because relief goods are now accessible in most places around the world due to improvements in the modes of transportation (Respondents A1, A6, and A8).

7.3.2 Evaluation of Location Attributes

7.3.2.1 Overall Results

Table 7.4 presents the overall results of the preference order of the sub-attributes for the Location (C_1) attributes.

Table 7.4 Preference order of Location attributes

Rank	Criteria	Normalised Weight	Accumulated Weight
1	Proximity to Disaster Prone Areas (SC_{17})	0.2275	0.2275
2	Disaster Free Location (SC_{13})	0.1826	0.4101
3	Donor's Opinion (SC_{14})	0.1790	0.5891
4	Proximity to Beneficiaries (SC_{12})	0.1604	0.7495
5	Closeness to Other Warehouses (SC_{16})	0.1194	0.8689
6	Geographical Location (SC_{11})	0.0864	0.9553
7	Climate (SC_{15})	0.0447	1.0000
	Total Weight	1.0000	

Source: Author

Proximity to a Disaster Prone Area (SC_{17}) is considered to be the most important attribute, with a normalised weight of 0.2275. Disaster Free Location (SC_{13}) follows, with a normalised weight of 0.1826. Meanwhile, the Donor's Opinion (SC_{14}) ranked third in the table, with a normalised weight of 0.1790. The first three attributes have an accumulated weight of 0.5891 (58.91%) among the attributes. Proximity to Beneficiaries (SC_{12}) is fourth in the table, with a normalised weight of 0.1604. However, the difference of the normalised weight among the Disaster Free Location (SC_{13}), the Donors' Opinion (SC_{14}), and the Proximity to Beneficiaries (SC_{12}) is very small. This shows that these three attributes are considered to be equally or slightly more important than the others. In addition, the rankings can change depending on the decision-makers preference. The fifth most popular attribute on the table is Closeness to Other

Warehouses (SC_{16}), with a normalised weight of 0.1194. The last two attributes are considered to be less important in warehouse selection, they are: Geographical Location (SC_{11}), which has a normalised weight of 0.0864 and Climate (SC_{15}) which has a normalised weight of 0.0447. Table 7.4 shows that Proximity to Disaster Prone Areas (SC_{17}) is considered to be the most important attribute for warehouse selection while Climate (SC_{15}) is the least important. In addition, Disaster Free Location (SC_{13}), Donor's Opinion (SC_{14}), and Proximity to Beneficiaries (SC_{12}) are slightly more important.

7.3.2.2 Group Comparison

Table 7.5 presents the preference order of the sub-attributes for Location (C_1) attributes for group comparison.

Table 7.5 Preference order of the Location attributes (Group)

Rank	Geneva	NW	AW	Budapest	NW	AW	Dubai	NW	AW
1	SC_{12}	0.2419	0.2419	SC_{17}	0.2190	0.2190	SC_{17}	0.2331	0.2331
2	SC_{17}	0.1913	0.4332	SC_{14}	0.2028	0.4218	SC_{12}	0.1788	0.4119
3	SC_{13}	0.1641	0.5973	SC_{12}	0.1752	0.5970	SC_{13}	0.1614	0.5733
4	SC_{14}	0.1502	0.7475	SC_{13}	0.1625	0.7595	SC_{14}	0.1442	0.7175
5	SC_{16}	0.1310	0.8785	SC_{16}	0.1076	0.8671	SC_{16}	0.1367	0.8542
6	SC_{11}	0.0824	0.9609	SC_{11}	0.0868	0.9539	SC_{11}	0.0799	0.9341
7	SC_{15}	0.0391	1.0000	SC_{15}	0.0461	1.0000	SC_{15}	0.0659	1.0000
Total Weight		1.0000			1.0000			1.0000	

SC_{11} – Geographical Location, SC_{12} – Proximity to Beneficiaries, SC_{13} – Disaster Free Location, SC_{14} – Donor's Opinion, SC_{15} – Climate, SC_{16} – Closeness to Other Warehouse, SC_{17} – Proximity to Disaster Prone Areas, NW – Normalised Weight, AW – Accumulated Weight

Source: Author

Table 7.5 shows that the most important attribute in Budapest and Dubai is Proximity to Disaster Prone Areas (SC_{17}). Meanwhile, in Geneva Proximity to Beneficiaries (SC_{12}) is the most important attribute. It is interesting to note that the first four most important attributes are Proximity to Beneficiaries (SC_{12}), Disaster Free Location (SC_{13}), Donor's Opinion (SC_{14}), and Proximity to Disaster Prone Areas (SC_{17}) in all three locations. The ranking order varies but remains in the top four for warehouse selection. Furthermore, Proximity to Disaster Prone Areas (SC_{17}) and Proximity to Beneficiaries (SC_{12}) are always preferred above Disaster Free Location (SC_{13}), because the decision-makers believe that a warehouse which is close to the beneficiaries enables them to deliver the relief goods quickly to the beneficiaries (Respondent

A11). However, the warehouse will be useless if the disaster hits that area so it is important to locate the pre-positioned warehouse to in a safe area (Respondents A2, A8, and A11). In addition, sometimes the donor's opinion can influence the positioning of the warehouse because they make a significant financial contribution (Respondent A11). The last three attributes remain in the same ranking order in all three locations while the Climate (SC_{15}) attributes are the least important. The geographical location of the warehouse can be considered to be less important because of the fact that the relief goods can be delivered from anywhere to the beneficiaries due to recent improvements in transport infrastructure (Respondents A1, A6, and A8). Climate is less important compare to the other attributes because the organisation stores only Non-Food-Items (NFIs), so there is no concern about the deterioration of the relief goods; however, they will affect the working environment of the staff (Respondent A1).

7.3.3 Evaluation of National Stability Attributes

7.3.3.1 Overall Results

Table 7.6 presents the overall result of the preference order of sub-attributes for National Stability (C_2) attributes.

Table 7.6 Preference order of National Stability attributes

Rank	Criteria	Normalised Weight	Accumulated Weight
1	Political (SC_{21})	0.4934	0.4934
2	Economic (SC_{22})	0.3108	0.8042
3	Social (SC_{23})	0.1958	1.0000
	Total Weight	1.0000	

Source: Author

Political Stability (SC_{21}) is considered as the most important attribute, with a normalised weight of 0.4934 (or almost half of the total percentage). Economic Stability (SC_{22}) follows next, with a normalised weight of 0.3108. These two attributes have an accumulated weight of 0.8042 (80.42%) of the total weight. The least important attribute is Social Stability (SC_{23}), with a normalised weight of 0.1958. This result shows to be same in the findings of Kayikci (2010).

7.3.3.2 Group Comparison

Table 7.7 presents the preference of the attributes of the National Stability (C_2) for group comparison.

Table 7.7 Preference order of the National Stability attributes (Group)

Rank	Geneva	NW	AW	Budapest	NW	AW	Dubai	Weight	AW
1	SC_{21}	0.5936	0.5936	SC_{21}	0.6250	0.6250	SC_{21}	0.5936	0.5936
2	SC_{22}	0.2493	0.8429	SC_{22}	0.2385	0.8635	SC_{22}	0.2493	0.8429
3	SC_{23}	0.1571	1.0000	SC_{23}	0.1365	1.0000	SC_{23}	0.1571	1.0000
Total Weight		1.0000			1.0000			1.0000	

SC_{21} – Political, SC_{22} – Economic, SC_{23} – Social, NW – Normalised Weight, AW – Accumulated Weight

Source: Author

The results from the above table show that in all three locations the most important attribute is Political Stability (SC_{21}). The results show that the decision-makers consider the political stability as important attribute in warehouse selection because it has a normalised weight that is 50% greater than the attributes. It is very likely that the future of the organisation can be severely affected by the political stability of the country. It is easier for the organisation to prepare and respond where political issues are predictable (Respondents A1, A7, and A11).

7.3.4 Evaluation of Cost Attributes

7.3.4.1 Overall Results

Table 7.8 presents the overall result of the preference order of sub-attributes for Cost (C_3).

Table 7.8 Preference order of Cost attributes

Rank	Criteria	Normalised Weight	Accumulated Weight
1	Logistics (SC_{32})	0.3281	0.3281
2	Replenishment (SC_{33})	0.2164	0.5445
3	Storage (SC_{31})	0.1884	0.7329
4	Labour (SC_{34})	0.1428	0.8757
5	Land (SC_{35})	0.1243	1.0000
	Total Weight	1.0000	

Source: Author

Logistics (SC_{32}) is considered to be the most important attribute, with a normalised weight of 0.3281. Replenishment Cost (SC_{33}) follows next, with a normalised weight of 0.2164. These two attributes have an accumulated weight of 0.5445 (54.45%) of the total weights. Storage Cost (SC_{31}) is ranked third on the table with, a normalised weight of 0.1844. Labour (SC_{34}) is ranked fourth on the table, with a normalised weight of 0.1428. Meanwhile, Land (SC_{35}) is considered to be the least important of the attributes, with a normalised weight of 0.1243.

7.3.4.2 Group Comparison

Table 7.9 presents the preference order of sub-attributes for Cost (C_3) attributes for group comparison.

Table 7.9 Preference order of the Cost attributes (Group)

Rank	Geneva	NW	AW	Budapest	NW	AW	Dubai	Weight	AW
1	SC_{31}	0.2384	0.2384	SC_{32}	0.2880	0.2880	SC_{32}	0.3281	0.3281
2	SC_{34}	0.2384	0.4768	SC_{33}	0.2498	0.5378	SC_{33}	0.2164	0.5445
3	SC_{32}	0.2166	0.6934	SC_{31}	0.1932	0.7310	SC_{31}	0.1884	0.7329
4	SC_{33}	0.1948	0.8882	SC_{34}	0.1440	0.8750	SC_{34}	0.1428	0.8757
5	SC_{35}	0.1118	1.0000	SC_{35}	0.1250	1.0000	SC_{35}	0.1243	1.0000
Total Weight		1.0000			1.0000			1.0000	

SC_{31} – Storage, SC_{32} – Logistics, SC_{33} – Replenishment, SC_{34} – Labour, SC_{35} – Land, NW – Normalised Weight, AW – Accumulated Weight

Source: Author

Logistics (SC_{32}) is considered to be the most important attribute in Budapest and Dubai while it is ranked third most important in Geneva. In all three groups, the least important attribute for warehouse selection consideration is Land (SC_{35}). Logistics costs are an important attribute because the office is provided free of charge in most cases and logistics costs are able to reduce their financial outlay (Respondent A1). The location of the warehouse should be in a reasonable place from suppliers to reduce the replenishment costs and it should be located close to the beneficiaries to reduce the logistics cost (Respondent A7). Geneva's most important attribute is the cost of Storage (SC_{31}). Even though the land cost is free of charge, many relief organisations still have to consider lowering the storage cost for maintenance of the relief items (Respondent A11).

7.3.5 Evaluation of Cooperation Attributes

7.3.5.1 Overall Results

Table 7.10 presents the overall result of the preference order of sub-attributes for Cooperation (C_4).

Table 7.10 Preference order of Cooperation attributes

Rank	Criteria	Normalised Weight	Accumulated Weight
1	Host Government (SC_{41})	0.3678	0.3678
2	United Nations (SC_{42})	0.2442	0.6120
3	Logistics Agents (SC_{44})	0.1620	0.7740
4	Neighbouring Countries (SC_{43})	0.0804	0.8544
5	International NGOs (SC_{45})	0.0764	0.9308
6	Local NGOs (SC_{46})	0.0692	1.0000
	Total Weight	1.0000	

Source: Author

The Host Government (SC_{41}) is considered as the most important attribute for warehouse selection, with a normalised weight of 0.3678. The United Nations (SC_{42}) follows next, with a normalised weight of 0.2442. The first two attributes have an accumulated weight of 0.6120 (61.20%). Logistics Agents (SC_{44}) are ranked in third place, with a normalised weight of 0.1620. Neighbouring Countries (SC_{41}) follow next, with a normalised weight of 0.0804. International NGOs (SC_{45}) and Local NGOs (SC_{46}) are the bottom two attribute in the list; International NGOs (SC_{45}) has a normalised weight of 0.0764 while Local NGOs (SC_{46}) has a normalised weight of 0.0692. Here, Local NGOs (SC_{46}) is selected to be the least important. These two attributes are considered as less important when compared to the top three and will hardly have an effect on the warehouse selection process (Respondents A3 and A5).

7.3.5.2 Group Comparison

Table 7.11 presents the preference order of sub-attributes for Cooperation (C_4) attributes for group comparison.

Table 7.11 Preference order of Cooperation attributes (Group)

Rank	Geneva	NW	AW	Budapest	NW	AW	Dubai	Weight	AW
1	SC_{41}	0.3853	0.3853	SC_{41}	0.3866	0.3866	SC_{41}	0.4440	0.4440
2	SC_{42}	0.2900	0.6753	SC_{42}	0.2982	0.6848	SC_{42}	0.1702	0.6142
3	SC_{44}	0.1070	0.7823	SC_{44}	0.1091	0.7939	SC_{44}	0.1538	0.7680
4	SC_{43}	0.0909	0.8732	SC_{43}	0.0809	0.8748	SC_{43}	0.0914	0.8594
5	SC_{46}	0.0635	0.9367	SC_{45}	0.0639	0.9387	SC_{46}	0.0780	0.9374
6	SC_{45}	0.0633	1.0000	SC_{46}	0.0613	1.0000	SC_{45}	0.0626	1.0000
Total Weight		1.0000			1.0000			1.0000	

SC_{41} –Host Government, SC_{42} – United Nations, SC_{43} – Neighbouring Countries, SC_{44} – Logistics Agents, SC_{45} – Int'l NGOs, SC_{46} – Local NGOs, NW – Normalised Weight, AW – Accumulated Weight

Source: Author

Host Government (SC_{41}) is considered to be the most important attribute and Local NGOs (SC_{46}) is the least important. The ranking of the attributes in three locations are in the same order as those in Table 7.10. The cooperation of the host government is very important because they are the body that deals with land, warehouse, customs regulations, and bills (Respondents A1, A4, A8, and A11). The United Nation agencies are also important because they are one of the largest humanitarian organisations and they are involved in many relief projects, especially in emergency response (Respondents A1 and A8). Cooperation with the logistics agents will ease the supply chain process in a way that enables it to provide better service with infrastructure and labour (Respondent A8).

7.3.6 Evaluation of Logistics Attributes

7.3.6.1 Overall Results

Table 7.12 presents the overall result of the preference order of sub-attributes for Logistics (C_5).

Table 7.12 Preference order for Logistics attributes

Rank	Criteria	Normalised Weight	Accumulated Weight
1	Seaport (SC_{52})	0.3465	0.3465
2	Airport (SC_{51})	0.2463	0.5928
3	Road (SC_{53})	0.2036	0.7964
	Warehouse (SC_{54})	0.2036	1.0000
	Total Weight	1.0000	

Source: Author

The availability of Seaport (SC_{52}) in the country is considered to be the most important attribute, with a normalised weight of 0.3465. Airport (SC_{51}) follows next, with a normalised weight of 0.2463. The importance weight of these two attributes consists of accumulated weight of 0.5928 (59.28%). The Road (SC_{53}) and Warehouse (SC_{54}) attributes have the same normalised weight of 0.2036.

7.3.6.2 Group Comparison

Table 7.13 presents the preference order of sub-attributes for Logistics (C_5) attributes for group comparison.

Table 7.13 Preference order of Logistics attributes (Group)

Rank	Geneva	NW	AW	Budapest	NW	AW	Dubai	NW	AW
1	SC_{52}	0.3427	0.3427	SC_{52}	0.3465	0.3465	SC_{52}	0.4039	0.4039
2	SC_{54}	0.2735	0.6162	SC_{51}	0.2463	0.5928	SC_{51}	0.2389	0.6428
3	SC_{51}	0.2389	0.8551	SC_{53}	0.2036	0.7964	SC_{54}	0.1907	0.8335
4	SC_{53}	0.1449	1.0000	SC_{54}	0.2036	1.0000	SC_{53}	0.1665	1.0000
Total Weight		1.0000			1.0000			1.0000	

SC_{51} – Airport, SC_{52} – Seaport, SC_{53} – Road, SC_{54} – Warehouse, NW – Normalised Weight, AW – Accumulated Weight

Source: Author

Availability of the Seaport (SC_{52}) is considered as the most important attribute in three locations while Road (SC_{53}) was the least important attribute. The availability of the seaport is very important; it should have an adequate capacity to handle large amounts of relief items, a frequent shipping service to the demand area, and facilities for quality storage and handling time (Respondents A1, A4, A8, and A10). Roads are not a big issue for warehouse selection because most relief items are delivered from suppliers by sea and to the beneficiaries by air. Meanwhile, the road networks in other countries are rarely used in pre-positioning warehouse countries (Respondent A1 and A7). Budapest and Dubai considered the Airport (SC_{51}) to be more important than the Warehouse (SC_{54}) because in an emergency they have to deliver their relief goods to the beneficiaries within 48 hours, which would not be possible if the facilities and the infrastructure of the airport are not well equipped (Respondents A1, A4, and A10). Geneva considered the Warehouse (SC_{54}) attributes to be more important than Airport (SC_{54}) because they use air delivery less but they do store large amounts of relief items. It is important for the warehouse to be equipped with adequate facilities and infrastructure to handle large quantities of relief items (Respondent A11).

7.3.7 The Final Weights

After obtaining the normalised weights for the major attributes and sub-attributes, the final weights of all the individual attributes were calculated to observe the ranking of the preference. The overall results of the final ranking for the sub-attributes are shown in Table 7.14.

Table 7.14 shows that Political Stability (SC_{21}) is considered to be the most important of the sub-attributes, with a final weight of 0.1126. It can be seen that the first seven attributes have an accumulated weight of 0.5380 (53.80%), which makes a big influence on the warehouse selection decision-making process. Of these seven attributes: Political Stability (SC_{21}) and Economic Stability (SC_{21}) are sub-attributes of National Stability (C_2); Logistics (SC_{32}) and Replenish (SC_{33}) are sub-attributes of Cost (C_3); Host Government (SC_{41}) and United Nations (SC_{42}) are sub-attributes of Cooperation (C_4) and, Seaport (SC_{52}) is a sub-attribute of Logistics (C_5). It can be noted that none of the sub-attributes from Location (C_1) are positioned in the top 50% of the accumulated weights that influence the decision-making process. Instead, they form the bottom of the table, which are considered to be the least important sub-attributes.

Table 7.14 The final weights of the sub-attributes for Case Study A

Ranking	Attributes	Final weights	Accumulated weights
1	Political Stability (SC_{21})	0.1126	0.1126
2	Host Government (SC_{41})	0.1070	0.2196
3	Logistics (SC_{32})	0.0744	0.2940
4	United Nations (SC_{42})	0.0710	0.3650
	Economic (SC_{22})	0.0710	0.4360
6	Seaport (SC_{52})	0.0528	0.4888
7	Replenishment (SC_{33})	0.0492	0.5380
8	Logistics Agents (SC_{44})	0.0472	0.5852
9	Social (SC_{23})	0.0446	0.6298
10	Storage (SC_{31})	0.0428	0.6726
11	Airport (SC_{51})	0.0376	0.7102
12	Labour (SC_{34})	0.0324	0.7426
13	Warehouse (SC_{54})	0.0310	0.7736
	Road (SC_{53})	0.0310	0.8046
15	Land (SC_{35})	0.0282	0.8328
16	Neighbouring Countries (SC_{43})	0.0234	0.8562
17	Proximity to Disaster Prone Areas (SC_{17})	0.0230	0.8792
18	International NGOs (SC_{45})	0.0222	0.9014
19	Local NGOs (SC_{46})	0.0202	0.9216
20	Disaster Free Location (SC_{13})	0.0186	0.9402
21	Donor's Opinion (SC_{14})	0.0182	0.9584
22	Proximity to Beneficiaries (SC_{12})	0.0162	0.9746
23	Closeness to Other Warehouses (SC_{16})	0.0122	0.9868
24	Geographical Location (SC_{11})	0.0088	0.9956
25	Climate (SC_{15})	0.0044	1.0000
Total weight		1.0000	

Source: Author

7.4 Evaluation of Alternatives and Determination of the Final Rank

This section aims to describe the results of building the decision matrix by comparing the alternatives that have been identified. The Weighted Evaluation Matrix (WEM) is established using the criteria weights calculated by AHP in the previous section. With the WEM, both TOPSIS and Fuzzy-TOPSIS analysis will be presented to evaluate the warehouse location.

7.4.1 TOPSIS

The WEM is established using the weights that were obtained in Table 7.2 and Table 7.14. This section analyses the findings by evaluating the alternative warehouse locations into major attributes and sub-attributes, which are described in more detail in the sub-sections which follow. The obtained results are based on the calculation process that was presented in Chapter 4, Section 4.4.2.2.

7.4.1.1 Major Attributes

The results of the decision matrix which compares the alternatives are shown in Table 7.15. 'C' indicates the criteria in the rows and the column indicates the warehouse locations.

Table 7.15 Evaluation matrix of major attributes for Case Study A

Location	C_1	C_2	C_3	C_4	C_5
A	**0.5217**	0.5076	0.4513	**0.4773**	**0.5740**
B	0.4815	**0.5857**	0.3385	**0.4773**	0.5357
C	0.4013	0.3514	**0.4889**	0.3978	0.3444
D	0.4815	0.3514	0.4513	**0.4773**	0.3444
E	0.3210	0.3904	**0.4889**	0.3978	0.3826

C_1 – Location, C_2 – National Stability, C_3 – Cost, C_4 – Cooperation, C_5 – Logistics, NW – Normalised Weight

Source: Author

Table 7.15 shows that Logistics (C_1) occupies the highest position Location A, with a value of 0.5217. Meanwhile, National Stability (C_2) occupies the highest position in Location B, with a value of 0.5857. Cost (C_3) occupies the highest position in Location C, with a value of 0.4889. Furthermore, Cooperation (C_4) occupies the highest position in Location A, B, and C, with a value of 0.4773. Logistics (C_5) occupies the highest position in Location A, with a value of 0.5740.

Table 7.16 presents the summary results of the highest and the lowest evaluated warehouse in accordance with the preference order of major-attributes.

Table 7.16 Location evaluation with major-attributes ranking for Case Study A

Rank	Criteria	Highest Evaluated Warehouse(s)	Lowest Evaluated Warehouse(s)
1	Cooperation (C_4)	A, B and D	C and E
2	National Stability (C_2)	B	C and D
3	Cost (C_3)	C and E	B
4	Logistics (C_5)	A	C and D
5	Location (C_1)	A	E

Source: Author

From Table 7.15 and Table 7.16, Cooperation (C_4) which ranked first being the most important major-attribute is evaluated as the highest attributes in Locations A, B and D. Location A is also evaluated as the highest warehouses in two other major-attributes, Logistics (C_5) and Location (C_1), which ranked fourth and fifth in the preference order. Location B is also evaluated as the highest warehouse for National Stability (C_2), which ranked second in the preference order. Locations C and E are evaluated as the highest warehouses for Cost (C_3), which is ranked third in the preference order. On the other hand, Locations C and E are evaluated the lowest warehouses for Cooperation (C_4) and Location E is evaluated the lowest warehouse for Location (C_1).

The calculated distance of each warehouse location from positive-ideal solution (PIS) (D_i^*), negative-ideal solution (NIS) (D_i^-), and relative closeness to ideal solution (CC_j^*) is presented in Table 7.17, which ranks the warehouse locations.

Table 7.17 Final ranking with major-attributes for Case Study A: TOPSIS

Rank	Warehouse Locations	D_i^*	D_i^-	CC_j^*
1	A	0.0198	0.0640	0.7642
2	B	0.0349	0.0672	0.6581
3	D	0.0646	0.0382	0.3714
4	E	0.0615	0.0358	0.3676
5	C	0.0691	0.0351	0.3371

D_i^*- positive-ideal solution (PIS), D_i^-- negative-ideal solution (NIS), CC_j^*- relative closeness to ideal solution

Source: Author

Location A is at the nearest distance from PIS with a value of 0.0198and Location B is located at the farthest distance from NIS with a value of 0.0672. Location C is located at the farthest distance from PIS with a value of 0.0691 and closest distance from NIS with a value of 0.0351. In summary, Location A shows the highest CC_j^* value as 0.7642 while warehouse Location B is ranked second with a CC_j^* value of 0.6581. Locations D, E, and C are evaluated in the lower position of the table with CC_j^* values of: Location D, 0.3714; Location E, 0.3676; and Location C, 0.3371.

Consequently, the descending order of the final ranking for the warehouse location using major attributes weights with TOPSIS analysis is:

A > B > D > E > C.

Sensitivity Analysis

Sensitivity analysis was carried out for getting accurate results. The idea of sensitivity is to exchange each criterion's weight with another criterion's weight with each combination stated as a condition. Out of 120 possibilities of combination, twenty were randomly selected to test the sensitivity analysis. The main condition expresses the original result of the case study. For each condition, the similarities of the warehouse location to the ideal solution (CC_j^*) are calculated. Table 7.18 below summarises the numerical results of the calculation and Figure 7.1 illustrates the graphical representation of these results.

According to Table 7.18, Location A has the highest CC_j^* value of 0.8870 from 0.7642 when the criteria weights are exchanged as in condition 15. It has the lowest CC_j^* value of 0.7610 in condition 10. Location B has the highest CC_j^* value of 0.8068 from 0.6581 when the criteria weights are exchanged as in condition 20, it has the lowest value of 0.5855 in condition 4. Location C has the highest CC_j^* value of 0.4171 from 0.3371 when the criteria weights are exchanged as in condition 4; it has the lowest value of 0.1797 in condition 20. Location D has the highest CC_j^* value of 0.5554 when the criteria weights are exchanged as in condition 17; it has the lowest value of 0.2585 in condition 11. Location E has the highest CC_j^* value of 0.3946 from 0.3676 when the criteria weights are exchanged as in condition 4; it has the lowest value of 0.1861 in condition 5.

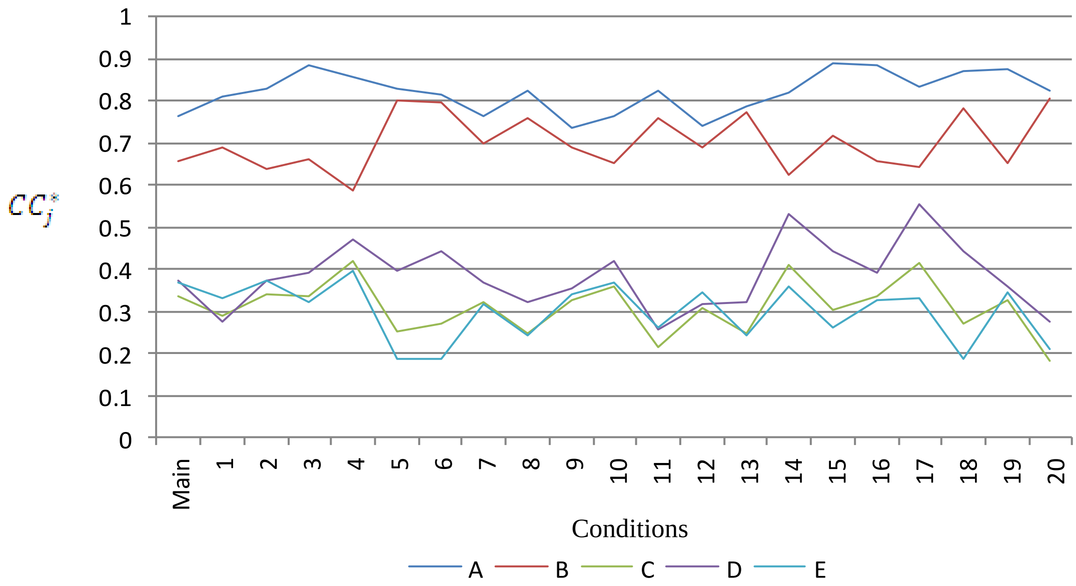
Table 7.18 Sensitivity analysis of major attributes for Case Study A: TOPSIS

Conditions	Weights						CC_j^* Values of Warehouse Locations				
	w_1	w_2	w_3	w_4	w_5		A	B	C	D	E
Main	0.1015	0.2282	0.2270	0.2908	0.1525		0.7642	0.6581	0.3371	0.3714	0.3676
						Ranking	1	2	5	3	4
1	0.1015	0.2282	0.2270	0.1525	0.2908		0.8083	0.6882	0.2869	0.2753	0.3301
						Ranking	1	2	4	5	3
2	0.1015	0.1525	0.2282	0.2908	0.2270		0.8266	0.6385	0.3403	0.3745	0.3705
						Ranking	1	2	5	3	4
3	0.2282	0.1015	0.2270	0.1525	0.2908		0.8822	0.6594	0.3349	0.3915	0.3231
						Ranking	1	2	4	3	5
4	0.2282	0.1015	0.2908	0.2270	0.1525		0.8565	0.5855	0.4171	0.4691	0.3946
						Ranking	1	2	5	3	4
5	0.2908	0.2270	0.1015	0.1525	0.2282		0.8286	0.7992	0.2507	0.3959	0.1861
						Ranking	1	2	4	3	5
6	0.2908	0.2282	0.1015	0.2270	0.1525		0.8140	0.7970	0.2709	0.4410	0.1868
						Ranking	1	2	4	3	5
7	0.2270	0.2908	0.2282	0.1015	0.1525		0.7627	0.6975	0.3223	0.3688	0.3172
						Ranking	1	2	4	3	5
8	0.2270	0.2282	0.1525	0.1015	0.2908		0.8284	0.7599	0.2453	0.3228	0.2412
						Ranking	1	2	4	3	5
9	0.1525	0.2908	0.2270	0.2282	0.1015		0.7350	0.6884	0.3217	0.3536	0.3416
						Ranking	1	2	5	3	4
10	0.1525	0.2270	0.2282	0.2908	0.1015		0.7610	0.6525	0.3588	0.4181	0.3662
						Ranking	1	2	5	3	4
11	0.1015	0.2270	0.1525	0.2282	0.2908		0.8251	0.7577	0.2165	0.2585	0.2616
						Ranking	1	2	5	4	3
12	0.1015	0.2908	0.2282	0.2270	0.1525		0.7383	0.6899	0.3070	0.3146	0.3455
						Ranking	1	2	5	4	3
13	0.2282	0.2908	0.1525	0.1015	0.2270		0.7841	0.7728	0.2451	0.3231	0.2407
						Ranking	1	2	4	3	5
14	0.2282	0.1525	0.2270	0.2908	0.1015		0.8190	0.6255	0.4100	0.5310	0.3585
						Ranking	1	2	4	3	5
15	0.2270	0.1015	0.1525	0.2908	0.2282		0.8870	0.7155	0.3018	0.4425	0.2619
						Ranking	1	2	4	3	5
16	0.2270	0.1015	0.2282	0.1525	0.2908		0.8818	0.6582	0.3357	0.3912	0.3245
						Ranking	1	2	4	3	5
17	0.2908	0.1525	0.2270	0.2282	0.1015		0.8350	0.6399	0.4159	0.5554	0.3304
						Ranking	1	2	4	3	5
18	0.2908	0.1525	0.1015	0.2270	0.2282		0.8714	0.7813	0.2720	0.4429	0.1869
						Ranking	1	2	4	3	5
19	0.1525	0.1015	0.2282	0.2270	0.2908		0.8746	0.6491	0.3258	0.3574	0.3450
						Ranking	1	2	5	3	4
20	0.1525	0.2282	0.1015	0.2270	0.2908		0.8224	0.8068	0.1797	0.2747	0.2078
						Ranking	1	2	5	4	3

w – weights, CC_j^*- relative closeness to ideal solution

Source: Author

Figure 7.1 Sensitivity analyses of major attributes for Case Study A: TOPSIS



CC_j^* - relative closeness to ideal solution

Source: Author

According to the sensitivity analysis result in Figure 7.1 and Table 7.18, Location A is evaluated to be the optimal warehouse location in all conditions. Meanwhile, Location B is the next optimal warehouse in every condition. The difference of ideal solution value between the first two locations to other warehouse locations are too large to be considered as ideal location for pre-positioning warehouse. Decision-makers can use these different weight combinations in the decision-making process according to priority. Therefore, the TOPSIS results with the main condition and the sensitivity analysis of the major attributes show that Location A is the ideal location for pre-positioning warehouse for Case Study A.

7.4.1.2 Sub-Attributes

This section presents the analyses of the evaluation of the alternative warehouse location using the results in the sub-attributes weights that were obtained in Table 7.14. The weighted decision matrix is presented in Table 7.19 below:

Table 7.19 The weighted decision matrix of sub-attributes for Case Study A

Attributes	Location A		Location B		Location C		Location D		Location E	
	NW	Weighted	NW	Weighted	NW	Weighted	NW	Weighted	NW	Weighted
SC_{11}	0.5489	**0.0051***	0.5399	0.0047	0.2699	0.0023-	0.4049	0.0035	0.3599	0.0031
SC_{12}	0.4264	0.0069	0.3411	0.0055-	0.4690	0.0075	0.4690	0.0075	0.5168	**0.0082***
SC_{13}	0.4610	**0.0085***	0.4610	**0.0085***	0.4255	0.0079-	0.4610	**0.0085***	0.4255	0.0079-
SC_{14}	0.4721	0.0085	0.5508	**0.0100***	0.3541	0.0064-	0.4721	0.0085	0.3541	0.0064-
SC_{15}	0.3087	0.0013-	0.5292	**0.0023***	0.4410	0.0019	0.4410	0.0019	0.4851	0.0021
SC_{16}	0.4345	0.0053	0.3801	0.0046-	0.4881	**0.0059***	0.4345	0.0053	0.4881	**0.0059***
SC_{17}	0.4000	0.0092-	0.4000	0.0092-	0.4445	0.0102	0.4445	0.0102	0.5334	**0.0122***
SC_{21}	0.5175	0.0582	0.5573	**0.0627***	0.3582	0.0403	0.3184	0.0358-	0.4379	0.0493
SC_{22}	0.5823	**0.0413***	0.5407	0.0383	0.2911	0.0206-	0.3327	0.0236	0.4159	0.0295
SC_{23}	0.4870	0.0217	0.5313	**0.0236***	0.3985	0.0177	0.3542	0.0157-	0.4428	0.0197
SC_{31}	0.4903	**0.0209***	0.4148	0.0177	0.4525	0.0193	0.3771	0.0161-	0.4903	**0.0209***
SC_{32}	0.4822	**0.0358***	0.4420	0.0328	0.4822	**0.0358***	0.4018	0.0298-	0.4219	0.0313
SC_{33}	0.4663	0.0229	0.5087	**0.0250***	0.3815	0.0187-	0.4239	0.0208	0.4451	0.0219
SC_{34}	0.4145	0.0134	0.2638	0.0085-	0.4899	0.0158	0.4899	0.0158	0.5276	**0.0190***
SC_{35}	0.4915	0.0138	0.3686	0.0103-	0.4505	0.0127	0.3686	0.0103-	0.5325	**0.0150***
SC_{41}	0.4660	0.0498	0.5048	**0.0540***	0.3495	0.0373-	0.5048	**0.0540***	0.3883	0.0415
SC_{42}	0.5314	**0.0377***	0.5314	**0.0377***	0.3416	0.0242-	0.3795	0.0269	0.4175	0.0296
SC_{43}	0.4000	0.0093-	0.5334	**0.0124***	0.4000	0.0093-	0.4445	0.0104	0.4445	0.0104
SC_{44}	0.5627	**0.0265***	0.4421	0.0208	0.3617	0.0170-	0.4421	0.0208	0.4019	0.0189
SC_{45}	0.5843	**0.0129***	0.3595	0.0079-	0.4045	0.0089	0.4045	0.0089	0.4494	0.0099
SC_{46}	0.4214	0.0085-	0.4635	**0.0093***	0.4635	0.0093	0.4214	0.0085-	0.4635	0.0093
SC_{51}	0.5739	**0.0215***	0.5359	0.0201	0.3443	0.0129-	0.3826	0.0143	0.3443	0.0129-
SC_{52}	0.5773	**0.0304***	0.5003	0.0264	0.3464	0.0182-	0.3849	0.0203	0.3849	0.0203
SC_{53}	0.5469	**0.0169***	0.5469	**0.0169***	0.3281	0.0101-	0.4011	0.0124	0.3644	0.0113
SC_{54}	0.6175	**0.0191***	0.5734	0.0177	0.2646	0.0082-	0.3087	0.0095	0.3528	0.0109

*: Positive-ideal solution - : Negative-ideal solution NW: Normalised Weight

Source: Author

From the above table, Political stability (SC_{21}) is evaluated as the highest attribute in Location B with a value of 0.0627. Economical stability (SC_{22}) is evaluated as the highest attribute in Location A with a value of 0.0413. Logistics cost (SC_{32}) is evaluated as the highest attribute in Locations A and B with a value of 0.0358. Replenishment cost (SC_{33}) is evaluated as the highest attribute in Location B and with a value of 0.0250. The cooperation of Host government (SC_{41}) is evaluated as the highest attribute in Locations B and D with a value of 0.0540. The cooperation of United Nations (SC_{42}) is evaluated as the highest attribute in Locations A and B with a value of 0.0377. Seaport (SC_{52}) is evaluated as the highest attribute in Location B with a value of 0.0304. Table 7.20 presents the summarised results of the highest and the lowest evaluated warehouse in accordance with the preference order of sub-attributes.

Table 7.20 Location evaluation with sub-attributes ranking for Case Study A

Rank	Criteria	Highest evaluated warehouse(s)	Lowest evaluated warehouse(s)
1	Political (SC_{21})	B	D
2	Host Government (SC_{41})	B and D	C
3	Logistics (SC_{32})	A and B	D
4	United Nations (SC_{42})	A and B	C
	Economic (SC_{22})	A	C
6	Seaport (SC_{52})	B	C
7	Replenishment (SC_{33})	B	C
8	Logistics Agents (SC_{44})	A	C
9	Social (SC_{23})	B	D
10	Storage (SC_{31})	A	D
11	Airport (SC_{51})	A	C and E
12	Labour (SC_{34})	E	B
13	Warehouse (SC_{54})	A	C
	Road (SC_{53})	A and B	C
15	Land (SC_{35})	E	B and D
16	Neighbour Countries (SC_{43})	B	A and C
17	Proximity to Disaster Prone Areas (SC_{17})	E	B
18	International NGOs (SC_{45})	A	B
19	Local NGOs (SC_{46})	B	A and D
20	Disaster Free Location (SC_{13})	A, B, and D	C and E
21	Donor's Opinion (SC_{14})	B	D
22	Proximity to Beneficiaries (SC_{12})	E	B
23	Closeness to Other Warehouses (SC_{16})	C and E	B
24	Geographical Location (SC_{11})	A	C
25	Climate (SC_{15})	B	A

Note: Rank 1 to 7 has an accumulation weight of 53.80% of the total (Table 7.14)

Source: Author

From Table 7.20, not only Location B is evaluated the highest with 13 sub-attributes, but also evaluated as the highest warehouse in the top seven sub-attributes that accumulates more than 50% of the total. Location A is evaluated as the highest warehouse in 11 sub-attributes. Location A is also evaluated as the highest warehouse in Logistics (SC_{32}), cooperation of United Nations (SC_{42}), and Economical stability (SC_{22}) which are ranked third and fourth in the preference order. On the other hand, Location C is evaluated as the lowest warehouse in 12 sub-attributes. Location C is also evaluated as the lowest warehouse in five out of the top seven sub-attributes. Location D is evaluated as the lowest warehouse in Political Stability (SC_{21}) and Logistics (SC_{32}) which are ranked first and third in the preference order. Location

B is evaluated as the lowest warehouse in six sub-attributes which is more than Location A with three sub-attributes.

The computed distance of each alternative warehouse location from PIS (D_i^*), NIS (D_i^-), and relative closeness to ideal solution (CC_j^*) are presented in Table 7.21.

Table 7.21 Final ranking with sub-attributes for Case Study A: TOPSIS

Rank	Warehouse Location	D_i^*	D_i^-	CC_j^*
1	A	0.0092	0.0439	0.8261
2	B	0.0148	0.0436	0.7468
3	E	0.0308	0.0222	0.4186
4	D	0.0405	0.0198	0.3281
5	C	0.0447	0.0117	0.2081

D_i^* - positive-ideal solution (PIS), D_i^- - negative-ideal solution (NIS), CC_j^* - relative closeness to ideal solution

Source: Author

From Table 7.21, Location A is located at the nearest distance from PIS with a value of 0.0092. Location A is also located at the farthest distance from NIS with a value of 0.0439. Location C is evaluated to be located at the farthest distance from PIS with a value of 0.0447 and closest distance to NIS with a value of 0.0117. In summary, Location A has the highest CC_j^* value of 0.8261 while warehouse location B ranked second with a CC_j^* value of 0.7468. Locations E, D, and C evaluated in the lower position of the table with a CC_j^* value of: Location E, 0.4186; Location D, 0.3281; and, Location C 0.2081.

Therefore, the descending order of the final ranking for the warehouse location using sub-attributes weights with TOPSIS analysis is:

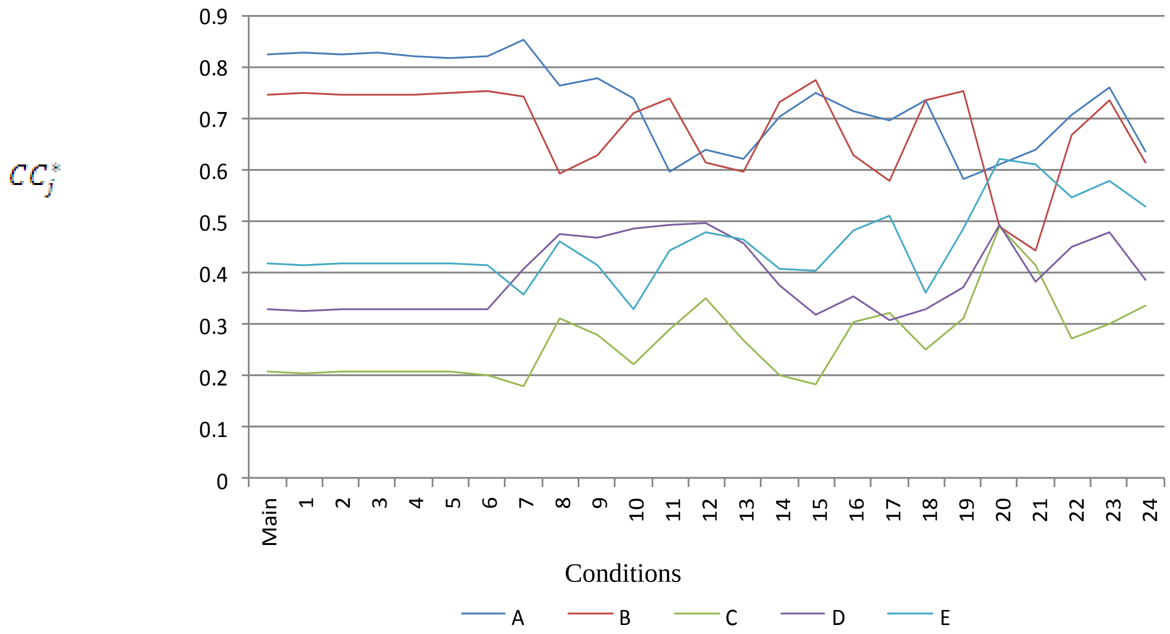
A > B > E > D > C.

Sensitivity Analysis

Sensitivity analysis was again used to ascertain the accuracy of the results. In the case of sub-attributes analysis, the criteria were exchanged randomly with the other criteria so that they can be analysed with each combination stated as a condition. The main condition expresses the original result of the case study. The similarities of the warehouse location to the ideal solution (CC_j^*) are calculated for each condition. Appendix C.3 presents the selected possibilities to test the sensitivity analysis. Table 7.22 summaries the numerical results of the calculation, and Figure 7.2 illustrates the graphical representation of these results.

Table 7.22 shows that Location A has the highest CC_j^* value of 0.8554 from 0.8261 when the weights of attributes are exchanged as in condition 7, it will have its lowest CC_j^* value of 0.5973 in condition 11. Location B will have the highest CC_j^* value of 0.7549 from 0.7468 when the weights of attributes are exchanged as in condition 19, it will have the lowest CC_j^* value of 0.4452 in condition 21. Location C will have the highest CC_j^* value of 0.4919 from 0.2081 when the weights of attributes are exchanged as in condition 20, it will have its lowest CC_j^* value of 0.1788 in condition 7. Location D will have the highest CC_j^* value of 0.4982 from 0.3281 when the weights of attributes are exchanged as in condition 12, it will have the lowest CC_j^* value of 0.3097 in condition 17. Location E will have the highest CC_j^* value of 0.6233 from 0.4186 when the weights of attributes are exchanged as in condition 20, it will have its lowest CC_j^* value of 0.3294 in condition 10.

Figure 7.2 Sensitivity analyses of sub-attributes for Case Study A: TOPSIS



CC_j^* - relative closeness to ideal solution

Source: Author

Table 7.22 Sensitivity analysis for sub-attributes for Case Study A: TOPSIS

Conditions		TOPSIS CC_j^* Values of Warehouse Locations				
		A	B	C	D	E
Main		0.8261	0.7468	0.2081	0.3281	0.4186
	Ranking	1	2	5	4	3
1		0.8279	0.7497	0.2056	0.3278	0.4164
	Ranking	1	2	5	4	3
2		0.8271	0.7475	0.2071	0.3288	0.4174
	Ranking	1	2	5	4	3
3		0.8277	0.7460	0.2083	0.3283	0.4193
	Ranking	1	2	5	4	3
4		0.8234	0.7456	0.2099	0.3283	0.4202
	Ranking	1	2	5	4	3
5		0.8183	0.7511	0.2074	0.3283	0.4180
	Ranking	1	2	5	4	3
6		0.8218	0.7531	0.2029	0.3303	0.4166
	Ranking	1	2	5	4	3
7		0.8554	0.7439	0.1788	0.4067	0.3569
	Ranking	1	2	5	3	4
8		0.7642	0.5942	0.3105	0.4773	0.4599
	Ranking	1	2	5	3	4
9		0.7788	0.6305	0.2788	0.4704	0.4165
	Ranking	1	2	5	4	3
10		0.7401	0.7112	0.2218	0.4854	0.3294
	Ranking	1	2	5	4	3
11		0.5973	0.7410	0.2919	0.4954	0.4420
	Ranking	2	1	5	3	4
12		0.6416	0.6137	0.3503	0.4982	0.4798
	Ranking	1	2	5	4	5
13		0.6208	0.5987	0.2677	0.4563	0.4637
	Ranking	1	2	5	4	3
14		0.7038	0.7342	0.2027	0.3774	0.4078
	Ranking	2	1	5	4	3
15		0.7489	0.7741	0.1841	0.3200	0.4044
	Ranking	2	1	5	4	3
16		0.7142	0.6306	0.3039	0.3531	0.4847
	Ranking	1	2	5	4	3
17		0.6977	0.5794	0.3228	0.3097	0.5116
	Ranking	1	2	5	4	3
18		0.7348	0.7372	0.2499	0.3313	0.3622
	Ranking	2	1	5	4	3
19		0.5835	0.7549	0.3136	0.3732	0.4866
	Ranking	2	1	5	4	3
20		0.6118	0.4908	0.4919	0.4943	0.6233
	Ranking	2	5	4	3	1
21		0.6383	0.4452	0.4146	0.3832	0.6103
	Ranking	1	3	4	5	2
22		0.7075	0.6675	0.2714	0.4501	0.5464
	Ranking	1	2	5	4	3
23		0.7617	0.7364	0.3007	0.4803	0.5807
	Ranking	1	2	5	4	3
24		0.6378	0.6157	0.3353	0.3878	0.5311
	Ranking	1	2	5	4	3

CC_j^* - relative closeness to ideal solution

Source: Author

According to the sensitivity analysis result in Figure 7.2 and Table 7.22, Location A is determined to be the most appropriate warehouse location in all conditions except in 11, 14, 15, 18, 19, and 20. Location B turned is determined to be the most appropriate in condition 11, 14, 15, 18, and 19. Location E is determined to be an optimal location in condition 20. Location C is mostly ranked in the bottom in all conditions, except in condition 21 and 21 where it is ranked fourth. Decision-makers can use these different weight combinations in the decision-making process, according to priority.

7.4.2 Fuzzy-TOPSIS

This section analysed the ranking of the alternative warehouse locations that are determined by using fuzzy-TOPSIS. Linguistic values are used for the evaluation of these locations. The relationship between linguistics values and triangular fuzzy numbers on a five point scale is presented in Figure 4.6. The results obtained for the fuzzy-TOPSIS analysis is based on the calculation that was explained in Chapter 4, Section 4.4.4.

7.4.2.1 Major Attributes

The construction result of fuzzy evaluation matrix of the major attributes by linguistic variables is presented in Table 7.23. In the table, weights (*w*) of the each major attributes are also presented in the first row.

Table 7.23 Fuzzy evaluation matrix of major attributes for Case Study A

	C_1	C_2	C_3	C_4	C_5
w	0.2908	0.2282	0.2270	0.1525	0.1015
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)	**(0.55, 0.70, 0.85)**
B	(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)
C	(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)
D	**(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)
E	**(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)

C_1 – Location, C_2 – National Stability, C_3 – Cost, C_4 – Cooperation, C_5 – Logistics,

Source: Author

Table 7.24 presents the summary results of the highest and the lowest evaluated warehouse in accordance with the preference order of major-attributes. Cooperation (C_4), the most important major attribute, is evaluated as the highest attribute in Locations A, B, C, D and E. National Stability (C_2), ranked second in the preference order, is evaluated as the highest attribute in Location B and the lowest in Locations C and D. Cost (C_3), ranked third in the preference order is evaluated as the highest attribute in Locations A, C, D and E while Location B is evaluated as the lowest. Logistics (C_5), ranked fourth in the preference order, is evaluated as the highest attribute in Location A and the lowest in Locations B, C, D and E. Location (C_1), ranked fifth in the preference order, is evaluated as the highest attribute in Locations A, B, D and E and the lowest in Location C.

Table 7.24 Location evaluation with major attributes ranking for Case Study A: Fuzzy

Rank	Criteria	Highest Evaluated Warehouse(s)	Lowest Evaluated Warehouse(s)
1	Cooperation (C_4)	A, B, C, D and E	-
2	National Stability (C_2)	B	C and D
3	Cost (C_3)	A, C, D and E	B
4	Logistics (C_5)	A	B, C, D and E
5	Location (C_1)	A, B, D and E	C

Source: Author

Table 7.23 shows the normalised triangular fuzzy numbers for every element, their ranges belong to the closed interval [0,1], as illustrated in Figure 4.6. The following definition is given to the following attributes: fuzzy positive-ideal solution (FPIS, A^*) as $\tilde{v}_i^*$ = (1,1,1) and $\tilde{v}_i^-$ = (0, 0, 0) for benefit criterion, and fuzzy negative-ideal solution (FNIS, A^-) as $\tilde{v}_i^*$ = (0,0,0) and $\tilde{v}_i^-$ = (1, 1, 1) for cost criterion. In this case, C_1, C_2, C_3, C_4, and C_5 are all benefit criteria and there are no cost criteria. The benefit and cost criterion are shown in Table 7.25.

Table 7.25 Benefit and cost criteria for major attributes for Case Study A

Criteria	$\tilde{v}_i^*$	$\tilde{v}_i^-$
C_1	(1, 1, 1)	(0, 0, 0)
C_2	(1, 1, 1)	(0, 0, 0)
C_3	(1, 1, 1)	(0, 0, 0)
C_4	(1, 1, 1)	(0, 0, 0)
C_5	(1, 1, 1)	(0, 0, 0)

C_1 – Location, C_2 – National Stability, C_3 – Cost, C_4 – Cooperation, C_5 – Logistics,
$\tilde{v}_i^*$ - fuzzy positive-ideal solution (FPIS), $\tilde{v}_i^-$ - fuzzy negative-ideal solution (FNIS)

Source: Author

In order to illustrate the calculation of the distance of each alternative, the evaluation process of PIS (D_1^*), NIS (D_1^-), and the relative closeness to ideal-solution value (CC_1^*) of Location A is presented as follows:

$$D_1^* = \sqrt{\frac{1}{3}[(1-0.035)^2 + (1- \ 0.050)^2 + (1-0.065)^2]}$$
$$+ \sqrt{\frac{1}{3}[(1-0.079)^2 + (1- \ 0.114)^2 + (1-0.148)^2]}$$
$$+ \sqrt{\frac{1}{3}[(1-0.079)^2 + (1- \ 0.113)^2 + (1-0.147)^2]}$$
$$+ \sqrt{\frac{1}{3}[(1-0.101)^2 + (1- \ 0.145)^2 + (1-0.189)^2]}$$
$$+ \sqrt{\frac{1}{3}[(1-0.083)^2 + (1- \ 0.106)^2 + (1-0.129)^2]}$$
$$= 4.4713$$

$$D_1^- = 0.5446$$

$$CC_1^* = 0.1058$$

Based on the relative closeness to the ideal solution obtained in the calculation for the other locations (as presented in Chapter 4, Section 4.4.4), the final step of Fuzzy-TOPSIS method consist of ranking the warehouse locations, which are illustrated in Table 7.26.

Table 7.26 Final ranking with major-attributes for Case Study A: Fuzzy-TOPSIS

Rank	Warehouse Location	D_i^*	D_i^-	CC_j^*
1	A	4.4713	0.5446	0.1085
2	B	4.5016	0.5161	0.1028
3	E	4.5526	0.4463	0.0929
4	D	4.5780	0.4421	0.0880
5	C	4.5982	0.4228	0.0842

D_i^*- positive-ideal solution (PIS), D_i^-- negative-ideal solution (NIS), CC_j^*- relative closeness to ideal solution

Source: Author

Table 7.26 shows that Location A is located at the nearest distance from PIS with a value of 4.4713 and Location C is located at the farthest distance from PIS with a value of 4.5982. Location A is also located at the farthest distance from NIS with a value of 0.5446 and Location D is located the closest distance to NIS with a value of 0.4221. In summary, Location A is the optimal warehouse location, with a CC_j^* value of 0.1085. Location B has a value CC_j^* value of 0.1028 and is ranked second in the table. Location E is ranked third, with a CC_j^* value of 0.0929. The last two warehouse locations are Location D (with a CC_j^* value of 0.0880) and Location C (with a CC_j^* value of 0.0842).

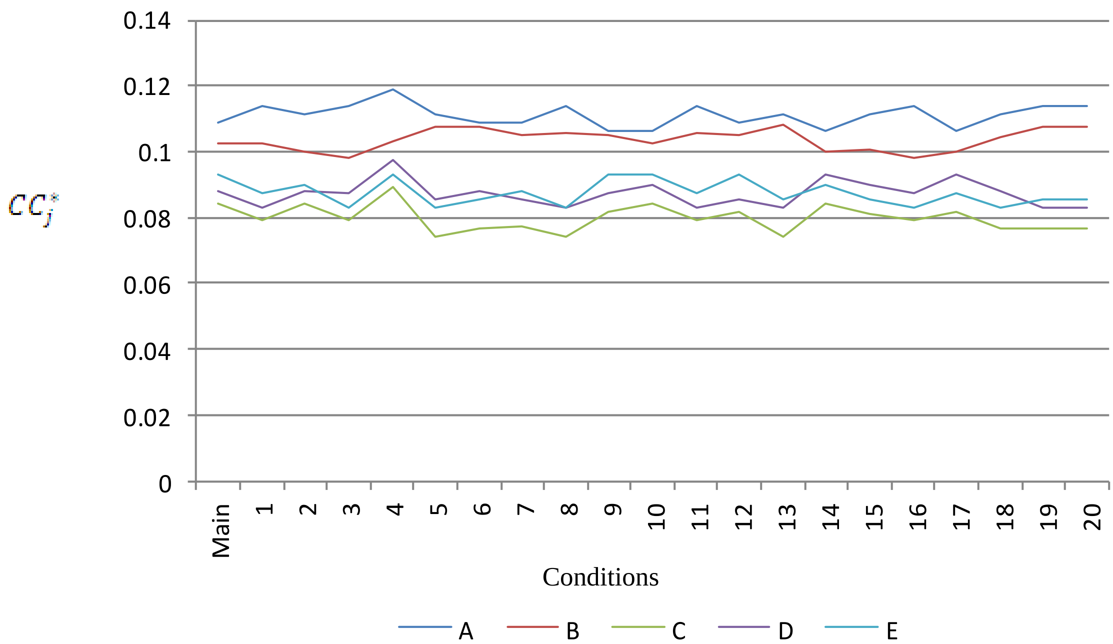
Therefore, the descending order of the final ranking for the optimal warehouse location using major attributes weights with fuzzy-TOPSIS is:

A > B > E > D > C.

Sensitivity Analysis

Sensitivity analysis was again carried out for getting accurate results. The main condition expresses the original result of the case study. For each condition, the similarities of the warehouse location to the relative closeness to ideal solution (CC_j^*) are calculated. The same combination of conditions is applied from Table 7.18 for the fuzzy-TOPSIS analysis. Table 7.27 summarises the numerical results of the calculation, and Figure 7.3 illustrates the graphical representation of these results.

Figure 7.3 Sensitivity analysis of major attributes for Case Study A: Fuzzy-TOPSIS



CC_j^* - relative closeness to ideal solution

Source: Author

Table 7.27 Sensitivity analysis of major attributes for Case Study A: Fuzzy-TOPSIS

Conditions	Weights					CC_j^* Values of Warehouse Locations					
	w_1	w_2	w_3	w_4	w_5		A	B	C	D	E
Main	0.1015	0.2282	0.2270	0.2908	0.1525		0.1085	0.1028	0.0842	0.0880	0.0929
						Ranking	1	2	5	4	3
1	0.1015	0.2282	0.2270	0.1525	0.2908		0.1139	0.1028	0.0789	0.0828	0.0876
						Ranking	1	2	5	4	3
2	0.1015	0.1525	0.2282	0.2908	0.2270		0.1114	0.0998	0.0842	0.0881	0.0900
						Ranking	1	2	5	4	3
3	0.2282	0.1015	0.2270	0.1525	0.2908		0.1139	0.0979	0.0789	0.0876	0.0828
						Ranking	1	2	5	3	4
4	0.2282	0.1015	0.2908	0.2270	0.2282		0.1192	0.1032	0.0890	0.0977	0.0930
						Ranking	1	2	5	3	4
5	0.2908	0.2270	0.1015	0.1525	0.2282		0.1115	0.1076	0.0741	0.0852	0.0828
						Ranking	1	2	5	3	4
6	0.2908	0.2282	0.1015	0.2270	0.1525		0.1085	0.1076	0.0769	0.0880	0.0856
						Ranking	1	2	5	3	4
7	0.2270	0.2908	0.2282	0.1015	0.1525		0.1085	0.1052	0.0770	0.0856	0.0881
						Ranking	1	2	5	4	3
8	0.2270	0.2282	0.1525	0.1015	0.2908		0.1139	0.1057	0.0741	0.0828	0.0829
						Ranking	1	2	5	4	3
9	0.1525	0.2908	0.2270	0.2282	0.1015		0.1064	0.1053	0.0818	0.0876	0.0929
						Ranking	1	2	5	4	3
10	0.1525	0.2270	0.2282	0.2908	0.1015		0.1065	0.1027	0.0842	0.0900	0.0929
						Ranking	1	2	5	4	3
11	0.1015	0.2270	0.1525	0.2282	0.2908		0.1139	0.1056	0.0789	0.0829	0.0876
						Ranking	1	2	5	4	3
12	0.1015	0.2908	0.2282	0.2270	0.1525		0.1085	0.1052	0.0818	0.0856	0.0929
						Ranking	1	2	5	4	3
13	0.2282	0.2908	0.1525	0.1015	0.2270		0.1114	0.1081	0.0741	0.0829	0.0852
						Ranking	1	2	5	4	3
14	0.2282	0.1525	0.2270	0.2908	0.1015		0.1064	0.0999	0.0842	0.0929	0.0900
						Ranking	1	2	5	3	4
15	0.2270	0.1015	0.1525	0.2908	0.2282		0.1115	0.1007	0.0813	0.0900	0.0852
						Ranking	1	2	5	4	3
16	0.2270	0.1015	0.2282	0.1525	0.2908		0.1139	0.0978	0.0789	0.0876	0.0829
						Ranking	1	2	5	3	4
17	0.2908	0.1525	0.2270	0.2282	0.1015		0.1065	0.0999	0.0818	0.0929	0.0876
						Ranking	1	2	5	3	4
18	0.2908	0.1525	0.1015	0.2270	0.2282		0.1115	0.1047	0.0769	0.0880	0.0828
						Ranking	1	2	5	3	4
19	0.1525	0.1015	0.2282	0.2270	0.2908		0.1139	0.1076	0.0769	0.0828	0.0856
						Ranking	1	2	5	4	3
20	0.1525	0.2282	0.1015	0.2270	0.2908		0.1139	0.1076	0.0769	0.0828	0.0856
						Ranking	1	2	5	4	3

CC_j^*- relative closeness to ideal solution

Source: Author

Table 7.27 shows that Location A has the highest CC_j^* value of 0.1192 from 0.1085 when the attribute weights are exchanged as in condition 4, it will have the lowest CC_j^* value of 0.1064 in condition 9 and 14. Location B has the highest CC_j^* value of 0.1081 from 0.1028 when the attribute weights are exchanged as in condition 13, it will have the lowest CC_j^* value of 0.0978 in condition 16. Location C has the highest CC_j^* value of 0.0890 from 0.0842 when the attribute weights are exchanged as in condition 4, it will have the lowest CC_j^* value of 0.0741 in condition 5, 8, and 13. Location D has the highest CC_j^* value of 0.0977 from 0.0880 when the attribute weights are exchanged as in condition 4, it will have the lowest CC_j^* value of 0.0828 in condition 8, 19, and 20. Location E has the highest CC_j^* value of 0.0929 when the attributes are exchanged in condition 9, 10, and 12 (this value is the same as in the main condition), it will have the lowest CC_j^* value of 0.0828 in condition 3, 5, and 18.

According to the result of the sensitivity analysis in Table 7.27 and Figure 7.3, location A is evaluated to be the optimal warehouse location for the full range of conditions. Then location B is followed to be next. Location C remains at the bottom of the table all the time. Location D and E exchange rankings of third and fourth some of the conditions. Decision-makers can use these different weight combinations in the decision-making process according to their priorities at the time.

7.4.2.2 Sub-Attributes

This section presents the analyses of the evaluation of the alternative warehouse location using the results of the sub-attributes weights obtained in Table 7.14. The construction result of fuzzy evaluation matrix of the major attributes by linguistic variables is presented in Appendix C.4. The fuzzy weighted normalised decision matrix of the alternative warehouse locations, calculated by multiplying fuzzy evaluation by the weights, is also presented. Table 7.28 presents the summarised results of the highest and the lowest evaluated warehouse in accordance with the preference order of sub-attributes in fuzzy-TOPSIS.

From Table 7.28, it is shown that both Locations A and B are evaluated as the highest warehouses at the top seven sub-attributes that accumulates more than 50% of the total. Location A is evaluated as the highest warehouse with 24 sub-attributes and followed by Location B with 19 sub-attributes. On the other hand, Locations C, D and E are evaluated the lowest warehouses at the top seven.

Table 7.28 Location evaluation with sub-attributes ranking for Case Study A: Fuzzy

Rank	Criteria	Highest evaluated warehouse(s)	Lowest evaluated warehouse(s)
1	Political (SC_{21})	A, B and E	C and D
2	Host Government (SC_{41})	A and B	C, D and E
3	Logistics (SC_{32})	A, B, C and D	E
4	United Nations (SC_{42})	A, B, D and E	C
	Economic (SC_{22})	A, B and E	C and D
6	Seaport (SC_{52})	A and B	C, D and E
7	Replenish (SC_{33})	A, B, C and D	E
8	Logistics Agents (SC_{44})	A, B, D and E	C
9	Social (SC_{23})	A and B	C, D and E
10	Storage (SC_{31})	A, B, C and E	D
11	Airport (SC_{51})	A and B	C , D and E
12	Labour (SC_{34})	A, C, D and E	B
13	Warehouse (SC_{54})	A, B and D	C and E
	Road (SC_{53})	A, B and D	C and E
15	Land (SC_{35})	A, C and E	B and D
16	Neighbour Countries (SC_{43})	A, B, C and E	D
17	Proximity to Disaster Prone Areas (SC_{17})	A, B, C, D and E	-
18	International NGOs (SC_{45})	A, C, D and E	B
19	Local NGOs (SC_{46})	A, B, C, D and E	-
20	Disaster Free Location (SC_{13})	A, B, C, D and E	-
21	Donor's Opinion (SC_{14})	A, B and D	C and E
22	Proximity to Beneficiaries (SC_{12})	A and E	B, C and D
23	Closeness to Other Warehouses (SC_{16})	A, C, D and E	B
24	Geographical Location (SC_{11})	A, B and D	C and E
25	Climate (SC_{15})	B, C and D	A and E

Note: Rank 1 to 7 has an accumulation weight of 53.80% of the total (Table 7.14)

Source: Author

It is shown that every element in Appendix C.4 is a normalised triangular fuzzy numbers and their ranges belong to the closed interval [0,1] (as illustrated in Figure 4.6. The following definitions are given to the following attributes: FPIS (A^*) as $\tilde{v}_i^*$ = (1,1,1) and $\tilde{v}_i^-$ = (0, 0, 0) for benefit criterion, and FNIS (A^-) as $\tilde{v}_i^*$ = (0,0,0) and $\tilde{v}_i^-$ = (1, 1, 1) for cost criterion. In this case, all of sub-attributes are benefit criteria and there is no cost criterion.

In order to illustrate the calculation, PIS (D_1^*), NIS (D_1^-), and ideal-solution value (CC_1^*), of Location A is presented as follows:

$$
\begin{aligned}
D_1^* = & \sqrt{\frac{1}{3}[(1-0.003)^2+(1-\ 0.004)^2+(1-0.005)^2]} \\
& + \sqrt{\frac{1}{3}[(1-0.005)^2+(1-\ 0.008)^2+(1-0.010)^2]} \\
& + \sqrt{\frac{1}{3}[(1-0.006)^2+(1-\ 0.009)^2+(1-0.012)^2]} \\
& \dots \\
& + \sqrt{\frac{1}{3}[(1-0.010)^2+(1-\ 0.015)^2+(1-0.020)^2]} \\
& + \sqrt{\frac{1}{3}[(1-0.017)^2+(1-\ 0.021)^2+(1-0.031)^2]} \\
& = 15.2002
\end{aligned}
$$

D_1^- = 0.2856

CC_1^* = 0.0184

The same calculation process is applied to obtain the ideal solution value of the rest of the locations. The final step of fuzzy-TOPSIS method consists of ranking the alternative warehouse locations are illustrated in Table 7.29.

Table 7.29 Final ranking with sub-attributes for Case Study A: Fuzzy-TOPSIS

Rank	Warehouse Location	D_i^*	D_i^-	CC_j^*
1	A	15.2002	0.2856	0.0184
2	B	15.5146	0.2787	0.0176
3	E	15.7564	0.2761	0.0168
4	D	15.9649	0.2404	0.0148
5	C	16.0886	0.2345	0.0143

D_i^*- positive-ideal solution (PIS), D_i^-- negative-ideal solution (NIS), CC_j^*- relative closeness to ideal solution

Source: Author

Table 7.29 shows that Location A is located at the nearest distance from PIS with a value of 15.2002. Location A is also located at the farthest distance from NIS with a value of 0.2856. Location C is located at the farthest distance to PIS with a value of 16.0886 and located at the closest distance to NIS with a value of 0.2345. In summary, the result shows that Location A is selected as the optimal warehouse location, with a CC_j^* value of 0.0184. Location B is the second option, with a CC_j^* value of 0.076. Location E is ranked in third position, with a CC_j^*

value of 0.0168. Location D and C remain at the bottom of the table, with a CC_j^* value of 0.0148 (Location D) and 0.0146 (Location C).

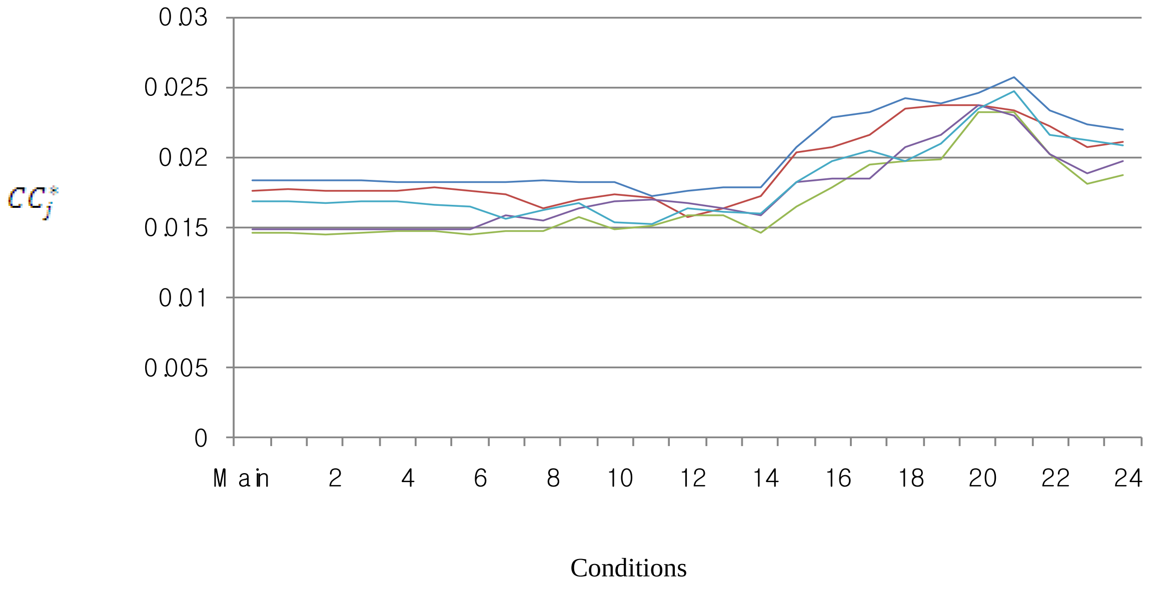
Therefore, the descending order of the final ranking for the evaluated warehouse location using sub-attributes weights with fuzzy-TOPSIS is:

A > B > E > D > C.

Sensitivity Analysis

Sensitivity analysis was again carried out in order to get accurate results. The main condition expresses the original result of the case study. For each condition, the similarities of the warehouse location to the relative closeness to ideal solution (CC_j^*) are calculated based on combinations of the condition matrix Appendix C.3. Table 7.30 summarises the numerical results of the calculation, and Figure 7.4 illustrates the graphical representation of these results.

Figure 7.4 Sensitivity analysis of sub-attributes for Case Study A: Fuzzy-TOPSIS



CC_j^* - relative closeness to ideal solution

Source: Author

Table 7.30 Sensitivity analysis of sub-attributes for Case Study A: Fuzzy-TOPSIS

Conditions		TOPSIS CC_j^* Values of Warehouse Locations				
		A	B	C	D	E
Main		0.0184	0.0176	0.0146	0.0148	0.0168
	Ranking	1	2	5	4	3
1		0.0184	0.0177	0.0146	0.0149	0.0168
	Ranking	1	2	5	4	3
2		0.0184	0.0176	0.0145	0.0148	0.0167
	Ranking	1	2	5	4	3
3		0.0184	0.0176	0.0146	0.0148	0.0168
	Ranking	1	2	5	4	3
4		0.0183	0.0176	0.0147	0.0148	0.0168
	Ranking	1	2	5	4	3
5		0.0183	0.0178	0.0147	0.0149	0.0166
	Ranking	1	2	5	4	3
6		0.0182	0.0176	0.0145	0.0148	0.0165
	Ranking	1	2	5	4	3
7		0.0182	0.0174	0.0147	0.0159	0.0156
	Ranking	1	2	5	4	3
8		0.0184	0.0164	0.0147	0.0155	0.0162
	Ranking	1	2	5	4	3
9		0.0183	0.0170	0.0157	0.0163	0.0167
	Ranking	1	2	5	4	3
10		0.0182	0.0173	0.0148	0.0169	0.0154
	Ranking	1	2	5	3	4
11		0.0172	0.0171	0.0151	0.0170	0.0152
	Ranking	1	2	5	3	4
12		0.0176	0.0157	0.0159	0.0167	0.0163
	Ranking	1	5	4	2	3
13		0.0179	0.0164	0.0159	0.0163	0.0161
	Ranking	1	2	5	3	4
14		0.0179	0.0172	0.0146	0.0158	0.0160
	Ranking	1	2	5	4	3
15		0.0208	0.0204	0.0165	0.0182	0.0182
	Ranking	1	2	5	4	3
16		0.0229	0.0208	0.0178	0.0185	0.0197
	Ranking	1	2	5	4	3
17		0.0233	0.0216	0.0195	0.0185	0.0205
	Ranking	1	2	3	5	4
18		0.0243	0.0235	0.0198	0.0208	0.0198
	Ranking	1	2	5	3	4
19		0.0239	0.0238	0.0199	0.0216	0.0210
	Ranking	1	2	5	3	4
20		0.0246	0.0238	0.0232	0.0237	0.0235
	Ranking	1	2	5	3	4
21		0.0257	0.0234	0.0233	0.0230	0.0247
	Ranking	1	3	4	5	2
22		0.0234	0.0222	0.0202	0.0203	0.0216
	Ranking	1	2	5	4	3
23		0.0224	0.0207	0.0181	0.0189	0.0212
	Ranking	1	3	5	4	2
24		0.0220	0.0211	0.0187	0.0197	0.0209
	Ranking	1	2	5	4	3

CC_j^* - relative closeness to ideal solution

Source: Author

The fuzzy-TOPSIS sub-attributes analysis shows that Location A has the highest CC_j^* value of 0.0257 from 0.0184 when the attributes weights are exchanged as in condition, it will have the lowest CC_j^* value of 0.0171 in condition 11. Location B has the highest CC_j^* value of 0.0238 from 0.0176 when the attributes weights are exchanged as in condition 19, it will have the lowest CC_j^* value of 0.0157 in condition 12. Location has the highest CC_j^* value of 0.0233 from 0.0146 when the attributes weights are exchanged as in condition 21, it will have the lowest CC_j^* value of 0.145 in condition 2. Location D has the highest CC_j^* value of 0.0237 from 0.0148 when the attributes are exchanged as in condition 20, it will have the lowest CC_j^* value of 0.143 in condition 2. Location E has the highest CC_j^* value of 0.0247 from 0.0168 when the attributes weights are exchanged as in condition 21, it will have the lowest CC_j^* value of 0.152 in condition 11.

The sensitivity analysis results in Table 7.30 and Figure 7.4, Location A emerges as the optimal warehouse location for the entire range of conditions. Location B is ranked second in entire conditions except in condition 12, 23, and 24. Location B drops to the bottom of the table in condition 12. Location C is always at the bottom of the ranking for the entire conditions except in condition 12 where it is ranked fourth. Decision-makers can use these different weight combinations in the decision-making process according to their priority. From these overall/combined results, it is sensible for the decision-makers to select Location A to be the optimal warehouse location.

7.5 Comparison of the Results

A comparison between the TOPSIS and fuzzy-TOPSIS methods is presented in this section based on the results of the sensitivity analysis that have been obtained previously. This section will first compare the major attributes and sub-attributes of each method. It will then examine the fuzzy and non-fuzziness results.

7.5.1 Major Attributes versus Sub-Attributes

This section will compare the TOPSIS ranking between the major attributes and sub-attributes. The first section will compare the results of the non-fuzzy method, which will be followed by the fuzzy results.

7.5.1.1 Non-fuzzy TOPSIS

Based on the sensitivity analysis results that are found in the previous sections, the comparison of the selection of the warehouse is presented Table 7.31, which represents the results of major attributes and sub-attributes.

Table 7.31 Comparison of the sensitivity analysis for Case Study A: Non-fuzzy TOPSIS

Major Attributes						**Sub-Attributes**					
	Warehouse Locations Rank						Warehouse Locations Rank				
Conditions	A	B	C	D	E	Conditions	A	B	C	D	E
Main	1	2	5	3	4	Main	1	2	5	4	3
1	1	2	4	5	3	1	1	2	5	4	3
2	1	2	5	3	4	2	1	2	5	4	3
3	1	2	4	3	5	3	1	2	5	4	3
4	1	2	5	3	4	4	1	2	5	4	3
5	1	2	4	3	5	5	1	2	5	4	3
6	1	2	4	3	5	6	1	2	5	4	3
7	1	2	4	3	5	7	1	2	5	3	4
8	1	2	4	3	5	8	1	2	5	3	4
9	1	2	5	3	4	9	1	2	5	4	3
10	1	2	5	3	4	10	1	2	5	4	3
11	1	2	5	4	3	11	2	1	5	3	4
12	1	2	5	4	3	12	1	2	5	4	3
13	1	2	4	3	5	13	1	2	5	4	3
14	1	2	4	3	5	14	2	1	5	4	3
15	1	2	4	3	5	15	2	1	5	4	3
16	1	2	4	3	5	16	1	2	5	4	3
17	1	2	4	3	5	17	1	2	5	4	3
18	1	2	4	3	5	18	2	1	5	4	3
19	1	2	5	3	4	19	2	1	5	4	3
20	1	2	5	4	3	20	2	5	4	3	1
						21	1	3	4	5	2
						22	1	2	5	4	3
						23	1	2	5	4	3
						24	1	2	5	4	3

Note: For major attributes, 1- 20 are the conditions in Table 7.18. For sub-attributes, 1 – 24 are the conditions in Appendix C3. Main conditions show the original result of the location ranking.

Source: Author

Table 7.31 shows that Location A is the optimal warehouse location in the evaluation of major attributes for the entire condition, although it varies a little for the sub-attributes evaluation. The evaluation of the results of the major attribute show that Location B is evaluated to be ranked second for the entire conditions, although it varies in sub-attribute evaluation. However, the results of Location A show that for the majority of the time it is the best warehouse location. For both analyses, Location C is ranked at the bottom of most of the conditions.

A comparison between the major and sub-attributes for the non-fuzzy-TOPSIS shows that Location A is ranked first in all of the major attributes. For the sub-attributes evaluation, the sensitivity analysis shows that the optimal warehouse location varies depending on the weights being exchanged. A comparison of the sensitivity analysis shows that the major attributes evaluation is more consistent than the sub-attributes analysis for the warehouse location selection in non-fuzzy-TOPSIS results.

7.5.1.2 Fuzzy-TOPSIS

A comparison of the selection of the warehouse is presented Table 7.32. The comparison is based on the sensitivity analysis results found in the previous sections and the table represents the results of the major attributes and sub-attributes.

The fuzzy-TOPSIS evaluation results show that Location A is ranked first consistently in every condition as well as in both major and sub-attributes. The results of the major attributes show that Location B and Location C are consistently ranked second and last for the entire condition. The sensitivity analysis of sub-attributes show that Location C is mostly evaluated at the bottom. Even though the fuzzy-TOPSIS analysis of the major attributes is more consistent than that of the sub-attributes, both analyses show that only Location A is determined to be evaluated first among the other warehouses in all conditions for the warehouse evaluation.

Table 7.32 Comparison of the sensitivity analysis for Case Study A: Fuzzy-TOPSIS

Major Attributes						Sub-attributes					
	Warehouse Locations Rank						Warehouse Locations rank				
Conditions	A	B	C	D	E	Conditions	A	B	C	D	E
Main	1	2	5	4	3	Main	1	2	5	4	3
1	1	2	5	4	3	1	1	2	5	4	3
2	1	2	5	4	3	2	1	2	5	4	3
3	1	2	5	3	4	3	1	2	5	4	3
4	1	2	5	3	4	4	1	2	5	4	3
5	1	2	5	3	4	5	1	2	5	4	3
6	1	2	5	3	4	6	1	2	5	4	3
7	1	2	5	4	3	7	1	2	5	4	3
8	1	2	5	4	3	8	1	2	5	4	3
9	1	2	5	4	3	9	1	2	5	4	3
10	1	2	5	4	3	10	1	2	5	3	4
11	1	2	5	4	3	11	1	2	5	3	4
12	1	2	5	4	3	12	1	5	4	2	3
13	1	2	5	4	3	13	1	2	5	3	4
14	1	2	5	3	4	14	1	2	5	4	3
15	1	2	5	4	3	15	1	2	5	4	3
16	1	2	5	3	4	16	1	2	5	4	3
17	1	2	5	3	4	17	1	2	3	5	4
18	1	2	5	3	4	18	1	2	5	3	4
19	1	2	5	4	3	19	1	2	5	3	4
20	1	2	5	4	3	20	1	2	5	3	4
						21	1	3	4	5	2
						22	1	2	5	4	3
						23	1	3	5	4	2
						24	1	2	5	4	3

Note: For major attributes, 1- 20 are the conditions in Table 7.18. For sub-attributes, 1 – 24 are the conditions in Appendix C.3. Main conditions show the original result of the location ranking.

Source: Author

7.5.2 TOPSIS versus Fuzzy-TOPSIS

This section will make a comparison of the results of the major attributes and sub-attributes between the TOPSIS and fuzzy-TOPSIS.

7.5.2.1 Major Attributes

A comparison of the sensitivity analysis result between the TOPSIS and fuzzy-TOPSIS of the major attributes is presented below in Table 7.33.

Table 7.33 Comparison of the sensitivity analysis for major attributes for Case Study A

Non-Fuzzy-TOPSIS						Fuzzy-TOPSIS					
	Warehouse Locations Rank						Warehouse Locations Rank				
Conditions	A	B	C	D	E	Conditions	A	B	C	D	E
Main	1	2	5	3	4	Main	1	2	5	4	3
1	1	2	4	5	3	1	1	2	5	4	3
2	1	2	5	3	4	2	1	2	5	4	3
3	1	2	4	3	5	3	1	2	5	3	4
4	1	2	5	3	4	4	1	2	5	3	4
5	1	2	4	3	5	5	1	2	5	3	4
6	1	2	4	3	5	6	1	2	5	3	4
7	1	2	4	3	5	7	1	2	5	4	3
8	1	2	4	3	5	8	1	2	5	4	3
9	1	2	5	3	4	9	1	2	5	4	3
10	1	2	5	3	4	10	1	2	5	4	3
11	1	2	5	4	3	11	1	2	5	4	3
12	1	2	5	4	3	12	1	2	5	4	3
13	1	2	4	3	5	13	1	2	5	4	3
14	1	2	4	3	5	14	1	2	5	3	4
15	1	2	4	3	5	15	1	2	5	4	3
16	1	2	4	3	5	16	1	2	5	3	4
17	1	2	4	3	5	17	1	2	5	3	4
18	1	2	4	3	5	18	1	2	5	3	4
19	1	2	5	3	4	19	1	2	5	4	3
20	1	2	4	4	3	20	1	2	5	4	3

Note: 1- 20 are the conditions in Table 7.18. Main conditions show the original result of the location ranking.

Source: Author

Table 7.33 shows that Location A and Location B are evaluated first and second consistently for the entire condition. Unlike the non-fuzzy TOPSIS result, Location C is at the bottom of the rank for the entire condition in fuzzy-TOPSIS analysis. The ranking of Locations D and E varies in some conditions when the criteria weights are exchanged.

7.5.2.2 Sub-Attributes

A comparison of the sensitivity analysis results between the TOPSIS and Fuzzy-TOPSIS of the sub-attributes is presented below in Table 7.34. The table includes the varied conditions obtained in the previous findings.

Table 7.34 Comparison of the sensitivity analysis for sub-attributes for Case Study A

	Non-Fuzzy-TOPSIS					Fuzzy-TOPSIS				
	Warehouse Locations Ranking					Warehouse Locations Rank				
Conditions	A	B	C	D	E	A	B	C	D	E
Main	1	2	5	4	3	1	2	5	4	3
1	1	2	5	4	3	1	2	5	4	3
2	1	2	5	4	3	1	2	5	4	3
3	1	2	5	4	3	1	2	5	4	3
4	1	2	5	4	3	1	2	5	4	3
5	1	2	5	4	3	1	2	5	4	3
6	1	2	5	4	3	1	2	5	4	3
7	1	2	5	3	4	1	2	5	4	3
8	1	2	5	3	4	1	2	5	4	3
9	1	2	5	4	3	1	2	5	4	3
10	1	2	5	4	3	1	2	5	3	4
11	2	1	5	3	4	1	2	5	3	4
12	1	2	5	4	5	1	5	4	2	3
13	1	2	5	4	3	1	2	5	3	4
14	2	1	5	4	3	1	2	5	4	3
15	2	1	5	4	3	1	2	5	4	3
16	1	2	5	4	3	1	2	5	4	3
17	1	2	5	4	3	1	2	3	5	4
18	2	1	5	4	3	1	2	5	3	4
19	2	1	5	4	3	1	2	5	3	4
20	2	5	4	3	1	1	2	5	3	4
21	1	3	4	5	2	1	3	4	5	2
22	1	2	5	4	3	1	2	5	4	3
23	1	2	5	4	3	1	3	5	4	2
24	1	2	5	4	3	1	2	5	4	3

Note: 1 – 24 are the conditions in Appendix C.3. Main conditions show the original result of the location ranking.

Source: Author

Table 7.34 shows that there is a slight difference in the results. The evaluation of the first non-fuzzy TOPSIS sensitivity analysis result for Location A varies while it is consistent in the fuzzy-TOPSIS result. Consequently, Location A is rated at the top of the rankings for the entire condition in fuzzy-TOPSIS.

Location A is selected to be the optimal warehouse in both the non-fuzzy TOPSIS and the Fuzzy-TOPSIS analysis of major attributes while it is selected as the optimal warehouse location by the fuzzy-TOPSIS analysis of the sub-attributes evaluation.

7.6 Chapter Summary

This chapter has identified the preference order of the regional (i.e. macro) determinant attributes that were applied for the warehouse selection for International Humanitarian Organisation A with the application of AHP. Among the major attributes, cooperation and the existence among the different actors involved in humanitarian relief logistics operation was considered to be the most important (Table 7.2). Meanwhile, the location attributes were considered to be the least important of the attributes. The cooperation of the host government was considered the most important attribute for among the cooperation attributes while local NGOs ranked at the bottom (Table 7.10). The political stability was considered the most important among the national stability attributes (Table 7.6). The same preference order of national stability can be found in Kayikci (2010). The proximity to disaster prone areas was considered the most important among the location attributes and climate ranked at the bottom (Table 7.4). Among the sub-attributes, the political stability of a country was considered to be the most important while climate result to be the least important attributes (Table 7.14).

Warehouses locations were evaluated with TOPSIS, the attribute weights were obtained by AHP. Moreover, a fuzzy-TOPSIS evaluation was made for robustness and consistent results. Both TOPSIS and fuzzy-TOPSIS results show Location A was evaluated as the most highest major attributes and Location C as the most lowest. (see Table 7.16 and Table 7.24). For sub-attributes analysis, location B is evaluated as the most highest in 13 sub-attributes in TOPSIS (see Table 7.20) and Location A in 24 sub-attributes in fuzzy-TOPSIS (see Table 7.28). However, Location B has more lowest evaluated sub-attributes than Location A in both TOPSIS and fuzzy-TOPSIS (see Table 7.20 and Table 7.28).

The distance from PIS, NIS and relative closeness to ideal solution was calculated for the final ranking of the warehouse. Location A is at the closest distance from PIS and at the farthest from NIS for all results (see Table 7.17, Table 7.21, Table 7.26, and Table 7.29). Location A also has the highest relative closeness to ideal solution in all results.

A sensitivity analysis was executed to ensure the accuracy results that were obtained by fuzzy-TOPSIS. The comparison results show that fuzzy-TOPSIS results are more consistent in terms of ranking order than the non-fuzzy TOPSIS results (see Table 7.33 and Table 7.34). It also clearly shows the rank order of the warehouse by determine the optimal warehouse.

The fluctuation results of the sensitivity analysis illustrate stability of the fuzzy-TOPSIS sensitivity analysis (see Figure 7.3 and Figure 7.4).

The results analysed through AHP, fuzzy TOPSIS, and sensitivity analysis result show that Location A is the optimal warehouse location. The comparison between the non-fuzzy and fuzzy TOPSIS results shows that the fuzzy method has more accurate and robust results for warehouse decision selection decision making process.

CHAPTER 8
INTERPRETATION OF FINDINGS II:
SPECIFIC SITE (MICRO) DETERMINANTS

8.1 Chapter Overview

This chapter aims to describe the preferences of the specific site attributes in humanitarian pre-positioned warehouse, which are found from the international humanitarian organisations. This chapter provides the findings for specific site (i.e. micro) determinants that were used to locate the warehouse. The attributes were evaluated using the ranking of alternatives warehouse locations. The evaluation of the preferences of the attributions have been analysed by AHP. Meanwhile, the evaluation of alternative warehouse location and determination of the final rank has been assessed by TOPSIS and fuzzy-TOPSIS. Finally, to ensure the robustness of the results a sensitivity analysis has been tested. Table 1.1 evaluates and identifies the attributes and optimal warehouse location that were used in micro level view (i.e. Q4 and Q5).

8.2 Case Study B Analysis

This section will describe the preference for the specific site (micro) warehouse location attributes that were discussed Chapter 6. The evaluation of alternative warehouse locations is assessed to determine the final rank of those warehouses that were identified in Chapter 6, Section 6.3.4. Finally, the sensitivity analysis is tested to ensure the robustness of the results.

8.3 The Criteria Weights

In the first part of this section, the overall result of the preference of the attributes for specific site determinants is analysed. The preferences of the attribution were calculated by the geometric means to avoid error and to obtain the pairwise comparison matrix on which there is a consensus (as presented in Chapter 4, Section 4.4.1.4). A detailed analysis of the group that participated in the decision-making process of the movement of the warehouse will then follow, which will compare how the groups preferences and opinions differ. The calculated results use the weights of criteria based on the analysis procedure that is presented in Chapter 4, Section 4.4.1.2.

8.3.1 Evaluation of Major Attributes

The result of the matrix for criteria for the pairwise comparison for the major attributes is shown in Appendix C.5. The results obtained from the computations based on the pairwise comparison matrix provided in Appendix C.5 are presented in Table 8.1. The table includes the value of the Eigen Value (λ_{max}), Consistency Index (CI), Random Consistency index (RI), and the Consistency Ratio (CR).

Table 8.1 Consistency checking of matrix for Case Study B

Attributes	λ_{max}	CI	RI	CR
Major	5.172	0.0430	1.12	0.0383
Distance (C_a)	6.4275	0.0855	1.24	0.0689
Security (C_b)	5.1384	0.0346	1.12	0.0308
Office Facilities (C_c)	4.2085	0.0695	0.90	0.0105
Warehouse Facilities (C_d)	9.708	0.0885	1.45	0.0610
Convenience (C_e)	6.4255	0.0851	1.24	0.0686

Source: Author

Based on the consistency checking obtained in the above table, the CR of the pairwise matrix for all attributes is calculated as being less than 0.1. This indicates that the weights are shown to be consistent and they are acceptable to be used in the selection process (Saaty, 1980). This also applies to the result of the group comparison (Appendix C.6).

8.3.1.1 Overall Results

Table 8.2 presents the preference order of the major attributes. The Warehouse Facilities (C_d) attribute turned out to be the most important factor for the consideration of the warehouse location selection with a normalised weight of 0.3797. The Distance (C_a) attribute follows with a normalised weight of 0.2875 as the next important attribute. The first two attributes add up to an accumulated the weight of 0.6672 (66.72%), more than a half of the total. The third most important attribute is Security (C_b) with a normalised weight of 0.2032. The accumulated weight increase 0.8704 (87.04%) from 0.6672 when this attribute is added. Office Facilities (C_c) and Convenience (C_e) attributes are ranked bottom of a table with a normalised weight of 0.0843 and 0.0453, which gives little influence on the warehouse selection decision-making.

Table 8.2 Preference order of major attributes for Case Study B

Rank	Criteria	Normalised Weight	Accumulated Weight
1	Warehouse Facilities (C_d)	0.3797	0.3797
2	Distance (C_a)	0.2875	0.6672
3	Security/Safety (C_b)	0.2032	0.8704
4	Office Facilities (C_c)	0.0843	0.9547
5	Convenience (C_e)	0.0453	1.0000
	Total Weight	1.0000	

Source: Author

8.3.1.2 Group Comparison

Table 8.3 presents the preference order of the major attributes for group comparison.

Table 8.3 Preference order of major attributes for Case Study B (Group)

Rank	UN Agency 1 NW		UN Agency 2 NW		UN Agency 3 NW		UN Agencies NW		NGO NW		Company NW	
1	C_d	0.4023	C_d	0.4055	C_d	0.4347	C_d	0.4416	C_d	0.3492	C_d	0.3295
2	C_a	0.3328	C_b	0.2915	C_a	0.2372	C_a	0.2388	C_b	0.2841	C_b	0.2702
3	C_b	0.1165	C_a	0.1876	C_b	0.1923	C_b	0.1804	C_a	0.2042	C_a	0.2617
4	C_c	0.0892	C_c	0.0743	C_c	0.0828	C_c	0.0824	C_c	0.1157	C_c	0.0899
5	C_e	0.0592	C_e	0.0411	C_e	0.0530	C_e	0.0568	C_e	0.0468	C_e	0.0487
Total Weight		1.0000		1.0000		1.0000		1.0000		1.0000		1.0000

C_a – Distance, C_b – Security/Safety, C_c – Office Facilities, C_d – Warehouse Facilities C_e – Convenience, NW – Normalised Weight

Source: Author

The results from the above tables show that the most important major attribute is Warehouse Facilities (C_d) and the least important major attribute is Convenience (C_e). The priority attributes for the alternative warehouse is the facility itself (Respondent B 2). The groups all agreed that they can sacrifice the convenience of their working environment to other attributes if they are satisfied in their category (Respondents B1, B3, B8, and B9). UN Agencies 1 and 3 responded that Distance (C_a) is more important than Security (C_b); they reported that they believe that distance to the key airports and seaport is the critical factor for humanitarian relief supply chain (Respondents B1 and B7). On the other hand, the NGOs and Company responded that Security (C_b) is more important because of the valuable characteristics of the relief items in the warehouse (Respondent 9). It can also be noted that the importance is almost equal in Company where the difference weight is only 0.0087 between Security (C_b) and Distance (C_a).

8.3.2 Evaluation of Distance Attributes

8.3.2.1 Overall Results

Table 8.4 presents the overall result of the preference order of the sub-attributes for Distance (C_a) attributes.

Table 8.4 Preference order of Distance attributes

Rank	Criteria	Normalised Weight	Accumulated Weight
1	Sharjah Airport (SC_{a4})	0.3446	0.3446
2	Al Maktoum Airport (SC_{a3})	0.2615	0.6061
3	Jebel Ali Seaport (SC_{a1})	0.1575	0.7636
4	Dubai Int'l Airport (SC_{a2})	0.1272	0.8908
5	MOFA (SC_{a6})	0.0572	0.9480
6	Abu Dhabi Airport (SC_{a5})	0.0520	1.0000
	Total Weight	1.0000	

Source: Author

Sharjah Airport (SC_{a4}) is considered to be the most important attribute, with a normalised weight of 0.3446. Al Maktoum Airport (SC_{a3}) follows, with a normalised weight of 0.2615. The first two attributes consists an accumulated weight of 0.6061 (60.61%). Jebel Ali Seaport (SC_{a3}) is ranked third in the table, with a normalised weight of 0.1575. This weight is very similar to that of Dubai International Airport (SC_{a2}), which ranked in fourth place. The bottom of the table is ranked by MOFA (SC_{a6}) and Abu Dhabi Airport (SC_{a5}), with a normalised weight of 0.0572 (MOFA) and 0.0520 (Abu Dhabi), which is considered to be the least important attributes. The contribution of these two attributes has been found to have a low influence on the warehouse selection process.

8.3.2.2 Group Comparison

Table 8.5 presents the preference order of the sub-attributes for Distance (C_a) attributes for group comparison.

Table 8.5 Preference order of Distance attributes (Group)

Rank	UN Agency 1	NW	UN Agency 2	NW	UN Agency 3	NW	UN Agencies	NW	NGO	NW	Company	NW
1	SC_{a3}	0.4375	SC_{a4}	0.3431	SC_{a4}	0.2714	SC_{a4}	0.3168	SC_{a4}	0.3216	SC_{a4}	0.3702
2	SC_{a4}	0.3020	SC_{a2}	0.2921	SC_{a2}	0.2100	SC_{a2}	0.2494	SC_{a3}	0.1942	SC_{a2}	0.2104
3	SC_{a1}	0.1366	SC_{a1}	0.1249	SC_{a3}	0.1880	SC_{a3}	0.1811	SC_{a2}	0.1605	SC_{a3}	0.2030
4	SC_{a6}	0.0539	SC_{a3}	0.1441	SC_{a1}	0.1789	SC_{a1}	0.1301	SC_{a1}	0.1381	SC_{a1}	0.1210
5	SC_{a2}	0.0393	SC_{a6}	0.0548	SC_{a6}	0.1045	SC_{a6}	0.0769	SC_{a6}	0.1167	SC_{a6}	0.0554
6	SC_{a5}	0.0307	SC_{a5}	0.0410	SC_{a5}	0.0472	SC_{a5}	0.0457	SC_{a5}	0.0689	SC_{a5}	0.0400
Total Weight		1.0000		1.0000		1.0000		1.0000		1.0000		1.0000

SC_{a1} – Jebel Ali Seaport, SC_{a2} – Dubai Int'l Airport, SC_{a3} – Al Maktoum Airport, SC_{a4} – Sharjah Airport, SC_{a5} – Abu Dhabi Airport, SC_{a6} – MOFA, NW – Normalised Weight

Source: Author

Table 8.5 shows that all of the groups felt that Sharjah airport (SC_{a4}) is the most important attribute for warehouse selection. UN Agency 1 considered Al Maktoum Airport (SC_{a3}) to be the most important attribute for their warehouse selection. Most of the airports in Dubai handle cargo aircrafts where the humanitarian organisations have lots of options to choose from (Respondents B3, B5, and B10). The only constraint is that they need to deliver the relief items during the night when it fully loaded due to the heat (Respondent B 2). Even though seaports play a critical role in humanitarian pre-positioned warehouse by receiving large quantity of relief items from suppliers, Jebel Ali Seaport (SC_{a1}) was evaluated as less important than the airports because relief goods are delivered via air-charter in an emergency situation (Respondents B2, B3, B5, and B10). Abu Dhabi Airport (SC_{a5}) is considered to be the least important of the attributes due to its geographical limitations (Respondent B4).

8.3.3 Evaluation of Security/Safety Attributes

8.3.3.1 Overall Results

Table 8.6 presents the overall result of the preference order of sub-attributes for Security and Safety (C_b) attributes.

Table 8.6 Preference order of Security/Safety attributes

Rank	Criteria	Normalised Weight	Accumulated Weight
1	Warehouse (SC_{b1})	0.4178	0.4178
2	Road Safety (SC_{b5})	0.2118	0.6296
3	Fire Fighting Station (SC_{b2})	0.1717	0.8013
4	Police Station (SC_{b3})	0.1183	0.9196
5	Hospital (SC_{b4})	0.0804	1.0000
	Total Weight	1.0000	

Source: Author

Warehouse Security (SC_{b1}) was considered as the most important attribute, with a normalised weight of 0.4178 (which is almost half of the total weight). Road Safety (SC_{b5}) ranked second, with a normalised weight of 0.2118. The total weight of these two factors adds up to 0.6296 (69.96%). However the normalised weight of the Warehouse Security (SC_{b1}) is almost twice as much of that of Road Safety (SC_{b5}), illustrating the importance of the warehouse security. Fire Fighting Station (SC_{b2}) and Police Station (SC_{b3}) ranked third and fourth, with a normalised weight of 0.1717 (Fire Fighting Station) and 0.1183 (Police Station). A Hospital (SC_{b4}) considered as the least important attribute, with a normalised weight of 0.0804.

8.3.3.2 Group Comparison

Table 8.7 shows that the most important attribute is the Warehouse Security (SC_{b1}) in all groups. A relief warehouse stocks a lot of valuable relief items such as medicines, telecommunications equipment, and armoured-vehicles which need extra surveillance with CCTV, security guards, electrified fans, and security guards (Respondents B1, B2, B4, and B8). Road Safety (SC_{b5}) is ranked second for all groups because the warehouse should be located in a safe traffic area to avoid any potential accidents during emergency operation. A road accident can delay the whole process of the dispatch of the relief goods (Respondent B2 and B4). The rest of the attributes remain in the bottom three of the table. The accumulated weights of those attributes are less than 50% of the total, which gives less impact on the warehouse selection problem. Hospital (SC_{b4}) is considered as the least important attribute for all groups for warehouse selection; however, UN Agency 1 selected a Fire Fighting Station (SC_{b2}) as the least important attribute.

Table 8.7 Preference order of Security/Safety attributes (Group)

Rank	UN Agency 1	NW	UN Agency 2	NW	UN Agency 3	NW	UN Agencies	NW	NGO	NW	Company	NW
1	SC_{b1}	0.3630	SC_{b1}	0.4316	SC_{b1}	0.3805	SC_{b1}	0.4436	SC_{b1}	0.3878	SC_{b1}	0.4659
2	SC_{b5}	0.2110	SC_{b5}	0.2418	SC_{b5}	0.2029	SC_{b5}	0.2052	SC_{b5}	0.1848	SC_{b5}	0.1965
3	SC_{b3}	0.1510	SC_{b2}	0.1837	SC_{b2}	0.1820	SC_{b2}	0.1981	SC_{b2}	0.1557	SC_{b2}	0.1807
4	SC_{b4}	0.1452	SC_{b3}	0.0984	SC_{b3}	0.1281	SC_{b3}	0.0936	SC_{b3}	0.1491	SC_{b3}	0.1019
5	SC_{b2}	0.1297	SC_{b4}	0.0445	SC_{b4}	0.1065	SC_{b4}	0.0595	SC_{b4}	0.1226	SC_{b4}	0.0550
Total Weight		1.0000		1.0000		1.0000		1.0000		1.0000		1.0000

SC_{b1} –Warehouse, SC_{b2} – Fire Fighting Station, SCb_3 – Police Station, SC_{b4} – Hospital, SC_{b5} – Road Safety, NW – Normalised Weight

Source: Author

8.3.4 Evaluation of Office Facilities Attributes

8.3.4.1 Overall Results

Table 8.8 presents the overall results of the preference order of sub-attributes for Office Facilities (C_c) attributes.

Table 8.8 Preference order of Office related attributes

Rank	Criteria	Normalised Weight	Accumulated Weight
1	Warehouse Distance (SC_{c3})	0.3894	0.3894
2	IT/Communication (SC_{c2})	0.3106	0.7000
3	Modular Space (SC_{c4})	0.1644	0.8644
4	Diplomatic Work (SC_{c1})	0.1356	1.0000
	Total Weight	1.0000	

Source: Author

Warehouse Distance (SC_{c3}) is considered to be the most important attribute, with a normalised weight of 0.3894. IT/Communication (SC_{c2}) ranked second, with a normalised weight of 0.3106 with a little difference. These two attributes have an accumulated weight of 0.7000

(70%) of the total weight, which shows the importance of the two attributes for office related attributes. The bottom two attributes are Modular Space (SC_{c1}) and Diplomatic Work (SC_{c4}) that are considered to be less important, with a normalised weight of 0.1644 (Modular Space) and 0.1356 (Diplomatic Work).

8.3.4.2 Group Comparison

Table 8.9 presents the preference order of sub-attributes for Office Facilities (C_c) attributes for group comparison.

Table 8.9 Preference order of Office related attributes (Group)

Rank	UN Agency 1		UN Agency 2		UN Agency 3		UN Agencies		NGO		Company	
		NW		NW		NW		NW		NW		NW
1	SC_{c3}	0.3461	SC_{c3}	0.4387	SC_{c3}	0.4085	SC_{c3}	0.3384	SC_{c2}	0.3940	SC_{c3}	0.4157
2	SC_{c1}	0.2855	SC_{c2}	0.3572	SC_{c2}	0.3131	SC_{c2}	0.2879	SC_{c3}	0.2948	SC_{c2}	0.3532
3	SC_{c2}	0.2050	SC_{c4}	0.1336	SC_{c1}	0.1671	SC_{c1}	0.2046	SC_{c4}	0.2048	SC_{c4}	0.1290
4	SC_{c4}	0.1634	SC_{c1}	0.0705	SC_{c4}	0.1113	SC_{c4}	0.1691	SC_{c1}	0.1064	SC_{c1}	0.1021
Total Weight		1.0000		1.0000		1.0000		1.0000		1.0000		1.0000

SC_{c1} –Diplomatic Work, SC_{c2} – IT/Communication, SC_{c3} – Warehouse Distance, SC_{c4} – Modular Space, NW – Normalised Weight

Source: Author

Warehouse Distance (SC_{c3}) is considered to be the most important attribute all of the groups, except for NGOs who IT/Communication (SC_{c2}) is ranked first. The warehouse is ideally located near the office so that the staff can frequently go to the facility to make maintenance checks (Respondents B2, B4, and B7). IT/Communication facility of the office is crucial for daily operation since the organisations make a considerable number of international calls and they also hold daily video conferences with their headquarters (Respondents B2, B4, and B8). Both of these attributes are considered fairly equally important for all of the groups. UN Agency 1 considered the Diplomatic Work (SC_{c1}) of the office function to be slightly higher than others because of their functional role in the country, which means that they deal with more diplomatic work than warehousing (Respondent B1).

8.3.5 Evaluation of Warehouse Facilities Attributes

8.3.5.1 Overall Results

Table 8.10 presents the overall result of the preference order of sub-attributes for Warehouse Facilities (C_d) attributes.

Table 8.10 Preference order of Warehouse facilities attributes

Rank	Criteria	Normalised Weight	Accumulated Weight
1	Capacity (SC_{d1})	0.3949	0.3949
2	Loading Bays (SC_{d6})	0.1193	0.5142
3	Ceiling Height (SC_{d5})	0.1154	0.6296
4	Openings (SC_{d8})	0.1109	0.7405
5	Doors at Both Ends (SC_{d9})	0.0803	0.8208
6	Open Storage (SC_{d2})	0.0690	0.8898
7	Spill-Over Area (SC_{d4})	0.0516	0.9414
8	Office Facility (SC_{d3})	0.0378	0.9792
9	Flood Lights (SC_{d7})	0.0208	1.0000
	Total Weight	1.0000	

Source: Author

Capacity (SC_{d1}) is considered to be the most important attribute for the warehouse selection, with a normalised weight of 0.3949. The next ranking of the table consist with Loading Bays (SC_{d6}), Ceiling Height (SC_{d5}), and Openings (SC_{d8}), with a normalised weight of 0.1193 (Loading Bays), 0.1154 (Ceiling Height) and 0.1109 (Openings); these attributes have a similar normalised weight which is equal in importance. Floor Capacity (SC_{d1}) has a large portion of weight by itself. The accumulated weight of Floor Capacity (SC_{d1}) adds up to more than 50% when it is paired with Loading Bays (51.42%), Ceiling Height (51.03%), and Openings (50.58%). Other attributes are considered less important. Flood Lights (SC_{d7}) are considered to be the least important, with a normalised weight of 0.0208.

8.3.5.2 Group Comparison

It can be seen in Table 8.11 that Capacity (SC_{d1}) is considered as the most important attribute in all groups. Ceiling Height (SC_{d5}), Loading Bays (SC_{d6}), and Openings (SC_{d8}) differ in rankings but are the second most important attributes for warehouse selection. Flood Lights (SC_{d7}) are considered to be the least important attribute in all groups because most of the loading and unloading activities are done during the day (Respondents B1 and B3). The most important attribute for warehouse facilities is the floor capacity of the warehouse which should be able to store a large volume of relief goods (Respondent B2). In addition, the height of the ceiling is important to measure volumetric size of the warehouse (Respondents B2 and B7). Meanwhile, warehouses equipped with acceptable loading bays and door openings will increase the loading and unloading time of the relief goods (Respondents B4 and B8).

Table 8.11 Preference order of Warehouse facilities attributes (Groups)

Rank	UN Agency 1		UN Agency 2		UN Agency 3		UN Agencies		NGO		Company	
		NW		NW		NW		NW		NW		NW
1	SC_{d1}	0.3591	SC_{d1}	0.3585	SC_{d1}	0.3132	SC_{d1}	0.3558	SC_{d1}	0.3661	SC_{d1}	0.3920
2	SC_{d6}	0.1236	SC_{d8}	0.1812	SC_{d5}	0.1529	SC_{d6}	0.1428	SC_{d6}	0.1368	SC_{d6}	0.1303
3	SC_{d5}	0.1175	SC_{d6}	0.1295	SC_{d8}	0.1264	SC_{d5}	0.1349	SC_{d8}	0.1291	SC_{d5}	0.1243
4	SC_{d2}	0.0959	SC_{d5}	0.0928	SC_{d6}	0.1216	SC_{d8}	0.1209	SC_{d5}	0.1278	SC_{d8}	0.1159
5	SC_{d4}	0.0958	SC_{d9}	0.0905	SC_{d9}	0.0874	SC_{d2}	0.0790	SC_{d9}	0.0796	SC_{d9}	0.0827
6	SC_{d8}	0.0770	SC_{d2}	0.0476	SC_{d2}	0.0774	SC_{d9}	0.0642	SC_{d2}	0.0512	SC_{d4}	0.0456
7	SC_{d3}	0.0537	SC_{d4}	0.0417	SC_{d4}	0.0515	SC_{d4}	0.0464	SC_{d4}	0.0457	SC_{d2}	0.0462
8	SC_{d9}	0.0448	SC_{d3}	0.0319	SC_{d3}	0.0402	SC_{d3}	0.0379	SC_{d3}	0.0388	SC_{d3}	0.0338
9	SC_{d7}	0.0326	SC_{d7}	0.0263	SC_{d7}	0.0294	SC_{d7}	0.0181	SC_{d7}	0.0249	SC_{d7}	0.0242
Total Weight		1.0000		1.0000		1.0000		1.0000		1.0000		1.0000

SC_{d1} – Capacity, SC_{d2} – Open Storage, SC_{d3} – Office Facility, SC_{d4} – Spill-Over Area, SC_{d5} – Ceiling Height, SC_{d6} – Loading Bays, SC_{d7} – Flood Lights, SC_{d8} – Openings, SC_{d9} – Doors at Both Ends, NW – Normalised Weight

Source: Author

8.3.6 Evaluation of Convenience Attributes

8.3.6.1 Overall Results

Table 8.12 presents the overall result of the preference order of the sub-attributes for Convenience (C_e) attributes.

Table 8.12 Preference order of Convenience attributes

Rank	Criteria	Normalised Weight	Accumulated Weight
1	Transportation (SC_{e6})	0.3343	0.3343
2	Main City (SC_{e4})	0.2327	0.5670
3	Residential (SC_{e5})	0.1790	0.7460
4	Cafeteria (SC_{e1})	0.1024	0.8484
5	ATM (SC_{e3})	0.0832	0.9316
6	Mini-Mart (SC_{e2})	0.0684	1.0000
	Total Weight	1.000	

Source: Author

Accessibility to a warehouse with an adequate Transportation (SC_{e6}) attribute is considered as the most important attribute, with a normalised weight of 0.3343. A warehouse which is located near the Main City (SC_{e4}) is ranked second, with a normalised weight of 0.2327. These two attributes consists an accumulated weight of 0.5670 (56.70%). The Residential (SC_{e5}) and Cafeteria (SC_{e1}) attributes are ranked third and fourth, with a normalised weight of 0.1790 (Residential) and 0.1024 (Cafeteria). Availability of an ATM (SC_{e3}) is ranked fifth, with a normalised weight of 0.0832. Finally, a Mini-Mart (SC_{e2}) is considered to be the least important attribute of all.

8.3.6.2 Group Comparison

Table 8.13 presents the preference order of sub-attributes for Convenience (C_e) attributes for group comparison.

Table 8.13 Preference order of Convenience attributes (Group)

Rank	UN Agency 1	NW	UN Agency 2	NW	UN Agency 3	NW	UN Agencies	NW	NGO	NW	Company	NW
1	SC_{e5}	0.2305	SC_{e6}	0.3476	SC_{e6}	0.3164	SC_{e6}	0.3294	SC_{e6}	0.2888	SC_{e6}	0.3294
2	SC_{e4}	0.1958	SC_{e4}	0.2044	SC_{e4}	0.2598	SC_{e4}	0.2370	SC_{e4}	0.2075	SC_{e4}	0.2370
3	SC_{e6}	0.1698	SC_{e5}	0.1701	SC_{e5}	0.1892	SC_{e5}	0.2048	SC_{e5}	0.1839	SC_{e5}	0.2048
4	SC_{e2}	0.1631	SC_{e1}	0.1102	SC_{e1}	0.1098	SC_{e1}	0.0997	SC_{e1}	0.1264	SC_{e1}	0.0997
5	SC_{e1}	0.1436	SC_{e3}	0.0942	SC_{e3}	0.0687	SC_{e3}	0.0664	SC_{e3}	0.1023	SC_{e2}	0.0668
6	SC_{e3}	0.1069	SC_{e2}	0.0735	SC_{e2}	0.0561	SC_{e2}	0.0627	SC_{e2}	0.0911	SC_{e3}	0.0623
Total Weight		1.0000		1.0000		1.0000		1.0000		1.0000		1.0000

Note: SC_{e1} – Cafeteria, SC_{e2} – Mini-mart, SC_{e3} – ATM, SC_{e4} – Main City, SC_{e5} – Residential, SC_{e6} – Transportation, NW – Normalised Weight

Source: Author

Transportation (SC_{e6}) is considered to be the most important attribute for all groups, except for UN Agency 1. Residential (SC_{e5}) was the first choice for UN Agency 1. The availability transportation to the warehouse is important for the staff because of the warehouse of the current lack of public transportation (Respondent B2, B5, and B7). Warehouse location should not be isolated from convenient facilities, such as residential area and main city (Respondents B1, B2, B4, and B9).

8.3.7 The Final Weights

After the normalised weights for the major attributes and sub-attributes were obtained, the final weights of the sub-attributes were calculated to observe the preference ranking. The overall result of the final ranking for the sub-attributes is shown in Table 8.14.

Table 8.14 shows that Capacity (SC_{d1}), a sub-attribute of Warehouse facilities (C_d), is considered to be the most important attributes among the sub-attributes, with a final weight of 0.1504. Sharjah Airport (SC_{a4}), a sub-attribute of Distance (C_a), ranked second, with a final weight of 0.0930. Warehouse (SC_{b1}), a sub-attribute of Security (SC_b), ranked third, with a final weight of 0.0848. The least important attribute was Mini-Mart (SC_{e2}), with a final weight of 0.0036. It can also be seen that the top seven attributes are: Capacity (SC_{d1}) Sharjah Airport (SC_{a4}), Warehouse (SC_{b1}), Al Maktoum Airport (SC_{a3}), Jebel Ali Seaport (SC_{a1}), Loading Bays (SC_{d6}), and Ceiling Height (SC_{e5}). These sub-attributes are under the major attributes of Distance (C_a), Security (C_b), and Warehouse Facilities (C_d). These seven attributes have an accumulated weight of 0.5376 (53.76%). Warehouse Distance (SC_{c3}), a sub-attribute of Office facilities (C_c), first appears in the table, with a final weight of 0.0328. Transportation (SC_{e6}), a sub-attribute of Convenience (C_e), first appears in the table, with a final weight of 0.0150. This result shows the importance of the attributes, which influence the decision-making process of the warehouse selection process.

Table 8.14 The final weights of the sub-attributes Case Study B

Ranking	Sub-Attributes	Final Weights	Accumulated Weights
1	Capacity (SC_{d1})	0.1504	0.1504
2	Sharjah Airport (SC_{a4})	0.0930	0.2434
3	Warehouse (SC_{b1})	0.0848	0.3282
4	Al Maktoum Airport (SC_{a3})	0.0752	0.4034
5	Jebel Ali Seaport (SC_{a1})	0.0454	0.4488
6	Loading Bays (SC_{d6})	0.0450	0.4938
7	Ceiling Height (SC_{d5})	0.0438	0.5376
8	Road Safety (SC_{b5})	0.0430	0.5806
9	Suitable Openings (SC_{d8})	0.0418	0.6224
10	Dubai Int'l Airport (SC_{a2})	0.0366	0.6590
11	Fire Fighting Station (SC_{b2})	0.0348	0.6938
12	Warehouse Distance (SC_{c3})	0.0328	0.7266
13	Doors at Both Ends (SC_{d9})	0.0304	0.7570
14	Open Storage (SC_{d2})	0.0262	0.7832
15	IT/Communication (SC_{c2})	0.0260	0.8092
16	Police Station (SC_{b3})	0.0240	0.8332
17	General Spill-Over Area (SC_{d4})	0.0194	0.8526
18	MOFA (SC_{a6})	0.0164	0.8690
19	Hospital (SC_{b4})	0.0162	0.8852
20	Transportation (SC_{e6})	0.0150	0.9002
21	Abu Dhabi Airport (SC_{a5})	0.0148	0.9150
22	Office Facility (SC_{d3})	0.0142	0.9292
23	Modular Office Space (SC_{c4})	0.0138	0.9430
24	Diplomatic Work (SC_{c1})	0.0124	0.9544
25	Main City (SC_{e4})	0.0114	0.9668
26	Residential (SC_{e5})	0.0094	0.9762
27	Flood Lights (SC_{d7})	0.0090	0.9852
28	Cafeteria (SC_{e1})	0.0066	0.9918
29	ATM (SC_{e3})	0.0046	0.9964
30	Mini-Mart (SC_{e2})	0.0036	1.0000
	Total weight	1.0000	

Source: Author

8.4 Evaluation of Alternatives and Determination of the Final Rank

This section gives the results of building the decision matrix by comparing the alternatives have been identified. The WEM is established using the criteria weights calculated by AHP in the previous section. With the WEM, both TOPSIS and fuzzy-TOPSIS analysis will be presented to evaluate the warehouse location.

8.4.1 TOPSIS

The WEM is established with the weights obtained in Table 8.2 and Table 8.14. This section analyses the findings by evaluating the alternative warehouse locations into major attributes and sub-attributes. The obtained results are based on the calculation process that has been presented in Chapter 4, Section 4.4.2.2.

8.4.1.1 Major Attributes

The results of the decision matrix that compares the alternatives are shown in Table 8.15. ‘C’ indicates the criteria in the rows and the column indicates the alternative warehouse locations. The ‘*w*’ in the bottom row indicates the weights obtained in Table 8.2.

Table 8.15 Evaluation matrix of major attributes for alternative locations Case Study B

Location	C_a	C_b	C_c	C_d	C_e
V	**0.5337**	**0.4904**	**0.4980**	0.4399	**0.5152**
W	0.2668	0.3678	0.4316	0.3553	0.3864
X	0.4803	0.4729	**0.4980**	**0.5076**	0.4416
Y	0.4803	0.4729	0.3984	0.4060	0.4416
Z	0.4270	0.4204	0.3984	**0.5076**	0.4416

Note: C_a – Distance, C_b – Security/Safety, C_c – Office Facilities, C_d – Warehouse Facilities C_e – Convenience

Source: Author

Table 8.15 shows that Distance (C_a) is evaluated the highest in Location V with a value of 0.5337. Security/Safety (C_b) is evaluated the highest in Location W with a value of 0.4904. Office Facilities (C_c) is evaluated the highest in Location V and Location X with a value of 0.4980. Warehouse Facilities (C_d) is evaluated the highest in Location X and Z with a value of 0.5076. Convenience (C_e) is evaluated the highest in Location V with a value of 0.5152.

Table 8.16 presents the summary results of the highest and the lowest evaluated warehouse in accordance with the preference order of major attributes.

Table 8.16 Location evaluation with major-attributes ranking for Case Study B

Rank	Criteria	Highest Evaluated Warehouse(s)	Lowest Evaluated Warehouse(s)
1	Warehouse Facilities (C_d)	X and Z	W
2	Distance (C_a)	V	W
3	Security/Safety (C_b)	V	W
4	Office Facilities (C_c)	V and X	Y and Z
5	Convenience (C_e)	V	W

Source: Author

From Table 8.16, Locations X and Z are evaluated as the highest alternatives in Warehouse Facilities (C_d), which ranked first in the preference order. Location V is evaluated as the highest alternative in Distance (C_a), Security/Safety (C_b), Office Facilities (C_c), and Convenience (C_e) which are ranked second to fifth in the preference order. Office facilities (C_c) is also evaluated as the highest attribute in Location X. On the other hand, Location W is evaluated as the lowest in Warehouse facilities (C_d), Distance (C_a), Security/Safety (C_b), and Convenience (C_e). Locations Y and Z are evaluated as the lowest in Office Facilities (C_c) which is ranked fourth in the preference order.

The calculated distance of each alternative warehouse location from PIS (D_i^*), NIS (D_i^-), and relative closeness to ideal solution (CC_j^*) are presented in Table 8.17, show the ranking of the warehouse locations.

Table 8.17 Final ranking with major-attributes for Case Study B: TOPSIS

Rank	Warehouse Location	D_i^*	D_i^-	CC_j^*
Current Location	V	0.0255	0.0688	0.0729
1	X	0.0104	0.0747	0.8771
2	Z	0.0340	0.0596	0.6364
3	Y	0.0405	0.0553	0.5769
4	W	0.0815	0.0027	0.0331

D_i^*- positive-ideal solution (PIS), D_i^-- negative-ideal solution (NIS), CC_j^*- relative closeness to ideal solution

Source: Author

From Table 8.17, Location X is at the nearest distance from PIS with a value of 0.0104 and the farthest from NIS with a value of 0.0747. Location W has the farthest distance from PIS with a value of 0.0815 and the closest from NIS with a value of 0.0027. Location V, the current warehouse, has a PIS value of 0.0255 which is farther than Location X. It is also closer from NIS than Location X with NIS value of 0.0688. In summary, Location X has the highest CC_j^* value of 0.8771. This is higher than the result for Location V, the current warehouse, which has CC_j^* value of 0.0729. Location Z ranked second with 0.86364 as the ideal solution, which is lower than the current warehouse. Location Y and Location W are ranked lower than the current location with a CC_j^* value of 0.5769 (Location Y) and 0.0331 (Location W). Therefore, the optimal site for alternative warehouse selection would be Location X.

Therefore, the descending order of the final ranking for the optimal alternative warehouse location using major attributes weights with TOPSIS is:

X > Z > Y > W

Sensitivity Analysis

Sensitivity analysis was executed to achieve accurate results. The idea of sensitivity is to exchange each criterion's weight with another criterion's weight with each combination stated as a condition. Out of 120 possibilities of the combination, twenty were randomly selected to test the sensitivity analysis. The main condition expresses the original result of the case study. For each condition, the similarities of the warehouse location to the ideal solution (CC_j^*) are calculated. Table 8.18 summarises the numerical results of the calculation and Figure 8.1 illustrates the graphical representation of these results.

Table 8.18 Sensitivity analysis of major attributes for Case Study B: TOPSIS

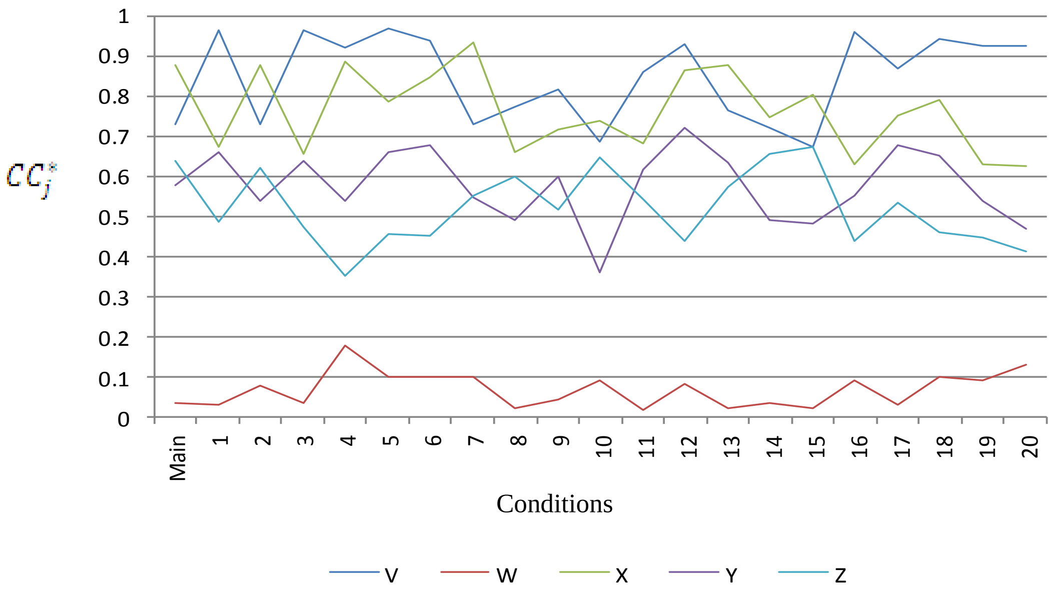
Conditions	Weights						CC_j^* Values of Warehouse Locations				
	w_1	w_2	w_3	w_4	w_5		V	W	X	Y	Z
Main	0.2875	0.2032	0.0843	0.3797	0.0453		0.7293	0.0331	0.8771	0.5769	0.6364
						Ranking	O	4	1	3	2
1	0.2875	0.2032	0.0843	0.0453	0.3797		0.9653	0.0319	0.6735	0.6595	0.4879
						Ranking	X	4	1	2	3
2	0.2875	0.0453	0.2032	0.3797	0.0843		0.7277	0.0778	0.8764	0.5393	0.6208
						Ranking	O	4	1	3	2
3	0.2032	0.2875	0.0843	0.0453	0.3797		0.9617	0.0352	0.6537	0.6378	0.4734
						Ranking	X	4	1	2	3
4	0.2032	0.2875	0.3797	0.0843	0.0453		0.9190	0.1767	0.8863	0.5378	0.3533
						Ranking	X	4	1	2	3
5	0.3797	0.0843	0.2875	0.0453	0.2032		0.9670	0.0990	0.7870	0.6579	0.4540
						Ranking	X	4	1	2	3
6	0.3797	0.2032	0.2875	0.0843	0.0453		0.9385	0.1015	0.8479	0.6772	0.4508
						Ranking	X	4	1	2	3
7	0.0843	0.3797	0.2032	0.2875	0.0453		0.7270	0.1017	0.9315	0.5459	0.5500
						Ranking	O	4	1	3	2
8	0.0843	0.2032	0.0453	0.2875	0.3797		0.7722	0.0200	0.6576	0.4898	0.5989
						Ranking	X	4	1	3	2
9	0.0453	0.3797	0.0843	0.2032	0.2875		0.8161	0.0413	0.7142	0.5972	0.5162
						Ranking	X	4	1	2	3
10	0.0453	0.0843	0.2032	0.3797	0.2875		0.6834	0.0889	0.7376	0.3622	0.6472
						Ranking	O	4	1	3	2
11	0.2875	0.0843	0.0453	0.2032	0.3797		0.8594	0.0170	0.6818	0.6140	0.5424
						Ranking	X	4	1	2	3
12	0.2875	0.3797	0.2032	0.0843	0.0453		0.9292	0.0840	0.8654	0.7221	0.4369
						Ranking	X	4	1	2	3
13	0.2032	0.3797	0.0453	0.2875	0.0843		0.7620	0.0209	0.8748	0.6351	0.5745
						Ranking	O	4	1	2	3
14	0.2032	0.0453	0.0843	0.3797	0.2875		0.7203	0.0342	0.7468	0.4886	0.6546
						Ranking	O	4	1	3	2
15	0.0843	0.2875	0.0453	0.3797	0.2032		0.6727	0.0214	0.8036	0.4803	0.6729
						Ranking	O	4	1	3	2
16	0.0843	0.2875	0.2032	0.0453	0.3797		0.9577	0.0908	0.6300	0.5525	0.4368
						Ranking	X	4	1	2	3
17	0.3797	0.0453	0.0843	0.2032	0.2875		0.8692	0.0290	0.7490	0.6747	0.5348
						Ranking	X	4	1	2	3
18	0.3797	0.0453	0.2875	0.0843	0.2032		0.9401	0.0987	0.7876	0.6521	0.4609
						Ranking	X	4	1	2	3
19	0.0453	0.2875	0.2032	0.0843	0.3797		0.9226	0.0919	0.6279	0.5381	0.4454
						Ranking	X	4	1	2	3
20	0.0453	0.2032	0.2875	0.0843	0.3797		0.9224	0.1285	0.6265	0.4671	0.4140
						Ranking	X	4	1	2	3

w – weights, CC_j^* - relative closeness to ideal solution

Source: Author

Table 8.18 shows that Location W has the highest value of 0.1767 from 0.0331 when the criteria weights are exchanged as in condition 4; it has the lowest CC_j^* value of 0.0170 in condition 11. Location X has the highest CC_j^* value of 0.9315 from 0.8771 when the criteria weights are exchanged as in condition 7; it has the lowest value CC_j^* of 0.6265 in condition 20. Location Y has the highest CC_j^* value of 0.7221 from 0.5769 when the criteria weights are exchanged as in condition 12; it has the lowest CC_j^* value of 0.3622 in condition 10. Location Z has the highest CC_j^* value of 0.6729 from 0.6364 when the criteria weights are exchanged as in condition 15; it has the lowest CC_j^* value of 0.3533 in condition 4. The current warehouse, Location V, has the highest value of 0.9670 from 0.7293 when the criteria weights are exchanged as in condition 5; it has the lowest CC_j^* value of 0.6834 in condition 10. 'O' is marked in the conditions where CC_j^* value of the first alternative warehouse location is higher than the current warehouse and 'X' indicates the opposite.

Figure 8.1 Sensitivity analyses of major attributes for Case Study B: TOPSIS



CC_j^* - relative closeness to ideal solution

Source: Author

The sensitivity analysis result in Figure 8.1 and Table 8.18 show that Location X is evaluated to be the most appropriate alternative in condition 2, 7, 10, 13, 14, 15. For those conditions, it will be sensible for the decision-makers to select Location X because it has a higher CC_j^* value than the current warehouse, Location V. For the rest of the conditions, the current warehouse, Location V result is higher ranking. It can also be seen that the ideal solution values do not exceed the current warehouse location in other alternative warehouse locations. Decision-makers can use these different weight combinations in the decision-making process according to priority. The TOPSIS results with the main condition and the sensitivity analysis of the major attributes show that Location X is the ideal alternative location for Case Study B.

8.4.1.2 Sub-Attributes

This section presents the analyses of the evaluation of the alternative warehouse location using the results in the sub-attributes weights that were obtained in Table 8.14. The weighted decision matrix of is presented in Table 8.19.

Table 8.19 The weighted decision matrix of sub-attributes for Case Study B

Attributes	Location V		Location W		Location X		Location Y		Location Z	
	NW	Weighted	NW	Weighted	NW	Weighted	NW	Weighted	NW	Weighted
SC_{a1}	0.3913	0.0177	0.3587	0.0162-	0.4892	0.0222*	0.4892	0.0222*	0.4892	0.0222*
SC_{a2}	0.5453	0.0199*	0.3895	0.0142-	0.4284	0.0156	0.4284	0.0156	0.4284	0.0156
SC_{a3}	0.3879	0.0291-	0.4848	0.0364*	0.4525	0.0340	0.4525	0.0340	0.4525	0.0340
SC_{a4}	0.5021	0.0467*	0.3347	0.0311-	0.4603	0.0428	0.4603	0.0428	0.4603	0.0428
SC_{a5}	0.3632	0.0053-	0.4540	0.0067	0.4994	0.0073*	0.4540	0.0067	0.4540	0.0067
SC_{a6}	0.5711	0.0093*	0.3075	0.0050-	0.4393	0.0072	0.4393	0.0072	0.4393	0.0072
SC_{b1}	0.5117	0.0434*	0.4094	0.0347	0.5117	0.0434*	0.4094	0.0347	0.3753	0.0318-
SC_{b2}	0.4330	0.0150-	0.4997	0.0173*	0.4330	0.0150-	0.4330	0.0150-	0.4330	0.0150-
SC_{b3}	0.4054	0.0097-	0.5068	0.0121*	0.4392	0.0105	0.1392	0.0105	0.4392	0.0105
SC_{b4}	0.5038	0.0081*	0.4318	0.0069-	0.4318	0.0069-	0.4318	0.0069-	0.4318	0.0069-
SC_{b5}	0.5250	0.0225*	0.3635	0.0156-	0.4442	0.0191	0.4442	0.0191	0.4442	0.0191
SC_{c1}	0.5768	0.0071*	0.2884	0.0035-	0.4944	0.0061	0.4120	0.0051	0.4120	0.0051
SC_{c2}	0.4810	0.0125*	0.4123	0.0107-	0.4466	0.0116	0.4466	0.0116	0.4466	0.0116
SC_{c3}	0.4525	0.0148	0.4848	0.0159*	0.4525	0.0148	0.3879	0.0127-	0.4525	0.0148
SC_{c4}	0.4776	0.0065*	0.4776	0.0065*	0.4458	0.0061	0.4458	0.0061	0.3821	0.0052-
SC_{d1}	0.3853	0.0579	0.3502	0.0526-	0.5254	0.0790*	0.4203	0.0632	0.5254	0.0790
SC_{d2}	0.4417	0.0115	0.4049	0.0106	0.5153	0.0135*	0.3312	0.0086-	0.5153	0.0135*
SC_{d3}	0.4344	0.0061	0.4706	0.0066	0.5430	0.0077*	0.3258	0.0046-	0.4344	0.0061
SC_{d4}	0.4423	0.0085	0.3686	0.0071-	0.5160	0.0100*	0.3686	0.0071-	0.5160	0.0100*
SC_{d5}	0.4789	0.0209*	0.2873	0.0125-	0.4789	0.0209*	0.4789	0.0209*	0.4789	0.0209*
SC_{d6}	0.3753	0.0168-	0.3753	0.0168-	0.5117	0.0230*	0.4776	0.0214	0.4776	0.0214
SC_{d7}	0.5283	0.0047	0.1509	0.0013-	0.5661	0.0050*	0.4151	0.0037	0.4529	0.0040
SC_{d8}	0.4253	0.0177	0.2835	0.0118-	0.4962	0.0207*	0.4962	0.0207*	0.4962	0.0207*
SC_{d9}	0.5542	0.0168*	0.1979	0.0060-	0.5542	0.0168*	0.3959	0.0120	0.4354	0.0132
SC_{e1}	0.5217	0.0034*	0.1739	0.0011-	0.5217	0.0034*	0.5217	0.0034*	0.3913	0.0025
SC_{e2}	0.5078	0.0018	0.2901	0.0010-	0.5803	0.0020*	0.4352	0.0015	0.3627	0.0013
SC_{e3}	0.6735	0.0030*	0.1347	0.0006-	0.4041	0.0018	0.4041	0.0018	0.4490	0.0020
SC_{e4}	0.6370	0.0072*	0.2275	0.0025-	0.4550	0.0051	0.4095	0.0046	0.4095	0.0046
SC_{e5}	0.5090	0.0047*	0.2313	0.0021-	0.5090	0.0047*	0.4627	0.0043	0.4627	0.0043
SC_{e6}	0.4276	0.0064	0.1900	0.0028-	0.5701	0.0085*	0.5226	0.0078	0.4276	0.0064

* - Positive-ideal solution $^{-}$ - Negative-ideal solution NW: Normalised Weight

Source: Author

Table 8.20 Location evaluation with sub-attributes ranking for Case Study B

Rank	Sub-attributes	Highest evaluated warehouse(s)	Lowest evaluated warehouse(s)
1	Capacity (SC_{d1})	X	W
2	Sharjah Airport (SC_{a4})	V	W
3	Warehouse (SC_{b1})	V and X	Z
4	Al Maktoum Airport (SC_{a3})	W	V
5	Jebel Ali Seaport (SC_{a1})	X, Y and Z	W
6	Loading Bays (SC_{d6})	X	V and W
7	Ceiling Height (SC_{d5})	V, X, Y and Z	W
8	Road Safety (SC_{b5})	V	W
9	Suitable Openings (SC_{d8})	X, Y and Z	W
10	Dubai Int'l Airport (SC_{a2})	V	W
11	Fire fighting Station (SC_{b2})	W	V, X, Y and Z
12	Warehouse Distance (SC_{c3})	W	Y
13	Doors at Both Ends (SC_{d9})	V and X	W
14	Open Storage (SC_{d2})	X and Z	Y
15	IT/Communication (SC_{c2})	V	W
16	Police Station (SC_{b3})	W	V
17	General Spill-Over Area (SC_{d4})	X and Z	W and Y
18	MOFA (SC_{a6})	V	W
19	Hospital (SC_{b4})	V	W, X, Y and Z
20	Transportation (SC_{e6})	X	W
21	Abu Dhabi Airport (SC_{a5})	X	V
22	Office Facility (SC_{d3})	X	V and Y
23	Modular Office Space (SC_{c4})	V and W	Z
24	Diplomatic Work (SC_{c1})	V	W
25	Main City (SC_{e4})	V	W
26	Residential (SC_{e5})	V and X	W
27	Flood Lights (SC_{d7})	X	W
28	Cafeteria (SC_{e1})	V, X and Y	W
29	ATM (SC_{e3})	V	W
30	Mini-Mart (SC_{e2})	X	W

Note: Rank 1 to 7 has an accumulation weight of 53.76% of the total (Table. 8.14)

Source: Author

Table 8.20 illustrated the summarised results of the preference order of the sub-attributes in accordance with the highest and the lowest evaluated warehouses. Location X is evaluated as the highest warehouse in 16 sub-attributes; five of them are in the top seven that accumulates more than 50% of the total. Location X is also evaluated as the highest warehouse in Capacity (C_{d1}), which is ranked first in the preference order. Location Y is evaluated as the highest warehouse in four sub-attributes; two of them are in the top seven. Location Y is evaluated as the highest warehouse in Jebel Ali Seaport (C_{a1}) and in Ceiling Height (C_{d5}), which is ranked fifth and seventh in the preference order. Location Z is evaluated as the highest warehouse in five sub-attributes; two of them are in the top seven. Location W is evaluated as the highest in Al Maktoum Airport (C_{a3}) which is ranked fourth in the preference order. The current warehouse, Location V, is evaluated as the highest warehouse in 15 sub-attributes; five of them are in the top seven. Location V is also evaluated as the highest warehouse in Sharjah Airport (C_{a4}), which is ranked second in the preference order.

The computed distance of each alternative warehouse location from PIS (D_i^*), NIS (D_i^-) and relative closeness to ideal solution (CC_j^*) are presented in Table 8.21.

Table 8.21 Final ranking of with sub-attributes for Case Study B: TOPSIS

Rank	Warehouse Location	D_i^*	D_i^-	CC_j^*
Current Location	V	0.0243	0.0288	0.5419
1	X	0.0086	0.0383	0.8164
2	Z	0.0155	0.0347	0.6914
3	Y	0.0219	0.0243	0.5254
4	W	0.0396	0.0097	0.1967

D_i^*- positive-ideal solution (PIS), D_i^-- negative-ideal solution (NIS), CC_j^*- relative closeness to ideal solution

Source: Author

From Table 8.21, Location X is at the nearest distance from PIS with a value of 0.0086 and is at the farthest distance from NIS with a value of 0.0383. Location W is located at the farthest distance from PIS with a value of 0.0396 and is at the nearest distance NIS with a value of 0.0097. Location V, the current warehouse, has a PIS value of 0.0243 and NIS value of 0.0288. The result of the warehouse evaluation of the sub-attributes shows that Location X has the highest CC_j^* value of 0.8164. Location Z follows next with a CC_j^* value of 0.6914. These two alternative warehouses have a higher CC_j^* value than the current warehouse, Location V (which has 0.5419 as a CC_j^* value). Location Y and Location W are ranked in third and fourth with a CC_j^* value of 0.5254 (Location Y) and 0.1967 (Location W). They have lower CC_j^* value than the current warehouse.

Therefore, the descending order of the final ranking for the optimal alternative warehouse location using sub-attributes weights with TOPSIS is:

X > Z > Y > W.

Sensitivity Analysis

A sensitivity analysis was again used to ensure the accuracy of the results. The main condition expresses the original result of the case study. For each condition, the similarities of the warehouse location to the ideal solution (CC_j^*) are calculated. Appendix C.7 presents the randomly selected possibilities to test the sensitivity analysis. Table 8.22 summarises the numerical results of the calculation and Figure 8.2 illustrates the graphical representation of these results.

Table 8.22 shows that Location W has the highest value of 0.3250 from 0.1967 when the criteria are exchanged as in condition 23; it has lowest CC_j^* value of 0.016 in condition 26. Location X has the highest CC_j^* value of 0.8548 from 0.8164 when the criteria weights are exchanged as in condition 19; it has the lowest CC_j^* value of 0.5771 in condition 16. Location Y has the highest CC_j^* value of 0.6282 from 0.5254 when the criteria weights are exchanged as in condition 27; it has the lowest CC_j^* value of 0.4443 in condition 19. Location Z has the highest CC_j^* value of 0.7461 from 0.6914 when the criteria weights are exchanged as in condition 6; it has the lowest CC_j^* value of 0.5072 in condition 16. The current warehouse, Location V, has highest CC_j^* value of 0.8855 from 0.5419 when the criteria weights are exchanged as in condition 29; it has lowest CC_j^* value of 0.4422 in condition 10. 'O' is marked in the conditions where CC_j^* value of the first alternative warehouse location is higher than the current warehouse and 'X' indicates the opposite.

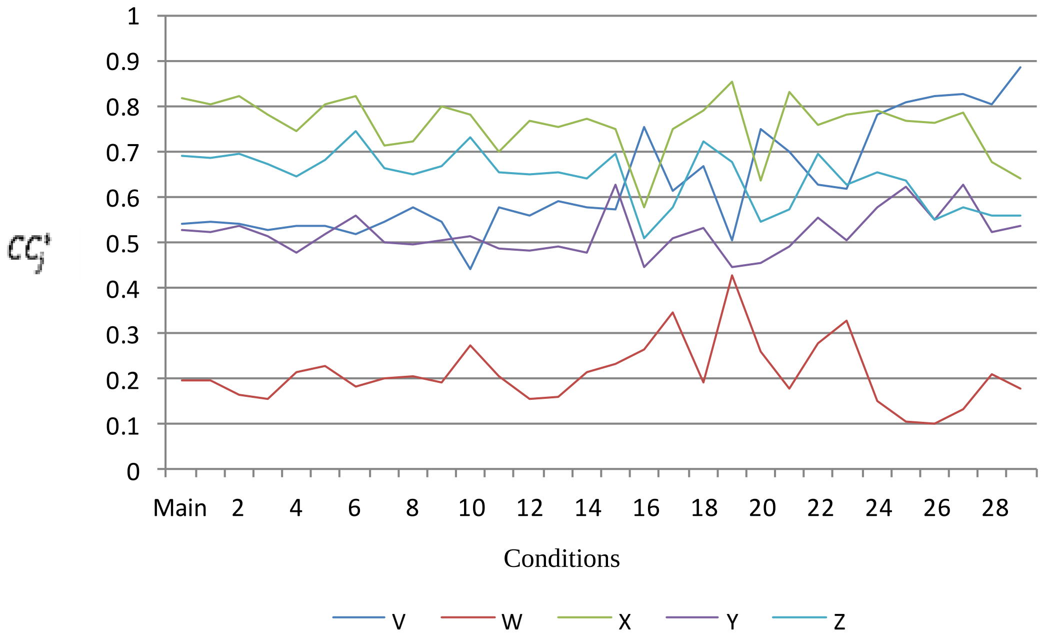
Table 8.22 Sensitivity analysis of Sub-attributes for Case Study B: TOPSIS

	Current Location	TOPSIS CC_j^* Values for Alternative Locations			
Conditions	V	W	X	Y	Z
Main	0.5419	0.1967	0.8164	0.5254	0.6914
Ranking	O	4	1	3	2
1	0.5458	0.1965	0.8063	0.5205	0.6861
Ranking	O	4	1	3	2
2	0.5423	0.1615	0.8225	0.5357	0.6971
Ranking	O	4	1	3	2
3	0.5258	0.1548	0.7796	0.5141	0.6734
Ranking	O	4	1	3	2
4	0.5340	0.2117	0.7444	0.4756	0.6443
Ranking	O	4	1	3	2
5	0.5371	0.2253	0.8025	0.5156	0.6821
Ranking	O	4	1	3	2
6	0.5163	0.1817	0.8223	0.5602	0.7461
Ranking	O	4	1	3	2
7	0.5454	0.1986	0.7147	0.4982	0.6654
Ranking	O	4	1	3	2
8	0.5781	0.2037	0.7224	0.4961	0.6497
Ranking	O	4	1	3	2
9	0.5441	0.1895	0.8006	0.5020	0.6674
Ranking	O	4	1	3	2
10	0.4422	0.2728	0.7813	0.5131	0.7295
Ranking	O	4	1	3	2
11	0.5753	0.2019	0.7011	0.4868	0.6550
Ranking	O	4	1	3	2
12	0.5598	0.1548	0.7676	0.4810	0.6497
Ranking	O	4	1	3	2
13	0.5921	0.1582	0.7530	0.4883	0.6564
Ranking	O	4	1	3	2
14	0.5769	0.2132	0.7722	0.4786	0.6397
Ranking	O	4	1	3	2
15	0.5715	0.2303	0.7488	0.6254	0.6969
Ranking	O	4	1	3	2
16	0.7559	0.2621	0.5771	0.4472	0.5072
Ranking	X	4	1	3	2
17	0.6146	0.3451	0.7514	0.5073	0.5778
Ranking	O	4	1	3	2
18	0.6689	0.1905	0.7902	0.5309	0.7209
Ranking	O	4	1	3	2
19	0.5020	0.4275	0.8548	0.4443	0.6754
Ranking	O	4	1	3	2
20	0.7507	0.2594	0.6369	0.4534	0.5453
Ranking	X	4	1	3	2
21	0.7007	0.1753	0.8327	0.4882	0.5709
Ranking	O	4	1	3	2
22	0.6274	0.2761	0.7605	0.5521	0.6952
Ranking	O	4	1	3	2
23	0.6179	0.3252	0.7826	0.5020	0.6259
Ranking	O	4	1	3	2
24	0.7837	0.1506	0.7892	0.5787	0.6560
Ranking	O	4	1	3	2
25	0.8098	0.1036	0.7663	0.6210	0.6367
Ranking	X	4	1	3	2
26	0.8227	0.1016	0.7648	0.5510	0.5482
Ranking	X	4	1	2	3
27	0.8265	0.1296	0.7848	0.6282	0.5749
Ranking	X	4	1	2	3
28	0.8047	0.2066	0.6765	0.5223	0.5604
Ranking	X	4	1	3	2
29	0.8855	0.1781	0.6388	0.5363	0.5604
Ranking	X	4	1	3	2

CC_j^* - relative closeness to ideal solution

Source: Author

Figure 8.2 Sensitivity analyses of sub-attributes for Case Study B: TOPSIS



CC_j^* - relative closeness to ideal solution

Source: Author

The sensitivity analysis result in Figure 8.2 and Table 8.22 shows that Location X is determined to be the most appropriate alternative in all conditions; however, the CC_j^* value of Location X is lower than that of the current warehouse, Location V, in the condition 16, 20, 25, 26, 27, 28, and 29. For those conditions it will not be sensible to select any of the alternative locations. Location Z will be the next alternative warehouse to be selected if Location X cannot be chosen for any reason except in condition 17, 21, and 24. If Location Z cannot be selected, Location Y can be chosen for next alternative warehouse in condition 1, 6, and 10. Location W cannot be selected for the alternative warehouse location in any of the conditions.

8.4.2 Fuzzy-TOPSIS

This section analyses the ranking of the alternative warehouse locations, which are determined by using fuzzy-TOPSIS. Linguistic values are used for the evaluation of those locations. The relationship between linguistics values and triangular fuzzy numbers for a 5 point grade scale is presented in Figure 4.6 and has been applied in this case. The results obtained for the fuzzy-TOPSIS analysis is based on the calculation as explained in Chapter 4, Section 4.4.4.

8.4.2.1 Major Attributes

The construction result of fuzzy evaluation matrix of the major attributes by linguistic variables is presented in Table 8.23. In the table, the weights (*w*) of the each major attributes are presented in the second row.

Table 8.23 Fuzzy evaluation matrix of major attributes for Case Study B

	C_a	C_b	C_c	C_d	C_e
w	0.2875	0.2032	0.0843	0.3797	0.0453
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)	(0.35, 0.50, 0.65)
W	(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)
X	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)
Y	(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)
Z	(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)

C_a – Distance, C_b – Security/Safety, C_c – Office Facilities, C_d – Warehouse Facilities C_e – Convenience

Source: Author

Table 8.24 presents the results of the highest and the lowest evaluated warehouse in accordance with the preference order of major attributes. Warehouse Facilities (C_d), ranked first in the preference order, is evaluated as the highest attribute in Location V, Location X and Location Z. The Distance (C_a), ranked second in the preference order, is evaluated as the highest attribute in Location V, Location X. Location Y, and Location Z and the lowest in Location W. The Convenience (C_e), ranked fifth in the preference order, is evaluated as the highest attribute in Locations V, X, Y, and Z and the lowest in Location W.

Table 8.24 Location evaluation with major attributes ranking for Case Study B: Fuzzy

Rank	Criteria	Highest Evaluated Warehouse(s)	Lowest Evaluated Warehouse(s)
1	Warehouse Facilities (C_d)	V, X and Z	W and Y
2	Distance (C_a)	V, X, Y and Z	W
3	Security/Safety (C_b)	V, X, Y and Z	W
4	Office Facilities (C_c)	V and X	W, Y and Z
5	Convenience (C_e)	V, X, Y and Z	W

Source: Author

Every element in Table 8.23 is a normalised triangular fuzzy number and their ranges belong to the closed interval [0,1], as illustrated in Figure 4.6. Therefore, there is no need for normalisation. The following definition is given to the following attributes: fuzzy positive-ideal solution (FPIS, A^*) as = (1,1,1) and = (0, 0, 0) for benefit criterion, and fuzzy negative-ideal solution (FNIS, A^-) as = (0,0,0) and = (1, 1, 1) for cost criterion. In this case, C_a, C_b, C_c, C_d, and C_e are all benefit criteria and there are no cost criteria. The benefit and cost criterion are shown in Table 8.25.

Table 8.25 Benefit and cost attributes of major attributes for Case Study B

Criteria	$\tilde{v}_i^*$	$\tilde{v}_i^-$
C_a	(1, 1, 1)	(0, 0, 0)
C_b	(1, 1, 1)	(0, 0, 0)
C_c	(1, 1, 1)	(0, 0, 0)
C_d	(1, 1, 1)	(0, 0, 0)
C_e	(1, 1, 1)	(0, 0, 0)

C_a – Distance, C_b – Security/Safety, C_c – Office Facilities, C_d – Warehouse Facilities C_e – Convenience

$\tilde{v}_i^*$ - fuzzy positive-ideal solution (FPIS), $\tilde{v}_i^-$ - fuzzy negative-ideal solution (FNIS)

Source: Author

In order to illustrate the calculation of the distance of each alternative, the evaluation process of PIS (D_1^*), NIS (D_1^-), and the closeness to ideal-solution value (CC_1^*) of Location A is presented as follows:

$$D_1^* = \sqrt{\frac{1}{3}[(1-0.100)^2+(1-\ 0.147)^2+(1-0.186)^2]}$$

$$+\sqrt{\frac{1}{3}[(1-0.071)^2+(1-\ 0.101)^2+(1-0.132)^2]}$$

$$+\sqrt{\frac{1}{3}[(1-0.029)^2+(1-\ 0.042)^2+(1-0.054)^2]}$$

$$+\sqrt{\frac{1}{3}[(1-0.132)^2+(1-\ 0.189)^2+(1-0.246)^2]}$$

$$+\sqrt{\frac{1}{3}[(1-0.015)^2+(1-\ 0.022)^2+(1-0.029)^2]}$$

$$= 4.5024$$

$$D_1^- = 0.2196$$

$$CC_1^* = 0.0465$$

The final step of the fuzzy-TOPSIS method is to rank the alternative warehouse locations, which is illustrated in Table 8.26.

Table 8.26 Final ranking with major-attributes for Case Study B: Fuzzy-TOPSIS

Rank	Warehouse Location	D_i^*	D_i^-	CC_j^*
Current Location	V	4.5024	0.2196	0.0465
1	X	4.5024	0.2196	0.0465
2	Z	4.5193	0.2196	0.0463
3	Y	4.5951	0.2196	0.0456
4	W	4.7022	0.1325	0.0274

D_i^* - positive-ideal solution (PIS), D_i^- - negative-ideal solution (NIS), CC_j^* - relative closeness to ideal solution

Source: Author

Table 8.26 shows that Location X is at the nearest distance from PIS with a value of 4.5024 and Location W is at the farthest distance from NIS with a value of 4.7022 among the alternative warehouses. On the other hand, Location W is at the nearest from NIS with a value of 0.1325 and Locations X, Y, and Z are at the farthest from NIS with a value of 0.2196. The current warehouse, Location V, has a PIS value of 4.5024 and NIS value of 0.2196. In summary, Location X is the optimal warehouse among the alternative sites, with a value of 0.0465. This value is exactly the same with the current warehouse, Location V. Location Z and Location Y ranked second and third in the table with a CC_j^* value of 0.0463 (Location Z) and 0.0456 (Location Y). The difference of the CC_j^* value of top three alternative warehouses is very small, showing that they are all evaluated similar in fuzzy-TOPSIS analysis; however, they are evaluated lower than the current location warehouse, Location V. Location W is evaluated at the bottom of the table, with a CC_j^* value of 0.0274.

Therefore, the descending order of the final ranking for the optimal alternative warehouse location using major attributes weights with fuzzy-TOPSIS is:

X > Z > Y > W.

Sensitivity Analysis

Table 8.27 summarises the numerical results of the sensitivity analysis.[3] The main condition expresses the original result of the case study. The exchanged weight combination used for Table 8.18 is used for fuzzy-TOPSIS analysis.

Table 8.27 Sensitivity analysis for major attributes for Case Study B: Fuzzy-TOPSIS

Conditions	Weights						Fuzzy CC_j^* Values of Warehouse Locations				
	w_1	w_2	w_3	w_4	w_5		V	W	X	Y	Z
Main	0.2875	0.2032	0.0843	0.3797	0.0453		0.0465	0.0274	0.0465	0.0456	0.0463
						Ranking	O	4	1	3	2
1	0.2875	0.2032	0.0843	0.0453	0.3797		0.0465	0.0274	0.0465	0.0462	0.0463
						Ranking	O	4	1	3	2
2	0.2875	0.0453	0.2032	0.3797	0.0843		0.0351	0.0212	0.0351	0.0342	0.0348
						Ranking	O	4	1	3	2
3	0.2032	0.2875	0.0843	0.0453	0.3797		0.0437	0.0251	0.0437	0.0434	0.0435
						Ranking	O	4	1	3	2
4	0.2032	0.2875	0.3797	0.0843	0.0453		0.0437	0.0251	0.0437	0.0428	0.0430
						Ranking	O	4	1	3	2
5	0.3797	0.0843	0.2875	0.0453	0.2032		0.0476	0.0287	0.0476	0.0469	0.0470
						Ranking	O	4	1	3	2
6	0.3797	0.2032	0.2875	0.0843	0.0453		0.0559	0.0333	0.0559	0.0551	0.0553
						Ranking	O	4	1	3	2
7	0.0843	0.3797	0.2032	0.2875	0.0453		0.0378	0.0209	0.0378	0.0370	0.0375
						Ranking	O	4	1	3	2
8	0.0843	0.2032	0.0453	0.2875	0.3797		0.0249	0.0139	0.0249	0.0245	0.0248
						Ranking	O	4	1	3	2
9	0.0453	0.3797	0.0843	0.2032	0.2875		0.0337	0.0184	0.0337	0.0333	0.0335
						Ranking	O	4	1	3	2
10	0.0453	0.0843	0.2032	0.3797	0.2875		0.0116	0.0065	0.0116	0.0113	0.0115
						Ranking	O	4	1	3	2
11	0.2875	0.0843	0.0453	0.2032	0.3797		0.0379	0.0227	0.0379	0.0375	0.0378
						Ranking	O	4	1	3	2
12	0.2875	0.3797	0.2032	0.0843	0.0453		0.0589	0.0342	0.0589	0.0582	0.0584
						Ranking	O	4	1	3	2
13	0.2032	0.3797	0.0453	0.2875	0.0843		0.0502	0.0287	0.0502	0.0495	0.0501
						Ranking	O	4	1	3	2
14	0.2032	0.0453	0.0843	0.3797	0.2875		0.0260	0.0156	0.0260	0.0255	0.0259
						Ranking	O	4	1	3	2
15	0.0843	0.2875	0.0453	0.3797	0.2032		0.0311	0.0173	0.0311	0.0305	0.0310
						Ranking	O	4	1	3	2
16	0.0843	0.2875	0.2032	0.0453	0.3797		0.0311	0.0173	0.0311	0.0308	0.0309
						Ranking	O	4	1	3	2
17	0.3797	0.0453	0.0843	0.2032	0.2875		0.0448	0.0272	0.0448	0.0443	0.0444
						Ranking	O	4	1	3	2
18	0.3797	0.0453	0.2875	0.0843	0.2032		0.0448	0.0272	0.0448	0.0441	0.0443
						Ranking	O	4		3	2
19	0.0453	0.2875	0.2032	0.0843	0.3797		0.0269	0.0147	0.0269	0.0266	0.0267
						Ranking	O	4	1	3	2
20	0.0453	0.2032	0.2875	0.0843	0.3797		0.0206	0.0113	0.0206	0.0203	0.0204
						Ranking	O	4	1	3	2

CC_j^*- relative closeness to ideal solution

Source: Author

[3] The graphical representation for Fuzz-TOPSIS sensivity analysis of major attributes is not presented in this section. This is because the difference of values between the warehouses are very little and appear to be a single line in the graphical data.

Table 8.27 shows that Location W has the highest ideal solution CC_j^* value of 0.0342 from 0.0274 when the criteria weights are exchanged as in condition 12; it has the lowest ideal solution CC_j^* value of 0.0065 in condition 10. Location X has the highest ideal solution CC_j^* value of 0.0589 from 0.0465 when the criteria weights are exchanged as in condition 12; it has the lowest CC_j^* value of 0.0116 in condition 10. Location Y has the highest CC_j^* value of 0.0582 from 0.0456 when the criteria weights are exchanged as in condition 12; it has the lowest CC_j^* value of 0.0113 in condition 10. Location Z has the highest ideal solution CC_j^* value of 0.0584 from 0.0463 when the criteria weights are exchanged as in condition 12; it has the lowest ideal solution CC_j^* value 0.0115 in condition 10. 'O' is marked in the conditions where CC_j^* value of the first alternative warehouse location is higher than the current warehouse and 'X' indicates the opposite.

The result of the sensitivity analysis shows that Location X is evaluated to be the optimal warehouse location for the entire condition. It has the same CC_j^* value with the current warehouse, Location V. Therefore, it will be sensible to choose Location X for an alternative warehouse. If Location X cannot be chosen for the selection, other alternative locations will be the next option. In addition, there is no big difference of CC_j^* value for Location Y and Location Z compared to that of Location X; however, they are still evaluated lower than the current warehouse. Location W is evaluated to be the lowest in the entire condition. The decision-makers can use these different weight combinations in the decision-making process according to priority.

8.4.2.2 Sub-Attributes

This section presents the analyses of the evaluation of the alternative warehouse location using the results in the sub-attributes weights obtained in Table 8.14. The construction result of fuzzy evaluation matrix of the major attributes by linguistic variables (see Figure 4.6) is presented in Appendix C.8. Table 8.28 presents the summarised results of the highest and the lowest evaluated warehouse in accordance with the preference order of sub-attributes in fuzzy-TOPSIS.

Table 8.28 Location evaluation with sub-attributes ranking for Case Study B: Fuzzy

Rank	Sub-attributes	Highest evaluated warehouse(s)	Lowest evaluated warehouse(s)
1	Capacity (SC_{d1})	X, Y and Z	V and W
2	Sharjah Airport (SC_{a4})	V, X, Y and Z	W
3	Warehouse (SC_{b1})	V, X, Y and Z	W
4	Al Maktoum Airport (SC_{a3})	W, X Y and Z	V
5	Jebel Ali Seaport (SC_{a1})	X, Y and Z	V and W
6	Loading Bays (SC_{d6})	X, Y and Z	V and W
7	Ceiling Height (SC_{d5})	V, X, Y and Z	W
8	Road Safety (SC_{b5})	V, W, X, Y and Z	-
9	Suitable Openings (SC_{d8})	V, X, Y and Z	W
10	Dubai Int'l Airport (SC_{a2})	V, X, Y and Z	W
11	Fire Fighting Station (SC_{b2})	V, W, X, Y and Z	-
12	Warehouse Distance (SC_{c3})	V, W, X and Z	Y
13	Doors at Both Ends (SC_{d9})	V, X and Z	W
14	Open Storage (SC_{d2})	V, W and Z	Y
15	IT/Communication (SC_{c2})	V, W, X, Y and Z	-
16	Police Station (SC_{b3})	V, W, X, Y and Z	-
17	General Spill-Over Area (SC_{d4})	V, X and Z	W and Y
18	MOFA (SC_{a6})	V, X, Y and Z	W
19	Hospital (SC_{b4})	V, W, X, Y and Z	-
20	Transportation (SC_{e6})	V, X, Y and Z	W
21	Abu Dhabi Airport (SC_{a5})	W, X, Y and Z	V
22	Office Facility (SC_{d3})	V, W, X and Z	Y
23	Modular Office Space (SC_{c4})	V, W, X and Y	Z
24	Diplomatic Work (SC_{c1})	V, X, Y and Z	W
25	Main City (SC_{e4})	V	W
26	Residential (SC_{e5})	V, X, Y and Z	W
27	Flood Lights (SC_{d7})	V, X, Y and Z	W
28	Cafeteria (SC_{e1})	V, X and Y	W
29	ATM (SC_{e3})	V	W
30	Mini-Mart (SC_{e2})	V, X and Y	W and Z

Note: Rank 1 to 7 has an accumulation weight of 53.76% of the total (Table. 8.14)

Source: Author

From Table 8.28, Location X, Location Y and Location Z are evaluated as the highest warehouse among the alternatives in the top seven sub-attributes that accumulates more than 50% of the total. Location W is evaluated as the highest warehouse in Al Matkoum Airport (C_{a3}), which is ranked fourth in the preference order. The current warehouse, Location V, is evaluated as the highest warehouse in three out the top seven sub-attributes. In 27 sub-attributes, Location X is evaluated as the highest warehouse among the alternatives. Location V is evaluated as the highest warehouse in 21 sub-attributes. On the other hand, Location W is evaluated as the lowest warehouse in six sub-attributes in the top seven of the ranking and Location V is evaluated as the lowest warehouse in four sub-attributes.

Every element in Appendix C.8 is a normalised triangular fuzzy number and their ranges belong to the closed interval [0,1], as illustrated in Figure 4.6. Therefore, there is no need for normalisation. The following definition is given to the following attributes: fuzzy positive-ideal solution (FPIS, A^*) as $\tilde{v}_i^* = (1,1,1)$ and $\tilde{v}_i^- = (0, 0, 0)$ for benefit criterion, and fuzzy negative-ideal solution (FNIS, A^-) as $\tilde{v}_i^* = (0,0,0)$ and $\tilde{v}_i^- = (1, 1, 1)$ for cost criterion. In this case, all of the sub-attributes are benefit criteria and there are no cost criteria.

In order to illustrate the calculation, PIS (D_1^*), NIS (D_1^-), and the closeness to ideal-solution value (CC_1^*) of Location V are presented as an instance as follows:

$$D_1^* = \sqrt{\frac{1}{3}[(1-0.006)^2 + (1- \ 0.013)^2 + (1-0.020)^2]}$$

$$+ \sqrt{\frac{1}{3}[(1-0.012)^2 + (1- \ 0.018)^2 + (1-0.023)^2]}$$

$$+ \sqrt{\frac{1}{3}[(1-0.011)^2 + (1- \ 0.022)^2 + (1-0.033)^2]}$$

$$\ldots$$

$$+ \sqrt{\frac{1}{3}[(1-0.003) + (1- \ 0.004)^2 + (1-0.006)^2]}$$

$$+ \sqrt{\frac{1}{3}[(1-0.005)^2 + (1- \ 0.007)^2 + (1-0.009)^2]}$$

$$= 29.5537$$

$$D_1^- = 0.4641$$

$$CC_1^* = 0.0154$$

The same calculation process is applied to obtain the ideal solution value of the rest of the locations. The final step of fuzzy-TOPSIS method consists of ranking the alternative warehouse locations, as illustrated in Table 8.29.

Table 8.29 Final ranking with sub-attributes for Case Study B: Fuzzy-TOPSIS

Rank	Warehouse Location	D_i^*	D_i^-	CC_j^*
Current Location	V	29.5537	0.4641	0.0154
1	X	29.5004	0.5147	0.0171
2	Z	29.5206	0.4955	0.0165
3	Y	29.5250	0.4913	0.0163
4	W	29.6115	0.3714	0.0123

D_i^*- positive-ideal solution (PIS), D_i^-- negative-ideal solution (NIS), CC_j^*- relative closeness to ideal solution

Source: Author

The result shows that the current warehouse, Location V, has a PIS value of 29.5537 and NIS value of 0.4641. Among the alternatives, Location X is at the closest distance from PIS with a value of 29.5004 and farthest distance from NIS with a value of 0.5147. Location W is at the farthest distance from PIS with a value of 29.6115 and closest distance from NIS with a value of 0.3714. The current warehouse, Location V, is evaluated with a CC_j^* value of 0.0154. Location X is evaluated to be the optimal warehouse location with a CC_j^* value of 0.0171. Location Z is the second option, with the ideal solution value CC_j^* of 0.0165. Location Y is ranked in third position, with the with the ideal solution value CC_j^* of 0.0163. These locations are all evaluated to be higher than the current warehouse. Location W is ranked at the bottom of the table with a CC_j^* value of 0.0123, which is evaluated lower than the current warehouse.

Therefore, the descending order of the final ranking for the optimal alternative warehouse location using sub-attributes weights with fuzzy-TOPSIS is:

X > Z > Y > W.

Sensitivity Analysis

The numerical results of the sensitivity analysis for fuzzy-TOPSIS are shown in Table 8.30. The main condition expresses the original result of the case study. For each condition, the similarities of the warehouse location to the ideal solution (CC_j^*) are calculated based on combination condition matrix Appendix C.7. Figure 8.3 illustrates the graphical representation of these results.

Table 8.30 Sensitivity analysis for sub-attributes for Case Study B: Fuzzy-TOPSIS

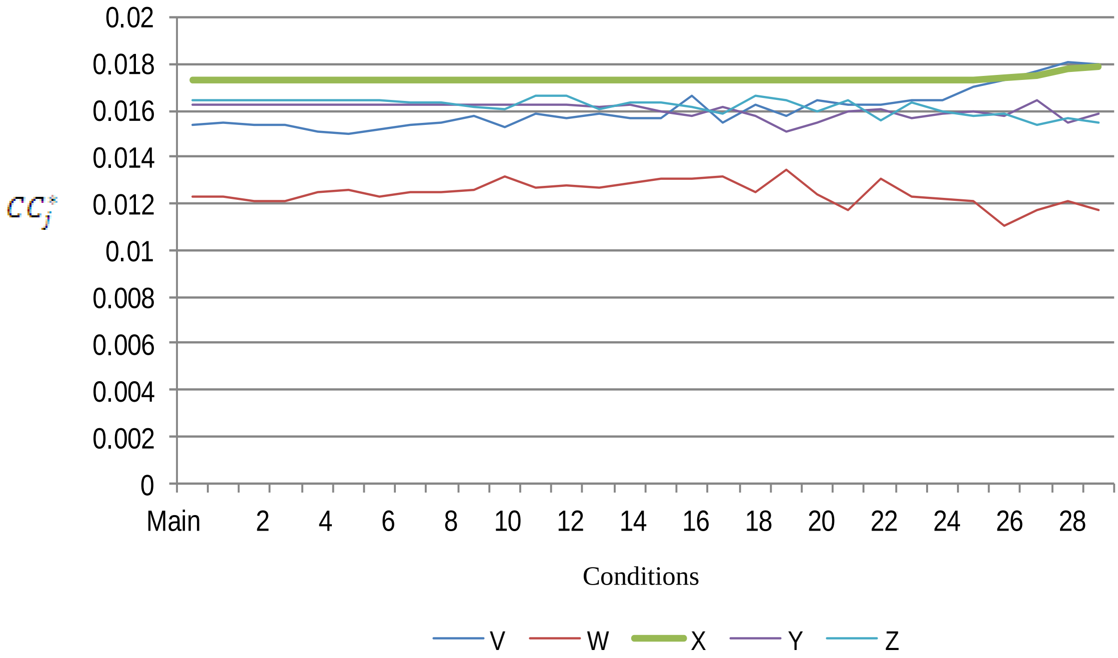
		Current Location	Fuzzy TOPSIS CC_j^* Values of Alternative Locations			
Conditions		V	W	X	Y	Z
Main		0.0154	0.0123	0.0173	0.0163	0.0165
	Ranking	O	4	1	3	2
1		0.0155	0.0123	0.0173	0.0163	0.0165
	Ranking	O	4	1	3	2
2		0.0154	0.0121	0.0173	0.0163	0.0165
	Ranking	O	4	1	3	2
3		0.0154	0.0121	0.0173	0.0163	0.0165
	Ranking	O	4	1	3	2
4		0.0151	0.0125	0.0173	0.0163	0.0165
	Ranking	O	4	1	3	2
5		0.0150	0.0126	0.0173	0.0163	0.0165
	Ranking	O	4	1	3	2
6		0.0152	0.0123	0.0173	0.0163	0.0165
	Ranking	O	4	1	3	2
7		0.0154	0.0125	0.0173	0.0163	0.0164
	Ranking	O	4	1	3	2
8		0.0155	0.0125	0.0173	0.0163	0.0164
	Ranking	O	4	1	3	2
9		0.0158	0.0126	0.0173	0.0163	0.0162
	Ranking	O	4	1	2	3
10		0.0153	0.0132	0.0173	0.0163	0.0161
	Ranking	O	4	1	2	3
11		0.0159	0.0127	0.0173	0.0163	0.0166
	Ranking	O	4	1	3	2
12		0.0157	0.0128	0.0173	0.0163	0.0165
	Ranking	O	4	1	3	2
13		0.0159	0.0127	0.0173	0.0162	0.0161
	Ranking	O	4	1	2	3
14		0.0157	0.0129	0.0173	0.0163	0.0164
	Ranking	O	4	1	3	2
15		0.0157	0.0131	0.0173	0.0160	0.0164
	Ranking	O	4	1	3	2
16		0.0166	0.0131	0.0173	0.0158	0.0162
	Ranking	O	4	1	3	2
17		0.0155	0.0132	0.0173	0.0162	0.0159
	Ranking	O	4	1	2	3
18		0.0163	0.0125	0.0173	0.0158	0.0165
	Ranking	O	4	1	3	2
19		0.0158	0.0135	0.0173	0.0151	0.0165
	Ranking	O	4	1	3	2
20		0.0165	0.0124	0.0173	0.0155	0.0160
	Ranking	O	4	1	3	2
21		0.0163	0.0117	0.0173	0.0160	0.0165
	Ranking	O	4	1	3	2
22		0.0163	0.0131	0.0173	0.0161	0.0156
	Ranking	O	4	1	2	3
23		0.0165	0.0123	0.0173	0.0157	0.0164
	Ranking	O	4	1	3	2
24		0.0165	0.0122	0.0173	0.0159	0.0160
	Ranking	O	4	1	3	2
25		0.0170	0.0121	0.0173	0.0160	0.0158
	Ranking	O	4	1	2	3
26		0.0173	0.0111	0.0174	0.0158	0.0159
	Ranking	O	4	1	3	2
27		0.0177	0.0117	0.0175	0.0165	0.0154
	Ranking	X	4	1	2	3
28		0.0181	0.0121	0.0178	0.0155	0.0157
	Ranking	X	4	1	3	2
29		0.0180	0.0117	0.0179	0.0159	0.0155
	Ranking	X	4	1	2	3

CC_j^*- relative closeness to ideal solution

Source: Author

For the fuzzy-TOPSIS sub-attributes analysis, Location W has the highest CC_j^* value of 0.0135 from 0.0123 when the criteria weights are exchanged as in condition 19; it has the lowest CC_j^* value of 0.0111 in condition 26. Location X has the highest CC_j^* value of 0.0179 from 0.0173 when the criteria weights are exchanged as in condition 29; it has the lowest CC_j^* value of 0.0173 which is the same of the main condition value. Location Y has the highest CC_j^* value of 0.0165 from 0.0163 when the criteria weights are exchanged as in condition 27; it has the lowest CC_j^* value of 0.0151 in condition 19. Location Z has the highest CC_j^* value of 0.0166 criteria weights are exchanged as in condition 11; it has the lowest CC_j^* value of 0.0154 in condition 27. The current warehouse, Location V, has the highest CC_j^* value of 0.0181 from 0.0154 when the criteria weights are exchanged as in condition 28; it has the lowest CC_j^* value of 0.0150 in condition 5.

Figure 8.3 Sensitivity analysis for sub-attributes for Case Study B: Fuzzy-TOPSIS



CC_j^*- relative closeness to ideal solution

Source: Author

According to the sensitivity analysis result in Table 8.30 and Figure 8.3, Location X is evaluated to be the optimal alternative warehouse location for the entire conditions except in condition 27, 28, and 29. Other alternative warehouses are evaluated lower than Location X in those conditions which will not be ideal for selection. Location Y and Location Z is evaluated to be the next alternative warehouse for the entire conditions except in condition 16, 20, 22, 23, 24, and 25. For those conditions, the current warehouse, Location V, is evaluated to be higher than the selected alternative warehouses. Location Y is also evaluated lower than the current warehouse in condition 18 and 19 which will be not ideal for selection. Location W is evaluated lower the current warehouse for the entire condition being bottom of the table.

8.5 Comparison of the results

A comparison of the results of the TOPSIS and fuzzy-TOPSIS analysis is presented in this section, based on the result of the sensitivity analysis that was obtained previously. This section begins by comparing the major attributes and sub-attributes. It will then compare the fuzzy and non-fuzziness results.

8.5.1 Major Attributes versus Sub-Attributes

This section will compare the TOPSIS ranking between the major attributes and sub-attributes. It will first compare the non-fuzzy results, which is followed by a comparison of the fuzzy results.

8.5.1.1 Non-fuzzy TOPSIS

A comparison of the selection of the warehouse is presented Table 8.31, which is based on the sensitivity analysis results found in the previous section. Table 8.31 represents the results of major attributes and sub-attributes.

Table 8.31 Sensitivity analysis comparison for Case Study B: Non-fuzzy TOPSIS

Major Attributes						Sub-Attributes					
	Current Location	Alternative Locations Rank					Current Location	Alternative Locations Rank			
Conditions	V	W	X	Y	Z	Conditions	V	W	X	Y	Z
Main	O	4	1	3	2	Main	O	4	1	3	2
1	X	4	1	2	3	1	O	4	1	3	2
2	O	4	1	3	2	2	O	4	1	3	2
3	X	4	1	2	3	3	O	4	1	3	2
4	X	4	1	2	3	4	O	4	1	3	2
5	X	4	1	2	3	5	O	4	1	3	2
6	X	4	1	2	3	6	O	4	1	3	2
7	O	4	1	3	2	7	O	4	1	3	2
8	X	4	1	3	2	8	O	4	1	3	2
9	X	4	1	2	3	9	O	4	1	3	2
10	O	4	1	3	2	10	O	4	1	3	2
11	X	4	1	2	3	11	O	4	1	3	2
12	X	4	1	2	3	12	O	4	1	3	2
13	O	4	1	2	3	13	O	4	1	3	2
14	O	4	1	3	2	14	O	4	1	3	2
15	O	4	1	3	2	15	O	4	1	3	2
16	X	4	1	2	3	16	X	4	1	3	2
17	X	4	1	2	3	17	O	4	1	3	2
18	X	4	1	2	3	18	O	4	1	3	2
19	X	4	1	2	3	19	O	4	1	3	2
20	X	4	1	2	3	20	X	4	1	3	2
						21	O	4	1	3	2
						22	O	4	1	3	2
						23	O	4	1	3	2
						24	O	4	1	3	2
						25	X	4	1	3	2
						26	X	4	1	2	3
						27	X	4	1	2	3
						28	X	4	1	3	2
						29	X	4	1	3	2

Note: For major attributes, 1 – 20 are conditions in Table 8.18. For sub-attributes, 1 – 29 are the conditions in Appendix C.7. Main conditions show the original result of the ranking.

Source: Author

Table 8.31 shows whether the optimal warehouse is evaluated higher than the current warehouse. The aim of the evaluation here is to select a new alternative warehouse. For the major attributes analysis, the sensitivity analysis shows that Location X is evaluated lower than the current location in 14 out of 20 (70%) conditions. The sub-attribute results shows that Location X is evaluated lower in seven out of thirty (i.e. 23%) conditions. Location W is evaluated to be the lowest in all conditions in both the attributes and sub-attributes. The ranking order of Location Y and Location Z varies depending on the different condition of the result of the major attributes. This is made much clearer in the result of the sub-attributes, where Location Z is mostly evaluated higher than Location Y (93%).

From the comparison, the evaluation result turned out to be a simpler and clearer tool that the decision-makers can use to decide the alternative warehouse selection in sub-attributes; however, the results are less convincing and they need more confidence.

8.5.1.2 Fuzzy-TOPSIS

A comparison of the selections for the location of the warehouse is presented Table 8.32, which is based on the sensitivity analysis results found in the previous section. Table 8.32 represents the results of major attributes and sub-attributes.

Table 8.32 Sensitivity analysis comparison for case study B: Fuzzy-TOPSIS

Major Attributes						Sub-Attributes					
	Current Location	Alternative Locations Rank					Current Location	Alternative Locations Rank			
Conditions	V	W	X	Y	Z	Conditions	V	W	X	Y	Z
Main	O	4	1	3	2	Main	O	4	1	3	2
1	O	4	1	3	2	1	O	4	1	3	2
2	O	4	1	3	2	2	O	4	1	3	2
3	O	4	1	3	2	3	O	4	1	3	2
4	O	4	1	3	2	4	O	4	1	3	2
5	O	4	1	3	2	5	O	4	1	3	2
6	O	4	1	3	2	6	O	4	1	3	2
7	O	4	1	3	2	7	O	4	1	3	2
8	O	4	1	3	2	8	O	4	1	3	2
9	O	4	1	3	2	9	O	4	1	2	2
10	O	4	1	3	2	10	O	4	1	2	2
11	O	4	1	3	2	11	O	4	1	3	2
12	O	4	1	3	2	12	O	4	1	3	2
13	O	4	1	3	2	13	O	4	1	2	3
14	O	4	1	3	2	14	O	4	1	3	2
15	O	4	1	3	2	15	O	4	1	3	2
16	O	4	1	3	2	16	O	4	1	3	2
17	O	4	1	3	2	17	O	4	1	2	3
18	O	4	1	3	2	18	O	4	1	3	2
19	O	4	1	3	2	19	O	4	1	3	2
20	O	4	1	3	2	20	O	4	1	3	2
						21	O	4	1	3	2
						22	O	4	1	2	3
						23	O	4	1	3	2
						24	O	4	1	3	2
						25	O	4	1	2	3
						26	O	4	1	3	3
						27	X	4	1	2	3
						28	X	4	1	3	2
						29	X	4	1	2	3

Note: For major attributes, 1 – 20 are conditions in Table 8.18. For sub-attributes, 1 – 29 are the conditions in Appendix C.7. Main conditions show the original result of the ranking.

Source: Author

In the fuzzy-TOPSIS evaluation result, Location X is evaluated to be the optimal alternative warehouse location among the alternatives for both major attributes and sub-attributes. Location X is also evaluated higher than the current warehouse for the entire conditions in the major attributes results while it is evaluated lower in three conditions for the sub-attributes results. The ranking orders of the alternative warehouses are more consistent in the major attributes than the sub-attributes. For both results, Location W evaluated the lowest for the entire conditions.

8.5.2 TOPSIS versus Fuzzy-TOPSIS

This section will compare the results of the major attributes and sub-attributes between the TOPSIS and fuzzy-TOPSIS methods.

8.5.2.1 Major attributes

Table 8.33 presents a comparison of the sensitivity analysis results between the TOPSIS and fuzzy-TOPSIS methods for the major attributes.

Table 8.33 shows that there is a significant difference in the results. For example, the rankings vary between the alternative warehouses in the results obtained by non-fuzzy-TOPSIS in the left column. In addition, there are certain conditions where the optimal warehouse, Location X, will not be selected because it has been evaluated lower than the current conditions. The results of the fuzzy-TOPSIS ranking shows that Location X is evaluated higher than the current warehouse for all conditions and the ranking orders of the alternative warehouses are consistent.

Table 8.33 Sensitivity analysis comparison result for major attributes: Case Study B

Non-Fuzzy-TOPSIS						Fuzzy-TOPSIS					
	Current Location	Alternative Location Rank					Current Location	Alternative Locations Rank			
Conditions	V	W	X	Y	Z	Conditions	V	W	X	Y	Z
Main	O	4	1	3	2	Main	O	4	1	3	2
1	X	4	1	2	3	1	O	4	1	3	2
2	O	4	1	3	2	2	O	4	1	3	2
3	X	4	1	2	3	3	O	4	1	3	2
4	X	4	1	2	3	4	O	4	1	3	2
5	X	4	1	2	3	5	O	4	1	3	2
6	X	4	1	2	3	6	O	4	1	3	2
7	O	4	1	3	2	7	O	4	1	3	2
8	X	4	1	3	2	8	O	4	1	3	2
9	X	4	1	2	3	9	O	4	1	3	2
10	O	4	1	3	2	10	O	4	1	3	2
11	X	4	1	2	3	11	O	4	1	3	2
12	X	4	1	2	3	12	O	4	1	3	2
13	O	4	1	2	3	13	O	4	1	3	2
14	O	4	1	3	2	14	O	4	1	3	2
15	O	4	1	3	2	15	O	4	1	3	2
16	X	4	1	2	3	16	O	4	1	3	2
17	X	4	1	2	3	17	O	4	1	3	2
18	X	4	1	2	3	18	O	4	1	3	2
19	X	4	1	2	3	19	O	4	1	3	2
20	X	4	1	2	3	20	O	4	1	3	2

Note: 1 – 20 are conditions in Table 8.18. Main conditions show the original result of the ranking.

Source: Author

8.5.2.2 Sub-attributes

Table 8.34 presents a comparison of the sensitivity analysis results between the TOPSIS and fuzzy-TOPSIS methods for the sub-attributes. Table 8.34 includes the varied conditions that were obtained in the previous findings.

Table 8.34 shows that there is a slight difference in the results. The optimal warehouse, Location X, has been evaluated lower than the current warehouse, Location V, in seven conditions for non-fuzzy TOPSIS result. Meanwhile, only three locations are evaluated lower in the fuzzy-TOPSIS result. Location X has been evaluated to the optimal warehouse location among the alternative sites and Location W has the lowest evaluation for both results.

Table 8.34 Sensitivity analysis comparison for sub-attributes: Case Study B

Non-Fuzzy-TOPSIS						Fuzzy-TOPSIS					
	Current Warehouse	Alternative Warehouses					Current Warehouse	Alternative Locations Rank			
Conditions	V	W	X	Y	Z	Conditions	V	W	X	Y	Z
Main	O	4	1	3	2	Main	O	4	1	3	2
1	O	4	1	3	2	1	O	4	1	3	2
2	O	4	1	3	2	2	O	4	1	3	2
3	O	4	1	3	2	3	O	4	1	3	2
4	O	4	1	3	2	4	O	4	1	3	2
5	O	4	1	3	2	5	O	4	1	3	2
6	O	4	1	3	2	6	O	4	1	3	2
7	O	4	1	3	2	7	O	4	1	3	2
8	O	4	1	3	2	8	O	4	1	3	2
9	O	4	1	3	2	9	O	4	1	2	2
10	O	4	1	3	2	10	O	4	1	2	2
11	O	4	1	3	2	11	O	4	1	3	2
12	O	4	1	3	2	12	O	4	1	3	2
13	O	4	1	3	2	13	O	4	1	2	3
14	O	4	1	3	2	14	O	4	1	3	2
15	O	4	1	3	2	15	O	4	1	3	2
16	X	4	1	3	2	16	O	4	1	3	2
17	O	4	1	3	2	17	O	4	1	2	3
18	O	4	1	3	2	18	O	4	1	3	2
19	O	4	1	3	2	19	O	4	1	3	2
20	X	4	1	3	2	20	O	4	1	3	2
21	O	4	1	3	2	21	O	4	1	3	2
22	O	4	1	3	2	22	O	4	1	2	3
23	O	4	1	3	2	23	O	4	1	3	2
24	O	4	1	3	2	24	O	4	1	3	2
25	X	4	1	3	2	25	O	4	1	2	3
26	X	4	1	2	3	26	O	4	1	3	3
27	X	4	1	2	3	27	X	4	1	2	3
28	X	4	1	3	2	28	X	4	1	3	2
29	X	4	1	3	2	29	X	4	1	2	3

Note: 1 – 29 are the conditions in Appendix C.7. Main conditions show the original result of the ranking.

Source: Author

8.6 Chapter Summary

This chapter has identified the importance of the specific site (i.e. micro) determinant attributes that were applied for the warehouse selection for IHC with the application of AHP research methods. The facilities of the alternative warehouse are considered to be the most important of the major attributes (see Table 8.2). On the other hand, the convenience of the working environment and the welfare of the staff were evaluated to be the least important of the major attributes. Among the sub-attributes, the floor capacity of the warehouse was considered as the most important while the existence or access to a mini-mart is the least important attribute (Table 8.14).

Location X was evaluated as the highest warehouse in 16 sub-attributes in TOPSIS and 27 sub-attributes in fuzzy-TOPSIS (see Table 8.20 and Table 8.28). Location X was also evaluated as the highest warehouse among the alternatives in fuzzy-TOPSIS major attributes evaluation (See Table 8.24). Location V had the highest evaluated attributes in four major attributes.

The distance from PIS, NIS and relative closeness to ideal solution was calculated for the final ranking of the warehouse. Location X was at the closest distance from PIS and at the farthest from NIS in TOPSIS major and sub-attributes evaluation (see Table 8.17 and Table 8.21) and fuzzy-TOPSIS sub-attribute evaluation (see Table 8.29). In fuzzy-TOPSIS major attribute evaluation, Location X, Y and Z were at the farthest distance from NIS. However, only Location X was located at the closest from PIS (see Table 8.26).

Warehouses locations were evaluated using TOPSIS, with the attributes weights obtained by AHP. Moreover, a fuzzy-TOPSIS evaluated was made for robustness and consistent results. A sensitivity analysis was executed to ensure the accuracy of the results that were obtained by (Fuzzy) TOPSIS. The comparison results show that the fuzzy-TOPSIS results are more consistent in terms of ranking order than the non-fuzziness results (Table 8.33 and Table 8.34). A sensitivity analysis of the fuzzy-TOPSIS shows that there is a stable fluctuation of the evaluation of the linguistic variables (see Figure 8.2 and Figure 8.3).

The results analysed through AHP and (fuzzy) TOPSIS analysis, with further application of sensitivity analysis, show that Location X was evaluated to be the optimal warehouse location among the alternative sites. The sensitivity analysis result in non-fuzzy TOPSIS shows the optimal warehouse location is evaluated lower than the current warehouse in many of the conditions while there are only a few results that were lower for the fuzzy-TOPSIS result. A comparison between the non-fuzzy and fuzzy TOPSIS results shows that fuzzy application are more accurate and have more robust results for the warehouse decision selection decision making process.

This chapter also illustrated the application of AHP and TOPSIS, that is widely used in the commercial sector, into the real case study of warehouse selection problem in humanitarian relief organisations that took place in Dubai, UAE. The decision-making process method of AHP and TOPSIS are not only reliable by providing giving robust and accurate results but also easy to carry out.

CHAPTER 9
DISCUSSION AND CONCLUSION

9.1 Chapter Overview

The impact of the warehouse location decision solving problem has been extensively examined in this study. This chapter starts with an overview of the study purpose, which is followed by a discussion of the research questions and research findings. The research implications for both the academic field and humanitarian relief field are illustrated, together with areas proposed for future study.

9.2 Purpose of the Study

The principal aim of this thesis was to explore the warehouse location attributes in humanitarian relief logistics from the perspectives of operations management (decision-makers), and to locate regional and specific site alternative warehouse locations. Along with an extension study of author's MSc dissertation which explored the humanitarian pre-positioned warehouse location, a lack of previous studies examining the warehouse decision attributes and sparse empirical hard data were among reasons that triggering the author's interest in conducting this research. Although many previous studies have researched warehouse location problems in the commercial sector, very few studies have been conducted in humanitarian relief logistics. Accordingly, this thesis has taken a step forward since it has explored the warehouse location decision attributes and location problem in humanitarian relief logistics by employing MADM research tool. Throughout this study, warehouse location decision making in humanitarian relief organisations were divided into macro (i.e. regional) and micro (i.e. specific site) determinants in a case study that was based on the organisations' need for criteria evaluation in the decision-making management levels. The main data analysis methods that were employed were the AHP, which was used to acquire attribute weights, and TOPSIS, which was used to obtain the final ranking order for the identified alternative warehouse location sties. A fuzzy set theory is applied to solve the incomplete information and the un-sharpness of classes of objects or situations in a flexible way (Chiclana *et al.* 1998). Finally, a sensitivity analysis is executed for robust and accurate result. The use of a case study method and a survey method has provided the study with a triangulation measure and methods to confirm the study findings.

9.3 Discussion of the Results

The research questions were listed in Table 1.1. Throughout chapters five to eight these research questions were extensively analysed. Below is a brief review of the results of such results.

Research Question 1: What are the humanitarian relief warehouse selection attributes?

The question was the first to emerge from the literature review. Different facility location selection problem models have been suggested using various operations research techniques. The location studies conducted in the humanitarian field have mainly used quantifiable methods dealing with complicated mathematical solutions. Furthermore, there are only a few studies that have used qualitative methods of MADM in solving of warehouse location decision problem especially in humanitarian relief logistics. The determinant attributes in multi-attribute location problem used in commercial logistics have been organised by Farahani *et al.* (2010) and the major location decision attributes for warehouse location selection are illustrated in Table 3.13. Even though the determinant attributes are well organised in the non-humanitarian industry, the attributes for the location problem selection for MADM methods vary case by case. The determinant attributes of the warehouse location selection for humanitarian logistics is explored and explained in Chapter 5, Section 5.4.1. According to Table 5.2, proximity to a disaster prone area is considered to be a major concern for humanitarian pre-positioned warehouse selection. Many attributes were responded to be less than five respondents, which indicate that most of the decision-makers have different opinions. Most of the respondents replied that all of the attributes are equally important for the warehouse location selection problem, which means that they cannot decide their most preferred attribute and this has led the author to move on to answer the next research question.

The attributes that have been found in Table 5.2 are used for further research step for acquirement of the weights of the attributes and ranking order for the warehouse selection.

Research Question 2: What are the priorities and the weights of the regional warehouse location selection determinant attributes?

To answer this question, the author has undertaken a case study to investigate the warehouse location problem.

The first case study was presented in Chapter 6, the regional determinant attributes were identified from international humanitarian organisation. The decision hierarchical structure for regional determining warehouse location attributes was constructed through group working method with a panel of eleven managerial level officers (as shown in Figure 6.3). The panels structured the attributes in to five major attributes and twenty-five sub-attributes. The AHP obtains the weight of the attributes, which also indicates the priority (preference). Table 7.1 shows that the CR for both major and sub-attributes is less than 0.1 where the judgements are consistent; therefore, the weights are consistent and can be used in the ranking process (Saaty, 1980). The existence of cooperation turned out to be the most important major attribute while the geographical location is found to be the least important attribute for the regional warehouse selection (as shown in Table 7.2). The further explanation of the respondents shows that the cooperation of the host government is essential for setting up the warehouse facility for incentives given from government since the humanitarian organisation is a non-profit organisation. On the other hand, geographical location of the warehouse is not a big issue since the developed transport mode enables most of the relief goods to be accessible to the rest of the world. Since the International Humanitarian Organisation A emphasis on sea-air based pre-positioned warehouse, road network conditions to neighbouring countries was considered less important for them. However, cases studies show that the road connections from the pre-positioned warehouse to the beneficiaries are critical in some cases (Choi *et al.* 2010). The proximity to disaster prone areas was considered to be more important than disaster free location (see Table 7.4). The decision-makers would prefer to locate the pre-positioned warehouse closer to the potential disaster area by risking the warehouse damage. The land cost was considered the least important in the cost attributes (see Table 7.8). The reason for this is that International Humanitarian Organisation A receives the land free of charge by the host government in most cases. However, this implies the importance of the land cost for they only consider a country that would provide free of charge. The cooperation of the host government result to be the most important because International Humanitarian Organisation A prefer a government that would give more favour with land cost, warehouse cost, customs regulations and bills.

The final weights of the sub-attributes that are shown in Table 7.14 indicate that political stability is the most important attribute. It is easier for the organisation to prepare and respond when political issues are predictable. Out of the twenty-five sub-attributes, the top seven account for more than 50% of the total percentage. In addition, the seven sub-attributes (i.e. political, host government, logistics, united nations, economical, seaport, and replenishment) are grouped under four major attributes (i.e. national stability, cost, cooperation, and logistics), which have great influence in the decision-making process. The location sub-attributes are at the bottom of the table, which is considered to be the least important attribute in regional warehouse selection.

Research Question 3: Where is the optimal warehouse location using the evaluation of the regional determinant attributes?

The panels for Case Study A evaluated those warehouse locations that could be optimal for the organisation (as explained in Chapter 6, Section 6.2.4). The organisation operates five pre-positioned warehouse around the world. Two are CES, which operate only during emergency crisis, and three regional stockpiles, which normally assist in post-disaster aid operations. The ranking order to obtain the optimal warehouse selection is acquired by employing TOPSIS from the result given by AHP. The analysis is compared between the major attributes and sub-attributes. Fuzzy set theory is adopted to overcome the vagueness of linguistic variable and to compare the result between TOPSIS and fuzzy-TOPSIS. A sensitivity analysis was executed to check the robustness of the TOPSIS result. The comparison result of the warehouse location between the major and sub-attributes with non-fuzzy-TOPSIS result is shown in Table 7.31. The main result shows that warehouse Location A is evaluated to be the optimal warehouse location for the organisation, both in major and sub-attributes. The ranking order for the first and second location does not change in the sensitivity analysis in the major attribute evaluation. On the other hand, when the detailed sub-attributes are evaluated, the ranking order varies depending on the weights being exchange. The comparison result between the major and sub-attributes with fuzzy-TOPSIS is shown in Table 7.32. The main result shows the ranking order for the warehouse is the same in both major and sub-attribute results, with Location A evaluated as the optimal warehouse location. In the sensitivity analysis result of the major attributes, the ranking of the first, second and the last are consistent. The sensitivity analysis result for sub-attributes shows that the top evaluated warehouse is consistent in all conditions; however the rest varies throughout the conditions. From the comparison of Table 7.31 and Table 7.32, the TOPSIS result shows more consistency with the major attribute evaluation compare to the sub-attributes.

The comparison analysis of the ranking order between the non-fuzzy-TOPSIS and fuzzy-TOPSIS of the major attributes is illustrated in Table 7.33. The main result shows Location A is evaluated to be the optimal location of the warehouse selection and Location B is the next alternative. For both results, Location C evaluated is the least preferable site. The result for the first and the second rank for non-fuzzy-TOPSIS are consistent throughout the conditions and the others vary according to the different conditions. The result of the fuzzy-TOPSIS shows that the ranking order for the first two and the last are consistent in the sensitivity analysis. Table 7.34 shows the result of the evaluation of the warehouse selection with the sub-attributes. The main result shows that Location A is evaluated as the optimal warehouse in both TOPSIS and fuzzy-TOPSIS analysis. When sensitivity analysis is executed, location A is not evaluated to be first in six conditions. For fuzzy-TOPSIS analysis, Location A is evaluated as the optimal warehouse throughout the sensitivity analysis.

The evaluation of the optimal warehouse finds that warehouse Location A is an optimal location for the organisation. In addition, the comparison result of the sensitivity analysis shows that the evaluation becomes less accurate as the attributes increases with detailed criteria in sub-attribute analysis. This unstable result has been overcome by adopting the fuzzy set theory in the TOPSIS analysis. The result shows that fuzzy-TOPSIS is able to provide more accurate and robust evaluation of the final ranking order for the warehouse selection with regional determinant attributes.

Research Question 4 What are the priorities and the weights of the specific site warehouse location selection determinant attributes?

Another case study was undertaken to answer this question. The humanitarian organisations that participate for this research are based in Dubai, UAE. They all share a warehouse compound that is provided by the UAE government. However, they have recently been informed by the government officials that they will be moving to an alternative site. The author was working with one of the humanitarian organisation as an intern when this process took place.

The second case study is presented in Chapter 6, the specific site attributes were identified by panels which consist of eleven decision-makers from six different humanitarian organisations (as shown in Table 6.7). The panels constructed the decision hierarchical structure into five major attributes and thirty sub-attributes (as illustrated in Figure 6.5). The AHP was able to obtain the weight of the attributes, which indicates the priority (preference). In Table 8.1 the CR for both major and sub-attributes is less than 0.1 where the judgements are consistent; therefore, the weights are consistent and are used in the ranking process (Saaty, 1980). Among the major attributes, warehouse facility was evaluated as the most important and the convenience of the working environment evaluated was evaluate as being the least important for specific site warehouse selection (as shown in Table 8.2). Since the panels set higher target goals for their own organisations in the following year, they all considered that the new warehouse compound must be better (or at least have equal facility quality) than the current warehouse compound. If they could meet the goals, the convenience of their working environment will not be a big issue for their concern. The distance from Sharjah Airport was considered the most important attribute for distance attributes (see Table 8.4). Sharjah Airport is mostly used by the IHC members during the emergency crisis. Due to this, the administrative process in Sharjah Airport is smoother than others. Abu Dhabi Airport is considered the least important because of the fact that it is located the farthest. The warehouse security was considered the most important among the security and safety attributes (see Table 8.6). This was due to the fact the IHC members stocks a lot of valuable relief items such as medicines, telecommunication equipments, and armoured vehicles. IHC members considered the warehouse should locate near to the administrative office so that the staff can frequently go to the facility to make maintenance checks (see Table 8.8). The warehouse capacity was considered the most important attribute among the warehouse facilities (see Table 8.10). IHC members needed to stock large volume of relief goods and floor capacity of the warehouse became the critical issue for warehouse selection naturally. The transportation to the warehouse was considered the most important among the convenience attributes (see Table 8.12). The panels have difficulty accessing the current compound because there lack public transportation. Staff or visitors could only access by using cabs or their own vehicles.

The final weights of the sub-attributes in Table 8.14 show that the capacity of the warehouse facility was evaluated as the most important attribute. Out of thirty sub-attributes, the top seven of the table account for more than a half of the total percentage. In addition, the seven sub-attributes (i.e. capacity, Sharjah airport, warehouse security, Al Maktoum airport, Jebel Ali seaport, loading bays, and ceiling height) are grouped under three major attributes (i.e. capacity, distance, and security/safety), which are in a position of influencing the decision-making process. The sub-attributes of the office facility and convenience form bottom of the table, which are considered to be the least important attributes.

Research Question 5: Where is the optimal warehouse location using the evaluation of the specific site determinant attributes?

The panels for Case Study B identified the possible warehouse locations that could be suitable for optimal site for the organisations (as explained in Chapter 6, Section 6.3.4). Along with the current warehouse, the panels located four potential warehouse sites in Dubai, UAE. The same data evaluation method has been employed that was used to answer Research Question 3. The comparison result of the warehouse locations between the major and sub-attributes with non-fuzzy-TOPSIS result is shown in Table 8.31. The main result of Table 8.31 is that Location X is evaluated to be the optimal location and Location W is evaluated to the least preferable site for both attributes and sub-attributes. From the sensitivity analysis it can be seen that Location X is evaluated higher than the current warehouse in Location V in seven conditions out of twenty-one (33%) in major attributes evaluation. For sub-attributes, Location X is evaluated higher than the current warehouse in twenty-four conditions out of thirty (80%). The comparison result between the major and sub-attributes with fuzzy-TOPSIS is shown in Table 8.32. The main result shows that Location X is evaluated as the optimal warehouse location. The ranking order is same throughout the condition when sensitivity analysis is executed for major attribute evaluation. Location X is evaluated to be higher than the current warehouse in every condition (100%). For sub-attributes, Location X remains in the top of the ranking when the sensitivity analysis is executed. In addition, Location X is evaluated higher than the current warehouse in twenty-seven conditions (90%), which is an improvement on the non-fuzzy-TOPSIS analysis.

The comparison analysis of the ranking order between the non-fuzzy-TOPSIS and fuzzy-TOPSIS of the major attributes is illustrated in Table 8.33. The main analysis shows that Location X is evaluated to be optimal and Location W is the least optimal location in both attributes and sub-attributes. This is consistent throughout the conditions when a sensitivity analysis is carried out. In a comparison of the sensitivity analysis, Location X is evaluated higher than the current warehouse only in seven conditions (33%) in non-fuzzy-TOPSIS evaluation. However, fuzzy-TOPSIS analysis shows that Location X is evaluated higher than the current warehouse in all conditions (100%); in addition, the ranking order of the alternative warehouse is consistent. Table 8.34 shows the result of the evaluation of the warehouse selection with the sub-attributes. The main result shows that Location X is evaluated to be the optimal warehouse location for both results. In the result of the sensitivity analysis, the first and the last ranking of the warehouse locations remain the same throughout the conditions while the second and third vary according to the conditions for both results. While Location X is evaluated higher than the current warehouse in twenty-four conditions (80%) in non-fuzzy-TOPSIS analysis, it has improved to 90% (i.e. twenty-seven conditions) for fuzzy-TOPSIS result.

Warehouse Location X is shown to be an optimal location for the organisations with specific site determinants. The linguistic evaluation brought less reliable result in non-fuzzy-TOPSIS, especially with major attributes; however, this was improved when fuzzy set theory was employed for the evaluation providing more accurate and robust result proved in sensitivity analysis.

9.4 Original Contribution

The main contribution of this study arises from the fact that this research has taken a progression approach in exploring and understanding the warehouse selection process in humanitarian relief logistics employing qualitative location problem in decision-makers perspective with regional and specific site determinant attributes. Previous studies on humanitarian warehouse location problem have mainly used a quantitative computational method which overlooks the qualitative perspective; this study has aimed at filling this gap. Moreover, this study has provided insights into humanitarian logistics; warehouse location problem with multi-attribute decision-making method.

From a theoretical perspective, despite an awareness of the importance of preparedness and the need for pre-positioned warehouse in humanitarian relief logistics, relatively few studies have used the MADM location problem method to identify the crucial criteria for locating warehouse as compared to commercial logistics. Consequently, the results of this empirical research, which is one of the few to investigate warehouse location decision factors in humanitarian relief logistics, can be used as a stepping stone for empirical research in this field.

Moreover, the author has used AHP-(fuzzy) TOPSIS location problem to help inform the understanding of the humanitarian warehouse location selection problem.

Through an exploratory study, this research provided the determinant attributes for warehouse selection problem that is identified by the decision-makers of humanitarian relief organisations. Most previous studies can be found in commercial warehouse location; however, there were certain attributes that are only suitable for the humanitarian relief field. These attributes provided by the humanitarian logistics experts gave an idea of what their thoughts were when they were considering the warehouse selection problem.

It was interesting to find that the regional determinants in the AHP result (which showed the priority of the attributes) showed that the cooperation of the humanitarian actors was evaluated to be the highest priority and location related attributes were evaluated as the least important of the major attributes. In the result of the sub-attributes, political stability was evaluated to be the most important criteria for the warehouse selection, followed by the cooperation of the host government. This result is due to the previous experience of the decision-makers where they have been forced to pull out the humanitarian facilities in an unstable country with unfriendly government officials. The top seven of the sub-attributes consist of 50% of the total weight. These seven sub-attributes are under the major attributes of national stability (i.e. political and economic), cost (i.e. logistics and replenish), cooperation (i.e. host government and United Nations), and logistics (i.e. seaport) while there is no sub-attribute from the geographical attribute (which makes up the top 50% of the total weight). This was a surprising result when national stability was commented on by only one respondent in the exploratory study and the geographical location was the most popular attribute in the exploratory study.

In the AHP result of the specific site determinants, it can be seen that the decision-makers are willing to give up certain part of the convenience and office facilities attribute for the warehouse facilities and logistics attribute. This can be clearly shown in the final ranking of the sub-attributes. The attributes chosen by the decision-makers in the humanitarian relief organisation are not that much different from those that are used in commercial logistics.

This research suggests warehouse location decision attributes that are specifically fitted to humanitarian logistics; it also proposes a systematic decision hierarchical structure that is verified by interviews with experts in this field. The attributes employed for selecting warehouse location in AHP are drawn various from different studies or different industries. Therefore, the attributes and the hierarchical structure suggested in this study will be helpful for future research.

Another contribution of this study is the employment of the multi-attribute decision making method to humanitarian relief logistics. The implementation of the integrated AHP-(fuzzy) TOPSIS studies is widely applied in answering many of the facility location problems; it is also used in other important decision-making problems. This integrated MADM method is straightforward and it requires only a simple calculation. The fuzzy set theory resolves the vagueness of the linguistic variables in the evaluation of the warehouse selection. The employment of the fuzzy set theory in TOPSIS along with the sensitivity analysis helps to justify the result of the selection of the optimal warehouse site because it provides an accurate and robust evaluation. The author believes that this useful decision-making tool will bring guidance to humanitarian relief decision-making problems.

9.5 Limitations of this Study

The range of subjects that could be included in this type of study is so wide that no single study at this level could cover all aspects; accordingly, there are several limitations, a number of which are worth mentioning.

This study has covered the use of integrated AHP-(fuzzy) TOPSIS for the humanitarian warehouse selection problem; therefore, the influence of the politic consideration in the higher level of the organisation is beyond the scope of this study. There are many complicated politic issues in decision-making problems in humanitarian organisations that the decision-makers must be aware of, especially in the larger organisations that receive tremendous financial aid. However, there have been several cases where the decision is already made at the highest level of the organisation for political reasons and the decision-making process was proceeded to intentionally cover the fault of the system.

Another limitation of the study is the low response of the initial survey. Humanitarian organisations that operate their own pre-positioned warehouse are rare due to the high maintenance cost. Even those who operate a warehouse are scattered around the world. Consequently, it was difficult to reach many of the logisticians, especially the decision-makers. Some of the logisticians' electronic mail addresses are invalid, some have moved to a different department or have left the organisation, and some could not reply due to a busy daily schedule. This was overcome by humanitarian logisticians introducing other colleagues who are related or who can answer such a survey. The limitation of the usage of the current research method is that the hierarchy structure and the alternatives will differ case by case. Different organisations will construct different attributes and alternative hierarchical structures that would fit for their organisation. Once the hierarchical structure is constructed by the panel, it can be evaluated by them. Since the attributes were selected and constructed by a humanitarian organisation that mainly focuses on refugee relief, they have identified the issues that are suitable for them. There are many areas that can influence the selection of the attributes, for example: character of the organisation, the role of the pre-positioned warehouse, the main beneficiaries, donors, financial volume, main geographical area where the most relief activity is taken place, number of the decision-makers, gender and religious background of the decision-makers. Even though a consistency ratio exists for AHP measurement to ensure consistent results, the evaluation is given by the subjectivity opinion of the decision-makers and this can change over time. To avoid this inconsistency (in addition to the consistency ration calculation) the panels that participated in the initial stage kindly measured the AHP and TOPSIS survey somewhat similar to a Delphi case study. The measurements were then double checked during a feedback session to determine whether the respondents have changed their minds since answering during the feedback.

9.6 Research Implications

9.6.1 Further Research

There are a number of suggestions and recommendations for further research, including an exploration of the relationship between regions, managerial levels, religious background and other issues that could have influence in attribute and warehouse selection. Humanitarian relief organisations provide relief aid for many different reasons around the world. Even though their common goal is to save lives and support people in need, the way they approach this problem are different and this reflects in their logistics. The author realised that there is a need for an in-depth study to organise the different pre-positioned warehouse strategies. These pre-positioned warehouses support the organisations' logistics in different ways for various reasons. Some of the organisations have just started or are planning to implement the pre-positioned warehouse system by running the warehouse by themselves or borrowing from other larger organisations. On the other hand, some large organisations have adopted the pre-positioned warehouse system for many years and they are now planning efficient ways to manage the warehouse by collaborating with partners. The breakdown of the samples and case study will provide more detailed insight of the comparison analysis. Comparing the humanitarian warehouse location problem with other research tools is another suitable topic for further research.

The understanding of the preference order of major attributes may provide a clue as to how humanitarian relief organisations can adjust their warehouse location selection process based on the results. In particular, the results may be of value to current and potential humanitarian relief organisations in South Korea who are considering their own warehouse for future research.

9.6.2 Research Implication for Humanitarian Relief Field

As aforementioned, the main research for the current study is focused on identifying the regional and specific site attributes and analysing the optimal site for humanitarian warehouse location selection problem with integrated AHP-(fuzzy) TOPSIS, one of the many MADM research tools. MADM is widely used by the researchers for analysing the decision-making process in the facility location selection problem and also in many other general decision making problems. This can be adopted for the humanitarian relief field where managerial-level decision-makers need to provide rational reasons for the evaluation. This method is also flexible enough to be employed in various decision-making problems in humanitarian organisations.

Cross industry knowledge could be shared in facility location problem. Even though the attributes are preferred differently case by case, there is an opportunity for knowledge learning between humanitarian organisations and commercial sectors. It has been observed that the humanitarian relief supply chains tend to be more donor driven, while commercial sectors have extensively developed to be profit driven.

As regards the warehouse selection problem, this study proved the positive adaptation of facility location problem research tool for humanitarian warehouse selection problem. Nevertheless, pre-positioned warehouse selection should be approached cautiously, since humanitarian organisations prefer different attributes from one another or misunderstanding the need of the pre-positioned warehouse might have a negative impact on the humanitarian pre-positioned warehouse selection problem and, hence, on the relief supply chain as a whole.

9.7 Chapter Summary

Humanitarian relief organisations implement pre-positioned warehouses around the world to deliver relief items for a rapid emergency response. This study has provided insights into humanitarian warehouse selection attributes for regional and specific site locations, highlighting some of the influential factors causing the decision-makers to locate a new warehouse. In addition, this study has adopted AHP and TOPSIS for warehouse selection problem, which are widely used in commercial sector. The vagueness of the linguistic variables was overcome by applying the fuzzy set theory. This study has relied on empirical soft data to evaluate the weight of the attributes and the warehouse locations. While many previous studies have approached the humanitarian warehouse problem quantitatively, this study has demonstrated qualitatively at the decision-makers' level.

REFERENCES

Aaker, A., Kumar, V., and Day, G. 1995. *Marketing Research.* 5th ed. New York: John Wiley, Inc.

Abdel-Kader, M.G. and Dugdale, D. 2001. Evaluating Investments in Advanced Manufacturing Technology: A Fuzzy Set Theory Approach. *British Accounting Review* 33 (4), pp. 455-489

Aczel, J. and Saaty, T.L. 1983. Procedures for synthesizing ratio judgement. *Journal of Mathematical Psychology* 27 (1), pp 93-102.

Australian Council for International Development's Humanitarian Reference Group (ACFID) 2007. *Emergency Response Supply Chain Assessment*. [online; cited: 2010 August 18], Available from URL: http://www.acfid.asn.au/what-we-do/docs_what-we-do/docs_Humanitarian-and-emergencies /emergresponseassessment.pdf.

Adinolfi, C., Bassiouni, D.S., Laurizsen, H.F. and Williams, H.R. 2007. *Humanitarian Response Review*. [online; cited 2008 June 5], Available from URL:http://www.reliefweb. int/library/documents/2005/ocha-gen-02sep.pdf.

Aguilar-Manjarrez, J. and Ross, L.G. 1995. Geographical information system (GIS) environmental models for aquaculture development in Sinaloa State. Mexico", *Aquaculture International* 3(2), pp. 103-115.

Ahn, B.S. 2000. The analytic hierarchy process in an uncertain environment: A simulation approach by Hauser and Tadikamalla (1996). *European Journal of Operational Research* 124, pp. 217- 218.

Akash, B.A., Mamlook, R. and Mohsen, M.S. 1999. Multi-criteria of electric power plants using analytical hierarchy process. *Electric Power Systems Research* 52, pp. 121-129.

Albayrak, E. and Erensal, Y.C. 2004. Using analytic hierarchy process (AHP) to improve human performance. An application of multiple criteria decision making problem. *Journal of Intelligent Manufacturing* 15, pp. 491-503.

Alberto, P. 2000. The logistics of industrial location decisions: an application of the analytic hierarchy process. *International Journal of Logistics* 3(3), pp. 273- 289.

Alphonce, C.B. 1997. Application of the analytic hierarchy process in agriculture in developing countries. *Agricultural Systems* 7, pp. 1-14.

Amiri, A. 2001. The multi-hour service system design. *European Journal of Operations Research* 128(3), pp. 626-638.

Amiri, M.P. 2010. Project selection for oil-fields development by using the AHP and fuzzy TOPSIS methods. *Expert Systems with Applications* 37, pp. 6218-6224.

Anderson, E.B. 1998. Optimising ammunition movement in support of the U.S. Pacific fleet's positioning plan. *Master's Thesis in Operational Research*, Naval Postgraduate School.

Angelis, V.D., Mecoli, M., Nikoi, C. and Storchi, G. 2007. Multiperiod integrated routing and scheduling of world food programme cargo planes in Angola. *Computer Operational Research* 34(6), pp. 1601-1615.

Aragones-Beltran, P., Pastor-Ferrando, J.P., Garcia-Garcia, F. and Pascual-Agullo, A. 2010. An analytic network process approach for siting a municipal solid waste plant in the Metropolitan Area of Valencia (Spain). *Journal of Environmental Management* 91, pp. 1071-1086.

Aras, H., Erdogmus, S. and Koc, E. 2004. Multi-criteria selection for a wind observation station location using analytic hierarchy process. *Renewable Energy* 29, pp. 1383-1392.

Ashtiani, B., Haghighirad, F., Fakui, F., and Montazer, G. 2009. Extension of fuzzy TOPSIS method based on interval-valued fuzzy sets. *Applied Soft Computing* 9, pp. 457-461.

Avella. P, Benati, S, Canovas Martinez. L, Dalby. K, Di Girolamo. D, Kimitrijevic. B, Ghiani. G, Giannikos. I, Guttmann. N, Hultberg, T.H., Fliege. J, Martin. A, Munoz Marquez. M, Ndiaye. M.M., Nickel. S, Peeters. P, Perez Brito. D, Policastro. S, Saldanha de Gama. F.A. and Zidda. P. 1998. Some persona views on the current state and the future of locational analysis. *European Journal of Operational Research* 104(2), pp. 269 – 287.

Awasthi, A., Chauhan, S.S., and Goyal, S.K. 2011. A multi-criteria decision making approach for location planning for urban distribution centres under uncertainty. *Mathematical and Computer Modelling* 53, pp. 98-109.

Badri, M.A. 1999. Combining the analytic hierarchy process and goal programming for global facility location-allocation problem. *International Journal of Production Economics*.62, pp. 237-248.

Badri, M.A. 2001. A combined AHP-GP model for quality control systems. *International Journal of Production Economics*17, pp. 179-190.

Balick, B. and Beamon, B.M. 2008. Facility location in humanitarian relief. *International Journal of Logistics: Research and Application* 11(2), pp. 101-121.

Balcik, B., Beamon, B.M. and Smilowitz, K. 2008. Last mile distribution in humanitarian relief. *Journal of Intelligent Transportation Systems*. 12(2), pp. 51-63.

Balcik, B., Beamon, B., Krejci, C.C., Muramatsu, K.M. and Ramirez, M. 2010. Coordination in humanitarian relief chains: Practices, challenges and opportunities. *International Journal of Production Economics*.126, pp. 22-34.

Bales, R.R., Maull, R.S., and Radnor, Z. 2004. The development of supply chain management within the aerospace manufacturing sector. *Supply Chain Management: An Introduction Journal*.3(3), pp. 250-255.

Ballou, R.H. 1978. *Basic Business Logistics*. NJ: Prentice-Hall, Englewood Cliffs.

Barbarosoglu, G. and Arda, Y. 2004. A two-stage stochastic programming framework for transportation planning in disaster response. *Journal of Operational Research Science* 55(1), pp. 43-53.

Barbarosoglu, G., Özdamar, L. and Cevik, A. 2002. An interactive approach for hierarchical analysis of helicopter logistics in disaster relief operations. *European Journal of Operations Research* 140(1), pp. 118-133.

Barda, O.H., Dupuis, J., and Lencioni, P. 1990. Multicriteria location of thermal power plants. *European Journal of Operational Research* 45, pp. 332-346.

Beamon, B. 2004. Humanitarian relief chains: issues and challenges. in *Proceedings of the 34th International Conference on Computers and Industrial Engineering*. San Francisco, CA.

Beamon, B.M. and Balcik, B. 2008. Performance measurement in humanitarian relief chains. *International Journal of Public Sector Management* 21(1), pp. 4-25.

Beamon, B.M. and Kotleba, S.A. 2006a. Inventory modelling for complex emergencies in humanitarian relief operations. *International Journal of Logistics: Research and Application* 9(1), pp. 1-18.

Beamon, B.M. and Kotleba, S.A. 2006b. Inventory management support systems for emergency humanitarian relief operations in South Sudan. *International Journal of Logistics Management* 17(2), pp. 187-212.

Bellman, R.E. and Zadeh, L.A. 1970. Decision making in fuzzy environment. *Management Science* 17, pp. 141-164.

Belton, V. and Gear, T. 1983. On a short-coming of Saaty's method of analytic hierarchies. *Omega* 11, pp. 228-230.

Belton, V. and Pictet, J. 1997. A framework for group decision using MCDM model: sharing, aggregating or comparing individual information?. *Journal of Decision Systems* 6(3), pp. 283-303.

Ben-Tal, A. Chung, B.D., Mandala, S.R. and Yao, T. 2010. Robust optimisation for emergency logistics planning: Risk mitigation in humanitarian relief supply chains. *Transportation Research Part B*. doi:10.1016/j.trb.2010.09.002.

Bhattacharya, U., Rao, J.R., and Tiwari, R.N. 1992. Fuzzy multi-criteria facility location problem. *Fuzzy Sets and Systems* 51, pp. 277-287.

Bhattacharya, U., Rao, J.R., and Tiwari, R.N. 1993. Bi-criteria multi facility location problem in fuzzy environment. *Fuzzy Sets and Systems* 56, pp. 145-153.

Bolloju, N. 2001. Aggregation of analytic hierarchy process models based on similarities in decision makers' preferences. *European Journal of Operational Research* 120, pp. 499-508.

Boran, F.E. 2011. An integrated intuitionist fuzzy multi criteria decision making method for facility location selection. *Mathematical and Computational Applications* 16(2), pp. 48-496.

Bottero, M. and Ferretti, V. 2011. An analytic network process-based approach for location problems: The case of a New waste incinerator plant in the province of Torino (Italy). *Journal of Multi-Criteria Decision Analysis* 17, pp. 63-84.

Bouma, G.D. and Atkinson, G.B.J. 1995. *A Handbook of Social Science Research*. Oxford: Oxford University Press.

Bourque, L. and Fielder, E. 1995. *How to Conduct Self-Administrated and Mail Surveys*. London: Sage.

Bowersox, D.J. and Closs, D.J. 1996. *Logistical Management: The Integrated Supply Chain Process,* McGraw-Hill, New York, NY.

Brown, B.J. (1979), *Disaster Preparedness and the United Nations – Advance Planning for Disaster Relief*, pp. 147. Oxford: Pregamon Press.

Bryman, A. 1988. *Quantity and Quality in Social Research.*London: Rutledge.

Bryman, A. 1989. *Research Methods and Organisational Studies*.London: Rutledge.

Bryman, A. 2008. *Social research methods*. 3rd ed. Oxford: Oxford University Press.

Buckley, J.J. 1985. Fuzzy hierarchical analysis. *Fuzzy Sets and Systems* 17, pp. 223-247.

Bryman, A. and Bell, E. 2007. *Business research methods*. 2nd ed. Oxford: Oxford university press.

Byman, D., Lesser, I.O., Pirnie, B.R., Benard, C. and Waxman, M. 2000. *Strengthening the Partnership: Improving Military Coordination with Relief Agencies and Allies in Humanitarian Operations.* Rand Corporation, Santa Monica, CA. (Available online at: www.ran.org/pubs/monograph_reports/MR1185/)

Byun, H.S. and Lee, K.H. 2005. A decision support system for the selection of a rapid prototyping process using the modified TOPSIS method. *International Journal of Advanced Manufacturing Technology* pp. 1338-347.

Campbell, A.M. and Jones, P.C. 2011. Prepositioning supplies in preparation for disasters. *European Journal of Operational Research* 209(2), pp. 156-165.

Canbolat, Y.B., Gupta, G., Matera, S. and Chelst, K. 2008. Analysing risk in sourcing design and manufacture of compents and sub-sytems to ermging markets. *Internatonal Journal of Production Research* 46(18), pp. 5145-5164.

Carter, W.N. 1999. *Disaster Management: A Disaster Management Handbook*, Manila: Asian Development Bank.

Cassidy, W.B. 2003. A Logistics Lifeline. *Traffic World* October 27, p. 1.

Caunhye, A.M., Nie, X., and Pokharel, S. 2011. Optimisation models in emergency logistics: A literature review. *Socio-Economic Planning Sciences*, doi:10.1016/j.seps.201104.004.

Chaikin, D. 2003. Towards Improved Logistics: Challenges and Questions for Logisticians and Managers. *Forced Migration Review* 18, pp. 10.

Charnpratheep, K., Zhou, Q. Garner, B. 1997. Preliminary landfill site screening using fuzzy geographical information system. *Waste Management and Research* 15, pp. 197-215.

Chan, F.R.S. and Kumar, N. 2007. Global supplier development considering risk factors using fuzzy extended AHP-based approach. *OMEGA* 35, pp. 417-431.

Chan, F.T.S. and Chung, S.H. 2004. Multi-criteria genetic optimisation for distribution network problems. *International Journal of Advanced Manufacturing Technology* 24, p. 517-532.

Chandler, A.D. 1990. *Scale and Scope,* Cambridge, MA: The Belknap Press.

Chang, Y, Wilkinson, S., Potangaroa, R., and Seville, E. 2010. Donor-driven resource procurement for post-disaster reconstruction: Constraints and actions. *Habitat International*, doi:10.1016/j.habitatint.2010.08.003.

Chen, C.T., Lin, C.T., and Huang, S.F. 2006. A fuzzy approach for supplier evaluation and selection in supply chain management. *International Journal of Production Economics* 102, pp. 289-301.

Chen, S.J. and Hwang, C.L. 1992. *Fuzzy Multiple Attribute Decision Making*, Berlin/Heidelberg/New York: Springer-Verlag.

Cheng, C.H. 1999. Evaluating weapon system using ranking fuzzy numbers *Fuzzy Systems*107, pp. 25-35.

Cheng, M.F. and Tzeng, G.H. 2005. Combining gray relation and TOPSIS concepts for selecting an expatriated host country.*Mathematical Computerisation Modelling*. pp. 1473-1490.

Cheng, S., Chan, C.W., and Huang, G.H. 2002. Using multiple criteria decision analysis for supporting decision of solid waste management. *Journal of Environmental Science and Health, Part A* 37(6), pp. 975-990.

Cheng, S., Chan, C.W., and Huang, G.H. 2003. An integrated multi-criteria decision analysis and inexact mixed integer linear programming approach for solid waste management. *Engineering Applications of Artificial Intelligence* 16, pp. 543-554.

Chiclana, F., Herrera, F. and Herrera-Viedma, E. 1998. Integrating three representation models in fuzzy multipurpose decision making based on fuzzy preference relations. *Fuzzy Sets and System* 97, pp. 33-48.

Chilerhouse, P. and Towill, D.R. 2004. Reducing uncertainty in European supply chain. *Journal of Manufacturing Technology Management* 15(7), pp. 585-598.

Choi, A.K.Y., Beresford, A.K.C., Pettit, S., and Bayusuf, F. 2010. Humanitarian aid distribution in East Africa: A study in supply chain volatility and fragility. *Supply Chain Forum* 11(3), pp. 20-31.

Chomilier, B., Samii, R. and Van Wassenhove, L.N. 2003. The central role of supply chain management at IFRC. *Forced Migration Review*18, pp. 15-16.

Chou, T.Y., Hsu, C.L. and Chen, M.C. 2008. A fuzzy multi-criteria decision model for international tourist hotels location decision. *International Journal of Hospitality Management* 27, pp. 293-301.

Chwolka, A. and Raith, M.G. 2001. Group preference aggregation with the AHP – Implication for multiple-issue agendas. *European Journal of Operational Research* 132, pp. 176-186.

Christopher, M. 1998. *Logistics and Supply Chain Management*, London: Routledge.

Chu, T.C. 2002a. Facility location selection using fuzzy TOPSIS under group decisions. *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems* 10(6), pp. 687-701.

Chu, T.C. 2002b. Selecting plant location via a fuzzy TOPSIS approach. *International Journal of Advanced Manufacturing Technology* 20, pp. 859-864.

Chuang, P.T. 2001. Combining the analytic hierarchy process and quality function deployment for a location decision from a requirement perspective. *International Journal of Advance Manufacturing Technology* 18(11), pp. 842-849.

Chung, K. and Tcha, D. 1992. A fuzzy set-theoretic method for public facility location. *European Journal of Operational Research* 58, pp. 90-98.

Church, R.L. and ReVelle, C. 1974. Maximal covering location problem. *Papers of the Regional Science Association* 32, pp. 101-118.

Church, R.L. and ReVelle, C. 1976. Theoretical and computational links between the *p*-median location set-covering and the maximal covering location problem. *Geographical Analysis* 8, pp. 406-415.

Cinar, N. 2009. A decision support model for bank branch location problem. *Proceedings of World Academy of Science, Engineering and Technology* 60 pp. 126-131.

Cohen, L. and Manion, L. 1994. *Research Methods in Education.* 4th ed. London: Rutledge.

Council of Logistics Management 1998. *Council of Logistics Management*, [online, cited 2011 March 14], available from URL:http://clm1.org.mission.html.

Coyle, J., Bardi, E.J., and Langley Jr., C.J. 1996. *The Management of Business Logistics*, St. Paul, MN: West Publishing Company.

Cummins, J.D. and Derrig, R.A. 1997. Fuzzy Financial Pricing of Property-Liability Insurance. *North American Actuarial Journal* 1(4), pp. 21-40.

Dagdeviren, M., Yavuz, S., and Kihnc, N. 2009. Weapon selection using the AHP and TOPSIS methods under fuzzy environment. *Expert Systems with Applications* 36, pp. 8143-8151.

Danermark, B. 2001. *Explaining society: An introduction to critical realism in the social sciences*. Florence, KY: Routledge.

Darzentas, J. 1987. A discrete location model with fuzzy accessibility measures. *Fuzzy Sets and Systems* 23, pp. 149 – 154.

Davis, T. 1993. Effective supply chain management. *Sloan Management Review*3(4), pp. 35-46.

DCLG (Department for Communities and Local Government) 2009. *Multi-criteria analysis: a manua*. West Yorkshire: Communities and Local Government Publication.

Delgado, M.R., Gomez-Skennata, A.F. and Martin, F. 1997. *Rapid Prototyping for Fuzzy Models.* In: Hellendoorn, H., Driankov, D. (eds.) Fuzzy Model Identification: Selected Approaches, pp. 121-161, Springer, Berlin.

DeJohn, P. 2005. Heroic efforts keep supplies coming in wake of Katrina. *Hospital Materials Management* 30(10), pp. 1-3.

Dekle, J., Lavieri, M.S., Martin, E., Emir-Farinas, H. and Francis, R.L. 2005. A Florida country locates disaster recovery centres. *Interfaces* 35(2), pp. 133-139.

De Leon, J.C.V., Bogardi, J., Dannenmann, S., and Bahser, R. 2006. Early warning system in the context of disaster risk management. [online, cited at 2008 March 30], available from URL: http://www.unisdr.org/ppew/info-resources/docs/ELR_dt_23-25.pdf.

Demirel, T., Demirel, N.C., and Kaharaman, C. 2010. Multi-criteria warehouse location selection using Choquet integral. *Expert Systems with Applications* 37, pp. 3943-3952.

Deng, H., Yeh, C.H. and Wills, R.J. 2000. Inter-company comparision suing modified TOPSIS with obejecitve weights. *Computers and Operations Research.* 27(10), pp. 963-973.

Denzin, N. 1978. *The Research Act: A Theoretical Introduction to Sociological Methods*. 2nd ed. USA: McGraw Hill.

Denzin, N. and Lincole, Y. 1994. *Introduction: Entering the Field of Qualitative Research*, CA. USA: SAGE.

Department of the Air Force. 1981. Compendium of authenticated systems and logistics terms, definitions and acronyms. *Air Force Institute of Technology*.

Department of the Navy .1998. MPF 2010 and beyond. *The Marine Corps Gazette*, 82.

Dessouky, M.M., Ordonez, F., Jia, H.Z. and Shen, Z.H. 2006. Rapid distribution of medical supplies", In R. Hall (Ed.), *Delay Management in Health Care Systems*, Springer.

Dey, P.K. and Ramcharan, E.K. 2008. Analytic hierarchy process helps select for limestone quarry expansion in Barbados. *Journal of Environmental Management* 88(4), pp. 1384-1395.

Dignan, L. 2005. Tricky currents; Tsunami relief is a challenge when supply chains are blocked by cows roads don't exist. *Baseline* 1(39), pp. 30.

Dubois, D. and Prade, H. *Fundamentals of Fuzzy Sets.* Boston: Kluwer.

Dyer, J.S. 1990a. Remarks on the analytic hierarchy process. *Management Science* 36, pp. 249-258.

Dyer, J.S. 1990b. A clarification of 'Remarks on the Analytic Hierarchy Process'. *Management Science* 36, pp. 274-276.

Easterby-Smith, M., Thorpe, R. and Lowe, A. 2002. *Management research: an introduction* 2nd ed. London: Sage publications.

Ekmekçioğlu, M., Kaya, T., and Kahraman, C. 2010. Fuzzy multicriteria disposal method and site selection for municipal solid wast *Waste Management* 30, pp. 1729-1736.

Ellram, L.M. and Cooper, M.C. 1993. Characteristics of supply chain management and the implications for purchasing and logistics strategy. *International Journal of Logistics Management* 4(2), pp. 1-10.

EM-DAT (Emergency Events Database). 2008. *Emergency Events Database*, Centre for Research on the Epidemiology of Disasters (CRED), Universite Catholique de Louvain, Louvain-La-Neuve, [Online, 2010 June 2], Available from URL: http://emdat.be.

Erkut, E. and Moran, S.R. 1991. Locating obnoxious facilities in the public sector: an application of the hierarchy process to municipal landfill siting decisions. *Socio-economics Planning Science* 25, pp. 89-102.

Ernst, R. 2003. The academic side of commercial logistics and the importance of this special issue. *Forced Migration Review* 18, pp. 5.

Ertuğrul, I. 2010. Fuzzy group decision making for the selection of facility location. *Group Decision* DOI 10.1007/s10726-010-92191.

Ertuğrul, I. and Karakasoglu, N. 2008. Comparison of fuzzy AHP and fuzzy TOPSIS methods for facility location selection. *International Journal of Advanced Manufacturing Technology*39, pp. 783-795.

EVZ (Erinnerung Verantortung Zukunft) 2012. *Humanitarian Programmes*. [online, cited 2012 August 19]. Available from URL: http://www.stiftung-evz.de/eng/forced-labour/humanitarian-programmes/.

Farahani, R.Z. and Asgari, N. 2007. Combination of MCDM and covering techniques in a hierarchical model for facility location: A case study. *European Journal of Operational Research* 176(3), pp. 1839-1858.

Farahani, R.Z., Steadieseifi, M., and Asgari, N. 2010. Multiple criteria facility location problems: A survey. *Applied Mathematical Modelling* 34, pp. 1689-1709.

Fernandez, I and Ruiz, M.C. 2009. Descriptive model and evaluation system to locate sustainable industrial areas. *Journal of Cleaner Production* 17, pp. 87-100.

Figureia, J., Greco, S., and Ehrgott, M. 2005. *Multiple Criteria Decision Analysis: Sate of the art surveys series*. Boston, MA: Springer.

Forman E. and Peniwati, K. 1998. Aggregating individual judgements and priorities with the Analytic Hierarchy Process. *European Journal of Operational Research*, Vol. 108, pp. 165-169.

Forza, C. 2002. Survey research in operations management: a process-based perspective. *International Journal of Operations and Production Management* 22(2), pp. 152-195.

Francis, R.L., McGinnis, L.F. and White, J.A. 1992. *Facility layout and location: an analytical approach*, 2nd Ed., Englewood Cliiffs, NJ: Prentice Hall.

Fritz Institute 2005. *From Logistics to Supply Chain Management: The Path Forward in the Humanitarian Sector*. Fritz Institute.

Freese, T.L. 1994. Site Selection. In *The Logistics Handbook*, J.F. Robeson and W.C. Copacino, New Yort: Free Press.

Fuller, R. and Carlsson, C. 1996. Fuzzy multiple criteria decision making: Recent developments. *Fuzzy Sets and Systems* 78, pp. 139-153.

Gatignon, A., Van Wassenhove, L.N., and Charles, A. 2010. The Yogyakarta earthquake: Humanitarian relief through IFRC's decentralised supply chain. *International Journal of Production Economics* 126, pp. 102-110.

Gattorna, J. 1988. Effective logistics management. *International Journal of Physical Distribution Management* 18(2), pp. 1-92.

Gemitzi, A., Tshirintzis, V.A., Voudrias, E., Petalas, C. and Stravodimos, G. 2007. Combining geographic information system, multi criteria evaluation techniques and fuzzy logic and fuzzy logic in siting MSW landfills. *Environmental Geology* 51(5), pp. 797- 811.

Gharakhlou, M., Faraji Sabokbar, H.A., and Givenchi, S. 2010. Access enhancement by making changes in the route network to facilitate rescue operations in urban disasters. *International Journal of Environmental Resource* 4(2), pp. 183-192.

Ghauri, P. and Grønhaug, K. 2002. *Research methods in business studies : a practical guide*. 2nd ed. Harlow; New York: Financial Times Prentice Hall.

Gligorić, Z., Beljić, C., Simeunović, V. 2010. Shaft location selection at deep multiple orebody deposit by suing fuzzy TOPSIS method and network optimisation. *Expert Systems with Application* 37, pp. 1408-1418,

Goode, W. and Halt, P. 1952. *Methods in Social Science Research*. New York: McGaw Hill

Greenhut, M.L. 1956. *Plant Location in Theory and in Practice*, University of North Carolina Press, Chapel Hill.

Guba, E. and Lincoln, Y. S. 1989. *Fourth Generation evaluation*. Newbury Park: Sage.

Guimaraes Pereira, A., Munda, G., and Paruccini, M. 1994 Generating alternatives for siting retail and service facilities using genetic algorithms and multi-criteria decision techniques. *Journal of Retail Consumer Services* 1(2), pp. 40-47.

Gumus. T. 2009. Evaluation of hazardous waste transportation firms by using a two step fuzzy-AHP and TOPSIS methodology. *Expert Systems with Applications*36, pp. 4067-4074.

Guo, L.S. and He, Y.S. 1999. Integrated multi-criteria decision model: a case study for the allocation of facilities in Chinese agriculture. *Journal of Agriculture Engineering Research* 73, pp. 87-94.

Gustavsson, L. 2003. Humanitarian logistics – context and challenges. *Forced Migration Review* 18, pp. 6-8.

Haas, J.E., Kates, R.W. and Bowden, M. 1977. *Reconstruction Following Disaster*, Cambridge: MIT Press.

Haghani, A. 1996. Capacitated maximum covering location models: Formulations and solution procedures. *Journal of Advanced Transportation* 30(3), pp. 101-136.

Haghani, A. and Oh, S.C. 1996. Formulation and solution of a multi-commodity, multi-modal network flow model for disaster relief operations. *Transport Research Part A-Policy and Practice* 30(3), pp. 231-250.

Hale, T.S. and Moberg, C.R. 2003. Location science research: A review. *Annals of Operational Research* 123, pp. 21-35.

Hale, T.S. and Moberg, C.R. 2005. Improving supply chain disaster preparedness – A decision process for secure site location. *Distribution and Logistics Management* 35(3), pp. 195 – 207.

Harker, P.T. and Vargas, L.G. 1987. The theory of ratio scale estimation: Saaty's Analytic Hierarchy Process. *Management Science* 33(11), pp 1383-1403.

Hegde, G.G. and Tadikamalla, R. (1990), "Site selection for a 'sure service terminal'", *European Journal of Operational Research*, Vol. 48, Issue. 1, pp. 77 – 80.

Herrera, F., Lopez, E., Mendena, C. and Rodriguez, M.A. 2001. A linguistic decision model for personnel management solved with a linguistic biobjective genetic algorithm. *Fuzzy Sets and Systems* 118, pp. 47-64.

Herrera, F. and Martinez, L. 2000. A 2-tuple fuzzy linguistic representation model for computing with words. *IEEE Transactions on Fuzzy Systems* 8, pp. 746-752.

Ho, W. 2008. Integrated analytic hierarchy process and its applications – A literature review. *European Journal of Operational Research* 186(1), pp. 211-228.

Ho, W., Dey, P.K., and Higson, H.E. 2006. Multiple criteria decision making techniques in higher education. *International Journal of Educational Management* 20(5), pp. 319-337.

Holguin-Veras, J., Perez, N., Ukkusuri, S., Wachtendorf, T., and Brown, B. 2007. Emergency logistics issue affecting the response to Katrina. *Transportation Research Record: Journal of the Transportation Research Board* 2022, pp. 76-82.

Hoover, E.M. 1948. *The Location of Economic Activity*. New York: McGraw-Hill.

Hsieh, L.F., Chin, J.B., and Wu, M.C. 2006. Performance evaluation for university electronic libraries in Taiwan. *The Electronic library* 24(2), pp. 212-224.

HRN (Humanitarian Response Network) 2006. *Comparative Analysis of Potential sites in SE-Asia – ELRF* [online, cited at 2012 May 16], Available from URL: http://www.unhrn.org/locations/asia/elrf_compare

Hughes, J. A. and Sharrock, W. W. 1997. *The philosophy of social research*. 3rd ed. London; New York: Longman.

Hussein, F.M., Obeid, M.A. and El-Malahy, K.S. 1987. Site selection of a dual purpose nuclear power plant in Saudi Arabia. *Nuclear Technology* 79, pp. 311-321.

Hwang, C. and Lin, M. 1987. *Group Decision Making Under Multiple Objective Methods and Applications*. Berlin: Springer-Verlag.

Hwang, C.L. and Masud, S.A.M. 1979. *Multiple Objective Decision making – Methods and Applications: A State-of-the-art survey*. New York: Springer.

Hwang, C.L. and Yoon, K. 1981., *Multiple Attribute Decision Making Methods and Applications: A State of the Art Survey*. New York: Springer.

Hwang, H.S. 1999. A food distribution model for famine relief.*Computers & Industrial Engineering* 37(½), pp. 335-338.

Iakovou, E., Ip, C.M., Douligeris, C., and Korde, A. 1997. Optimal location and capacity of emergency cleanup equipment for oil spill response. *European Journal of Operational Research* 96(1), pp. 72-80.

IOM (International Organisation for Migration) 2004. *Proposal for the Provision of Humanitarian Assistance*. [online, cited at 2012 June 10], Available from URL: http://www.swissbankclaims.com /pdfs_eng/InternationalOrganizationForMigrationProposal(C_ENG0076098).pdf.

Jahanshahloo, G.R., Lotfi, F.H., and Izadikah, M. 2006. Extension of the TOPSIS method for decision-making problems with fuzzy data. *Applied Mathematics and Computation* 181, pp. 1544-1551.

Jahre, M. and Heigh, I. 2008. Does the current constraints in funing promote failure in humanitarian supply chains?. *Supply Chain Forum: An International Journal* 9(2), pp. 44-54.

Janic, M. 2003. Multicriteria evaluation of high-spped rail, transrapid maglev, and air passenger transport in Europe. *Transporation Planning Technology*, pp. 491-512.

Javaheri, H., Nasrabadi, T., Jafarian, M.H., Rowshan, G.R. and khoshnam, H. 2006. Site selection of municipal solid waste landfills using analytical hierarchy process method in a geographical information technology environment in Giroft. *Iranian Journal of Environment Health Science Engineering* 3(3), pp. 177-184.

Jennings E., Beresford, A.K.C. and Banomyong, R. 2000. Emergency relief logistics: a disaster response model. *Occasional Paper*. No. 64, Cardiff University.

Jia, H., Ordonex, F. and Dessouky, M.M. 2007. Solution approaches for facility location of medical supplies for large-scale emergencies. *Computers and Industrial Engineering* 52(2), pp. 257-276.

Jick, T. 1979. Mixing qualitative and quantitative methods: Triangulation in action. *Administrative Science Quarterly* 24(4), pp. 602-611.

Johnson, C. F. 1996. Deductive versus inductive reasoning: A closer look at economics. *The Social Science Journal* 33(3), pp. 287-299.

Johnstone, D.P., Hill, R.R. and Moore, J.T. 2004. Mathematically modelling munitions prepositioning and movement. *Mathematical and Computer Modelling* 39(6 – 8), pp. 759 – 772.

Joshi, R., Banwet, D.K., and Shankar, R. 2011. A Delphi-AHP-TOPSIS based benchmarking framework for performance improvement of a cold chain. *Expert Systems with Applications* doi:10.1016/j.eswa.2011.02.072.

Kaatrud, D.B., Samii, R. and Van Wassenhove, L.N. 2003. UN Joint Logistics Centre: A coordinated response to common humanitarian logistics concerns. *Forced Migration Review* 18, pp. 11-14.

Kaboli, A., Arqanezhad, M.B. and Shahanaghi, K. 2007. A holistic approach based on MCDM for solving location problems. *International Journal of Engineering Transactions A; Basics* 20(3), pp. 252-262.

Kahraman, C., Cebi, S., and Tuysuz, F. 2010. Fuzzy location selection techniques. *Studies in Fuzziness and Soft Computing* 252, pp. 329-358.

Kahraman, C., Rhan, D. and Doganel. 2003. Fuzzy group decision-making for facility location selection. *Information Sciences* 157, pp. 135-153.

Karimi, M.S., Yusop, Z., and Law, S.H. 2010. Location decision for foreign direct investment in ASEAN countries: A TOPSIS approach. *International Research Journal of Finance and Economics* 36, pp. 196-207.

Karsak, E.E. 2002. Distance-based fuzzy MCDM approach for evaluating flexible manufacturing system alternatives. *International Journal of Production Research* 40(13), pp. 3167-3181.

Kashani, R.B. 1989. A new method for site suitability analysis: the analytic hierarchy process. *Environmental Management* 13(6), pp. 685-693.

Kathawala, Y. and Gholamnezhad, H. 1987. New approach to facility location decisions. *International Journal of Systems Science* 18, pp. 389-402.

Kaufmann, A. and Gupta, M.M. 1985. *Introduction to fuzzy arithmetic: Theory and applications*, New York: von Nostrand Reinhold.

Kayikci, Y. 2010. A conceptual model for intermodal freight logistics centre location decisions. *Procedia Social and Behavioural Sciences* 2, pp. 6296-6311.

Keeney, R.L. and Raiffa, H. 1976. *Decisions with Multiple Objectives: Preferences and Value Tradeoffs.* New York: John Wiley and Sons.

Kelemenis, A. and Askounis, D. 2010. A new TOPSIS-based multi-criteria approach to personnel selection. *Expert System with Applications* 37, pp. 4999-5008.

Kengpol, A. 2004. Design of a decision support system to evaluate the investment in a new distribution centre. *International Journal of Production Economics* 90, pp. 59-70.

Kim, G., Park, C.S., and Yoon, K.P. 1997. Identifying investment opportunities for advanced manufacturing system with comparative-integrated performance measurement. *International Journal of Production Economics* 50, pp. 23-33.

Kim, S.H. and Ahn, B.S. 1997. Group decision making procedure considering preference strength under incomplete information. Computers and Operations Research, Vol. 24, 1101-1112.

Kinara, A. and Kotzab, H. 2008. A macro-institutional perspective on supply chain environmental complexity. *International Journal of Production Economics* 115, pp. 283-295.

King, J.E. 1991. *War reserve materiel pre-positioning. Its history, its significance, and its future*. MS Thesis, School of Systems and Logistics, Air Force Institute of Technology, Wright-Patterson AFB, OH.

Klincewicz, J.G. 1985. A large-scale distribution and location model. *AT&T Technical Journal* 64, pp. 1705-1730.

Klose, A. 1999. LP-based heuristic for two-stage capacitated facility location problem. *Journal of the Operational Research Society* 50(2), pp. 157-166.

Klir, G.J., Clari, U.H. and Yuan, B. 1997. *Fuzzy Set Theory: Foundations and Applications.* NJ: Prentice Hall

Knott, R. 1987. The logistics of bulk relief supplies. *Disasters* 11, pp. 113-115.

Knott, R. 1988. Vehicle scheduling for emergency relief management: A knowledge-based approach. *Disasters* 12, p. 285-293.

Kornhauser, A. and Lazarsfeld, P. F. 1955. The analysis of consumer actions. In: Lazarsfeld, P.F. and Rosenberg, M. eds. *The Language of Social Research*. Glencoe, IL: Free Press.

Kontos, T.D., Komilis, D.R. and Halvadakis, C.P. 2003 Siting MSW landfills on Lesvos island with a GIS-based methodology. *Waste Management and Research* 21(3), pp. 262-277.

Korpela, J. and Tuominen, M. 1996. A decision aid in warehouse site selection. *International Journal of Production Economics* 45, pp. 169-180.

Kovács, G. and Spens K.M. 2007. Humanitarian logistics in disaster relief operations. *International Journal of Distribution and Logistics Management* 37(2), pp. 99-114.

Kovács, G. and Spens, K.M. 2009. Identifying challenges in humanitarian logistics. *International Journal of Physical Distribution and Logistics Management* 39(6), pp. 506-528.

Kucas, A. 2010. Location prioritisation by means of multicriteria spatial decision-support systems: A case study of forest fragmentation-based ranking of forest administrative areas. *Journal of Environmental Engineering and Landscape Management* 18(4), pp. 312-320.

Kulak, O., Durmusoglu, B. and Kahraman, C. 2005. Fuzzy multi-attribute equipment selection based on information axiom. *Journal of Materials Processing Technology* 169, pp. 337-345.

Kuo, M.S. 2011. Optimal location selection for an international distribution centre by suing a new hybrid method. *Expert Systems with Applications.* pp. 7208-7221.

Kuo, M.S. and Liang, G.S. 2011. A novel hybrid decision-making model for selecting locations in a fuzzy environment. *Mathematical and Computer Modelling* 54, pp. 88-104.

Kuo, M.S., Tzeng, G.H., and Huang, W.C. 2007. Group decision-making based on concepts of ideal and anti-ideal points in a fuzzy environment. *Mathematical and Computer Modelling* 45, pp. 324-339.

Kuo, R.J. Chi, S.C, and Kao, S.S. 1999. A decision support system for locating convenience store through fuzzy AHP. *Computers and Industrial Engineering* 37, pp. 323-326.

Kuo, R.J., Chi, S.C. and Kao, S.S. 2002. A decision support system for selecting convenience store location through integration of fuzzy AHP and artificial neural network. *Computers in Industry* 47, pp. 199 – 214.

Lahdelma, R., Salminen, P. and Hokkanen, J. 2002. Locating a waste treatment facility by using stochastic multicriteria acceptability analysis with ordinal criteria. *European Journal of Operational Research* 142, pp. 345-356.

Lai, S.K. 1995. A preference-based interpretation of AHP. *Omega* 23(4), pp. 453-462.

Lee, H.I. Chen, H.H. and Kang, H.Y. 2009. Multi-criteria decision making on strategic of wind farms. *Renewable Energy* 34, pp. 120-126.

Lee, H.W. and Zbinden, M. 2003. Marrying logistics and technology for effective relief. *Forced Migration Review* 18, pp. 34-35.

Leonard, D 2005. The only lifeline was the Wal-Mart. *Fortune* 52(7), pp. 74-78.

Levine, T.M. 1991. How site seekers rate communities. *Plant Location.* pp. 6-10.

Li, Y., Liu, X., and Chen, Y. 2011. Selection of logistics centre location using Axiomatic fuzzy set and TOPSIS methodology in logistics management." *Expert Systems with Application.* doi:10.1016/j.ewa.2010.12.161.

Liang, G.S. 1999. Fuzzy MCDM based on ideal and anti-ideal concepts. *European Journal of Operational Research* 112(3), pp. 682-691.

Liang, G.S. and Wang, M.J.J. 1991. A fuzzy multi-criteria decision-making method for facility site selection. *International Journal of Production Research* 29 pp. 2313 – 2330.

Liao, Y. 2009. Evaluation method for the location selection of railway passenger station based on triangular fuzzy number. *Zhongguo Tiedao Kexue/China Railway Science* 30(6), pp. 119-125.

Lin, C.T. and Tsai, M.C. 2010a. Location choice for direct foreign investment in new hospitals in China by using ANP and TOPSIS. *Qualitative and Quantitative* 44, pp. 375-390.

Lin, C.T. and Tsai, M.C. 2010b. Evaluating the optimal city in South China for new medical facilities: The application modified porter's diamond framework. *Journal of Testing and Evaluation* 38(4).

Lin, M.C., Wang, C.C., Chen, M.S. and Chang, C.A. 2008. Using AHP and TOPSIS approaches in customer-driven product design process. *Computers in Industry* 59, pp. 17-31.

Lirn, T.C., Thanopoulou, H.A., Beynon, M.J. and Beresford, A.K.C. 2004. An application of AHP on transhipment port selection: A global perspective. *Maritime Economics and Logistics* 6, pp. 70-91.

Lodree, E.J. and Taskin, S. 2008a. An insurance risk management framework for disaster relief and supply chain disruption inventory planning. *Journal of the Operational Research Society* 59(5), pp. 674-684.

Long, D. 1997. Logistics for disaster relief. *IIE Solutions* 29(6), pp. 26-29.

Long, D.C. and Wood, D.F. 1995. The logistics of famine relief. *Journal of Business Logistics* 16(1), pp. 213-229.

Longo, V. 2005. Reinforcing the front line. *Transmissions and Distribution World.* pp. 44-52.

Ludema, M.W. 2000. Military and civil logistic support of humanitarian relief operations. in Arnold, E. and Walden, D. (Eds), *A Decade of Progress – A New Century of Opportunity, Proceedings of the 10th Annual International Symposium of the International Council on Systems Engineering, INCOSA, Minneapolis, MN, pp. 143-150.*

Magee, J.F., Copacino, W.C. and Rosenfield, D.B. 1985. *Modern Logistics Management.* New York: Wiley.

Malczewski, J. and Moreno-Sacnhez, L.A. 2000. Multicrieria group decision-making model for environmental conflict analysis in the Cape Region Mexico. *Journal of Environmental Planning and Management* 40(3), pp. 349-374.

Mangan, J., Lalwani, C. and Gardner, B. 2004. Combining quantitative and qualitative methodologies in logistics research. *International Journal of Physical Distribution & Logistics Management* 34(7), pp. 565-578.

Marianov, V. and ReVelle, C. 1995. Siting emergency services. In *Facility Location: A Survey of Applications and Methods.* edited by Z. Drezner, Springer-Verlag Inc : New York, pp. 199 – 223

May, T. 1993. *Social research: issues, methods, and process*. Buckingham, England: Open University Press.

Maylor, H. and Blackmon, K. 2005. *Researching business and management*. Basingstoke; New York: Palgrave Macmillan.

McDaniel, C. and Gates, R. 1999. *Contemporary marketing research*. 4th ed. Cincinnati: South-Western College Publishing.

Mete, H.O. and Zabinsky, Z.B. 2010. Stochastic optimisation of medical supply location and distribution in disaster management. *International Journal of Production Economics*126(1), pp. 76-84.

Mentzer, J. T. and Kahn, K. B. 1995. A framework of logistics research. *Journal of Business Logistics* 16(1), pp. 231-250.

Milani, A.S., Shanjan, A. and Madoliat, R. 2005. The effect of normalisation norms in multiple attribute decision making models: A case study in gear material selection. *Structural Multidisciplinary Optimisation*, pp. 312 – 318.

Miller, G.A. 1965. The magic number seven, plus or minus two. *Psychological Review* 63, pp. 81-97.

Miller, T. 1993. Learning about facility location models. *Distribution* 92(5), pp. 47-50.

Min, H. 1994. Location planning of airport facilities using the Analytic Hierarchy Process. *Logistics and Transportation Review* 30(1), pp. 79-94.

Min, H. and Melachrinoudis, E. 1999. The relocation of a hybrid manufacturing/distribution facility from supply chain perspectives: a case study. *Omega: International Journal of Management Science* 27, pp. 75-85.

MoD (Ministry of Defence) 2002. *Humanitarian/Disaster Relief Operations*. Joint Warfare Publication.

MoD (Ministry of Defence) 2003. *Peace Support Operations*. Joint Warfare Publication.

Moeinaddini, M., Khorasani, N., Danehkar, A., Darvishsefat, A.A. and Zienalyan, M. 2010. Siting MSW landfill using weighted linear combination and analytical hierarchy process (AHP) methodology in GIS environment (case study: Karaj). *Waste Management* 30, pp. 912-920.

Mohajeri, N. and Amin, G.R. 2010. Railway station site selection using analytical hierarchy process and data envelopment analysis. *Computers and Industrial Engineering* 59, pp. 107-114.

Moon, J.H. and Kang, C.S. 2001. Application of Fuzzy Decision Making Method to the Evaluation of Spent Fuel Storage Options. *Progress in Nuclear Energy* 39, pp. 534-351.

Moshen, S., Mohammad, A., Reza, K. and Mohammad, K. 2010. Mineral processing plant location using the analytic hierarchy process – a case study: the Sangan iron ore mine (phase 1). *Mining Science and Technology* 20, pp. 691-695.

Mummolo, G. 1996. An analytic hierarchy process model for landfill site selection. *Journal Environmental Systems* 24(4), pp. 445-465.

Murali, P., Ordonez, F. and Dessouky, M.M. 2009. Capacitated facility location with distance dependent coverage under demand uncertainty. *Special Issue of Networks and Spatial Economics on Facility Location.*

Murray, S. 2005. How to deliver on the promises supply chain logistics: Huamanitarian agencies are learning lessons from business in brining essential supplies to regions hit by the Tsunami. *Financial Times*, January 7, pp. 9.

Nachmias, C. and Nachmias, D. 1996. *Research Methods in the Social Sciences*, 5th ed. UK: Arnold, St. Martin's Press.

Naghedehi, M.Z., Mikaeil, R., and Ataei, M. 2009. The application of fuzzy analytic hierarchy process (FAHP) approach to selection of optimum underground mining method for Jajarm Bauxite Mine, Iran. *Expert Systems with Applications*36, pp. 8218-8226.

Narasimhan, R. 1979. A fuzzy subset characterisation of a site-selection problem. *Decision Sciences* 10, pp. 618-628.

Narasimhan, R. 1983. An analytical approach to supplier selection. *Journal of Purchasing and Materials Management* 19(1), pp. 27-32.

Näslund, D. 2002. Logistics needs qualitative research–especially action research. *International Journal of Physical Distribution & Logistics Management* 32(5), pp. 321-338.

Negi, D.S. 1989. *Fuzzy Analysis and Optimisation*, Ph. D. Thesis, Department of Industrial Engineering, Kansas State University.

Nettleton, H. and Taylor, K. 1990. *Sociology for Pharmacists,* London: Macmillan Academic and Professional Ltd.

Neuman, L. 1997. *Social Research Methods: Qualitative and Quantitative Approaches,* 3th ed. USA: Allyn and Bacon.

Nisha de Silva, F. 2001. Providing special decision support for evacuation planning: A challenge in integrating technologies. *Disaster Prevention and Management* 10(1), pp. 11.

Norese, M.F. 2006. ELECTRE III as a support for participatory deicion-making on the localisation of waste-treatment plants. *Land Use Policy* 23, pp. 76-85.

Oh, S.C. and Haghani, A. 1997. Testing and evaluation of a multi-commodity multi-modal network flow model for disaster felief management. *Journal of Advanced Transport* 31(3), pp. 249-282.

Ölçer, A.I. and Odabasi, A.Y. 2005. A new fuzzy multiple attributive group decision making methodology and tis application to population/manoeuvring system selection problem. *European Journal of Operational Research* 166(1), pp. 93-114.

Oliver, R.K. and Webber, M.D. 1992. Supply chain management: Logistics catches up with strategy. In: Christopher, M. *Logistics: The Strategic Issues.* London: Chapmen and Hall, pp. 63-75.

Oloruntoba, R. and Gray, R. 2006. Humanitarian aid: an agile supply chain?. *Supply Chain Management* 11(2), pp. 115-120.

Önut, S., Efendigil, T., and Kara, S.S. 2010. A combined fuzzy MCDM approach for selecting shopping centre site: An example from Istanbul, Turkey. *Expert Systems with Applications* 37, pp. 1937-1980.

Önut, S. and Soner, S. 2007. Transhipment site election using the AHP and TOPSIS approaches under fuzzy environment. *Waste Management* 28(9), pp. 1552-1559.

Owen, S.H. and Daskin, M.S. 1998. Strategic facility location: A review. *European Journal of Operational Research* 111, pp. 423-447.

Özcan, T., Celebi, N. and Esnaf, S. 2011. Comparative analysis of multi-criteria decision making methodologies an implementation of a warehouse location selection problem. *Expert Systems with Applications* 38, pp. 9773-9779.

Özdamar, L., Ekinci, E. and Küçükyazici, B. 2004. Emergency logistics planning in natural disasters. *Annual Operational Research* 129(1-4), pp. 217-245.

PAHO (Pan American Health Organisation) 2001. *Humanitarian Supply Management in Logistics in the Health Sector*. [online; cited 2010 March 5], Available from URL: http://www.paho.org/English/PED/Humanitarian Supply-part1.pdf).

Pano, R. 1994. Pull out the stops in your network. *Transportation and Distribution* 35(8), pp. 38-39.

Pardee, E.S. 1969. *Measurement and Evaluation of Transportation System Effectiveness*, RAND Memorandum RM-5869-DOT

Park, C. 1991. *Environmental Hazards*, Cheltenham: Thomas Nelson.

Parkan, C. and Wu, M. 1999. Decision-making and performance measurement 553 models with application to robot selection. *Computers and Insdustrial 554 Engineering* 36(3), pp. 503-523.

Partovi, F.Y. 2006. An analytic model for locating facilities strategically. *International Journal of Management Science* 34, pp. 41-55.

Peirce, C. S. 1931. In: Hartshorne, C. and Weiss, P. eds. *Collected papers of Charles Sanders Peirce: Principles of philosophy*. Vol. 1. Cambridge, MA: Harvard University Press.

Pettit, S.J. and Beresford, A.K.C. 2006. Emergency relief logistics: an evaluation of military, non-military, and composite response models. *International Journal of Logistics: Research and Applications* 8(4), pp. 313 – 31.

Psaraftis, H.N., Tahrakan, G.G. and Ceder, A. 1986. Optimal response to oil spills: the strategic decision case. *Operational Research* 34(2), pp. 203-217.

Ramanathan, R. and Ganesh, L.S. 1995. Energy resource allocation incorporating qualitative and quantitative criteria: An integrated model using goal programming and AHP. *Socio-Economic Planning Science* 29(3), pp. 197-218.

Ramsbottom, O. and Woodhouse, T. 1996. *Humanitarian Intervention in Contemporary Conflict*, Cambridge: Polity Press.

Rangone, A. 1996. An Analytical Hierarchy Process framework for comparing the overall performance of manufacturing departments. *International Journal of Operations and Production Management* 16(8), pp. 104.

Rathi, A.K., Church, R.L. Solanki 1993. Allocating resources to support a multicommodity flow tih time windows. *Logistics and Transportation Review* 28, pp. 167-188.

Rawls, C.G and Turnquist, M.A. 2010. Pre-positioning of emergency supplies for disaster response. *Transportation Research Part B* 44, pp. 521-534.

ReVelle, C., Bigman, D., Schilling, D., Cohon, J. and Church R. 1977. Facility location: A review of context-free and EMS models. *Health Services Research* 12(2), pp. 129-146.

Robson, C. 2002. *Real world research*. 2nd ed. Oxford: Blackwell.

Roh, S. 2007. *Humanitarian Aid Logistics: Humanitarian Response Depot Network*.MSc Thesis, Business School, Cardiff University.

Roy, B. *Multi-Criteria Methodology for Decision Aiding*, Kluwer Dordrecht, 1985.

Rubin, H. J. and Rubin, I. S. 2005. *Qualitative interviewing: the art of hearing data*. Thousan Oaks, Calif; London: Sage publications.

Saaty, T.L. 1980. *Fundamentals of Decision Making and Priority-Theory with the Analytic Hierarchy Process*. Pittsburgh: RWS Publications.

Saaty, T.L. 1988. *Multicriteria Decision Making: The Analytic Hierarchy Process*. RWS Publications, Pittsburgh, PA.

Saaty, T.L. 1989. Decision-making, scaling, and number crunching. *Decision Sciences*. 20, pp. 404-409.

Saaty, T.L. 1994a. How to make a decision: the analytic hierarchy process. *Interfaces* 24(6), pp. 19-43.

Saaty, T.L. 1994b. Highlights and critical points in the theory and applications of the analytic hierarchy process. *European Journal of Operational Research* 74, pp. 426 – 447.

Saaty, T.L. and Kearns, K.P. 1985. *Analytical Planning: The Organisation of Systems*. Oxford, UK: Pergamon Press.

Saaty, T.L. and Ozdemir, M.S. 2004. Why the magic number seven plus or minus two. *Mathematical and Computer Modelling* 39(11-12), pp. 1397-1425.

Saccommano, F.F. and Allen, B. 1998. Locating emergency response capability for dangerous goods incidents on a road network. *Transportation Research Record* 1193, pp. 1-9.

Safari, M., Kakaei, R., Ataei, M., and Karamoozian, M. 2010. Using fuzzy TOPSIS method for mineral processing plant site selection – Case study: Sangan iron ore mine (phase 2). *Arabian Journal of Geosciences* pp. 1 – 9.

Safran, P. 2003. A strategic approach for disaster and emergency assistance. *Contribution to the 5th Asian Disaster Reduction Centre International Meeting and the 2nd UN-ISDR Asian Meeting*, 15 – 17 Jan, 2003, Kobe, Japan [online, cited at 2010 Jan 25]. Available from URL: http://www.adb.org./Doucments/Policies/Disaster_Emergency/disaster_emergency.pdf.

Salisbury, D. 2007. Personal Interviewed, (2 April 2004) *In:* Balcik, B. and Beamon, B.M (2008), Facility location in humanitarian relief. *International Journal of Logistics: Research and Application* 11(2), pp. 101-121.

Sarkis, J. and Sundarraj, R.P. 2002. Hub location at Digital Equipment Corporation: A comprehensive analysis of qualitative and quantitative factors. *European Journal of Operational Research* 137, pp. 336-347.

Sathe, A. and Miller-Hooks, E. 2005. Optimising location and relocation of response units in guarding critical facilities. *Transportation Research Record* 1923, pp. 127-136.

Saunders, M., Lewis, P. and Thornhill, A. 2000. *Research Methods for Business Students*. 2nd ed. Harlow: Financial Times/Prentice Hall.

Schary, P.B. 1984. *Logistcs Decisions: Text and Cases*. Chicago: The Dryden Press.

Schmenner, R.W. 1982. *Making Business Location Decisions*. NJ: Prentice-Hall.

Schilling, D.A., Elzinga, D.J., Cohon, J., Church, R. and ReVelle, C. 1979. The TEAM/FLEET models for simultaneous facility and equipment siting. *Transportation Science* 13(2), pp. 163-175.

Scott-Bowden, P. 2003. The World Food Programme: Augmenting logistics. *Forced Migration Review* 18, pp. 17-19.

Seaman, J. 1999. Malnutrition in emergencies: how can we do better and where do the responsibilies lie?. *Disasters* 23(4), pp. 306-315.

Sen, P., Tan, J.K.G., and Spencer, D. 1999. An integrated probabilistic risk analysis decision support methodology for systems with multiple state variables. *Reliability Engineering and Systems Safety* 64, pp. 73-87.

Sener, B., Suzen, M.L. and Doyuran, V. 2006. Landfill site selection by using geographic information systems. *Environmental Geology* 49, pp. 376-388.

Sener, S., Sener, E., Nas, B. and Karaguzel, R. 2010. Combining AHP with GIS for landfill site selection: A caste study in the Lake Beysehir catchment area (Konya, Turkey). *Waste Management* 30, pp. 2037-2046.

Sener, S., Sener, E. and Karaguzel, R. 2011. Solid waste disposal site selection with GIS and AHP methodology: a case study in Senirkent – Uluborlu (Isparta) Basin, Turkey. *Environment Monitoring Assessment* 173, pp. 533 – 554.

Sentlinger, B.K. 2000. *Optimal positioning of naval precision guided munitions.*Master's Thesis in Operations Research, Naval Postgraduate School.

Shen, C.Y and Yu, K.T. 2009. A generalised fuzzy approach for strategic problems: the empirical study on facility location selection of authors' management consultation client as an example. *Expert System with Application* 36, pp. 4709-4716.

Sheu, J.B. 2007. An emergency logistics distribution approach for quick response to urgent relief demand in disasters. *Transportation Research Part E: Logistics and Transportation Review* 43(6), pp. 687-709.

Shih, H.S., Shyur, H.J., and Stanley Lee, E. 2007. An extension of TOPSIS for group decision making. *Mathematical and Computer Modelling* 45, pp. 801-813.

Shipley, M.F., Korvin, D.K., and Obit, R. 1991. A decision making model for multi-attribute problems incorporating uncertainty and bias measures. *Computers and Operations Research* 18, pp. 335-342.

Shyur, H.J. .2006 COSTS evaluation using modified TOPSIS and ANP. *Applied Mathematics and Computation* 177, pp. 251-259.

Shyur, H.J. and Shih, H.S. 2006. A hybrid MCDM model for strategic vendor selection. *Mathematical and Computer Modelling* 44, pp. 749-761.

Siddiqui, M., Everett, J.M. and Vieux, B.E. 1996, Landfill siting using geographical information systems: a demonstration, *Journal of Environmental Engineering* 122(6), pp. 515-523.

Sinuany-Stern, Z., Mehrez, A., Tal, A.G. and Shemuel, B. 1995. The location of a hospital in a rural region: The case of the Negev. *Location Science* 3(4), pp. 255-266.

Silverman, D. 2006. *Interpreting qualitative data: Methods for analysing talk, text and interaction*. 3rd ed. London; Thousand Oaks, CA: Sage publications.

Song, Y.Y., Maher, T.E., Nicholson, J.D. and Gurney, N.P 2000. Strategic alliances in logistics outsourcing. *Asia Pacific Journal of Marketing and Logistics* 12(4), pp. 3-21.

Soon, S.V. 2007. *A two-stage scenario-based stochastic programming approach to pre-positioning hurricane supplies*. Master's thesis, Aubrun University, Department of Industrial and Systems Engineering.

Spens, K. M. and Kovács, G. 2006. A content analysis of research approaches in logistics research. *International Journal of Physical Distribution & Logistics Management* 36(5), pp. 374-390.

Srdjevic, B., Medeiros, Y.D.P. and Faria, A.S. 2004. An objective multi-critiera evaluation of water management scenarios. *Water Resource Management*, pp. 35-54.

Stevenson, W.J. 1993. *Production/Operations Management*, Irwin, USA.

Stock, J. R., Boyer, S. L. and Harmon, T. 2010. Research opportunities in supply chain management. *Journal of the Academy of Marketing Science* 38(1), pp. 32-41.

Stock, J.R. and Lambert, D.M. 1987. *Strategic Logistics Management.* Richard D. Irwin, Homewood, IL.

Strash, R. 2004. Personal Interviewed, (2 April 2004) *In:* Balcik, B. and Beamon, B.M (2008), "Facility location in humanitarian relief", *International Journal of Logistics: Research and Application* 11(2), pp. 101-121.

Suarez-Vega, R., Santos-Penate, D.R., Dorta-Ganzalez, P. and Rodriguez-Diaz, M. 2011. A multi-criteria GIS based procedure to solve a network competitive location problem. *Applied Geography* 31, pp. 282-291.

Sullivan, L. 2005. Logistics plans pay off", *Information Week* 1055, pp. 36.

Szidarovszky, F., Gershon, M.E., and Duchstein, L. 1986. *Techniques for Multi-objective Decision making in Systems Management*, Amsterdam: Elsevier Science Publishers B.V.

Tabari, M., Kaboli, A., Aryanezhad, M.B., Shahanaghi, K., and Siadat, A. 2008. A new method for location selection: a hybrid analysis. *Application of Mathematical Computing* 206, pp. 598-606.

Taskin, S. and Lodree, E.J. 2010. Inventory decisions for emergency supplies based on hurricane count predictions. *International Journal of Production Economics* 126(1), pp. 66-75.

Tatham, P. and Kovács, G. 2007. An initial investigation into the application of the military sea-basing concept to the provision immediate relief in a rapid onset disaster. POMS 18th Annual Conference, Dallas Texas, USA, May 4 – May 7, 2007.

Taylor, S. S., Fisher, D. and Dufresne, R. L. 2002. The aesthetics of management storytelling: a key to organisational learning. *Management Learning* 33(3), pp. 313-330.

Thomas, A.S. 2002. Supply chain reliability for contingency operations. *Proceedings of the Annual Reliability and Maintainability Symposium*, pp. 61 – 67.

Thomas, A.S. 2003. Why Logistics?. *Forced Migration Review* 18, pp. 4.

Thomas, A. and Kopczak, L. 2005. *From logistics to supply chain management. The path forward in the humanitarian sector*. Fritz Institute.

Thomas, A.S. 2007. Humanitarian logistics: Enabling Disaster Response. [online, cited at: 2009 July 12]. Available form URL: http://www.fritzinstitute.org/PDFs/WhitePaper/EnablingDisaster Response.pdf.

Tomasini R.M. and Van Wassenhove, L.N. 2009. *Humanitarian Logistics*. London: Palgrave, Macmilan.

Torfi, F., Farahani, R.Z., and Rezapour, S. 2010. Fuzzy AHP to determine the relative weights of evaluation criteria and Fuzzy TOPSIS to rank the alternatives. *Applied Soft Computing* 10, pp. 520-528.

Towill, D.R. 1997. The seamless supply chain – The predator's strategic advantage. *International Journal of Technology Management* 131, pp. 37-56.

Triantaphyllou, E.V. 2000. *Multi-Criteria Decision-Making Methods: A Comparative Study,* Kluwer Academic Publishers.

Trunick, P.A. 2005. Tsunami aftermath: how to make good logistics better. *Logistics Today* 46(4), pp. 12.

Tseng, C.T., Chen, S.C., Huang, C.S. and Liu, C.C. 2001 GIS-assisted site selection for artificial reefs. *Fisheries Science* 67, pp. 1015-1022.

Turetkan, O. 2008. Is your back-up IT infrastructure in a safe location – a multi-criteria approach to location analysis for business continuity facilities. *Information System Frontier* 10, pp. 375-383.

Tuzkaya, G., Önut, S., Tuzkaya, U.R. and Gülsün, B. 2008. An analytic network process approach for locating undesirable facilities: an example from Istanbul, Turkey. *Journal of Environmental Management* 88, pp. 970-983.

Tzeng, G.H., Cheng, H.J. and Huang, T.D. 2007. Multi-objective optimal planning for designing relief delivery systems. *Transportation Research Part E* 43(6), pp. 673-686.

Tzeng, G.H. and Lin J.J. 1996. Using backup coverage and TOPSIS fuzzy approach to emergency facilities layout in new development planning area. *Proceedings of the Asian Fuzzy Systems Symposium* pp. 109-114.

Tzeng, G.H., Teng, M.H., Chen, J.J. and Opricovic, S. 2002. Multicriteria selection for a restaurant location in Taipei. *International Journal of Hospitality Management* 21, pp. 171-87.

Uddin, S. and Hossain, L. 2011. Disaster coordination preparedness of soft-target organisations. *Disaster* 35(3), pp. 623-638.

Ugboma, C., Ugboma, O. and Ogwude, I. 2006. An analytic Hierarchy Process (AHP) approach to Port selection decisions – empirical evidence from Nigerian Ports. *Maritime Economics & Logistics* 8, pp. 251-266.

Ukkusuri, S.V. and Yushimoto, W.F. 2008. Location routing approach for the humanitarian prepositioning problem. *Transportation Research Record: Journal of the Transportation Research Record* 2089, pp. 18-25.

UNDHA (United Nations Department of Humanitarian Affairs) 1994. *Study on Emergency Stockpiles*. [online; cited 2011 October 13], Available from URL: http://releifweblint/ocha_ol/programs/ response/stocknet/StudyE.html#factors.

UNHRD (United Nations Humanitarian Response Depot) 2012. *UNHRD: Humanitarian Response Depot*. [online; cited 2012 May 17], Available online from URL: http://www.hrdlab.eu/.

UNICEF (United Nations International Children's Emergency Fund). 2012. *Humanitarian Action for Children 2012*. [online; cited 2012 July 9], Available from URL: http://www.unicef.org/hac2012 /hac_intro.html

UNOCHA (United Nations Office for the Coordination of Humanitarian Affairs) 2012. *Global Mapping of Emergency Stockpiles*. [Online; cited 2012 August 21], Available from URL: http://www.humanitarianinfo.org/Stockmap/Client/ItemsSearch/Search.aspx?t=97b3 BJPhyITFISFdPeA5YVEmztvIc/yTfQPh75PdHWw=.

Vaidya, O.S. and Kumar, S. 2006. Analytic hierarchy process: An overview of application. *European Journal of Operational Research* 169, pp. 1-29.

Van der Kleij, C.S., Hulscher, S.J.M.H. and Louters, T. 2003. Comparing uncertain alternatives for a possible airport island location in the North Sea. *Ocean and Coastal Management* 46, pp. 1031-1047.

Van Maane, J. 1979. *Qualitative Methodology*. USA: Sage.

Van Wassenhove, L.N. 2006. Humanitarian aid logistics: supply chain management in High Gear. *Journal of Operational Research Soc*, Vol. 57, No. 5, pp. 475 – 489.

Viswanath, K. and Peeta, S. 2003. Multicommodity maximal covering network design problem forp planning critical routes for earthquake response. *Transportation Research Record* 1857, pp. 1-10.

Vitoriano, B., Ortuno, M.T., Tirado, G. and Montero, J. 2011. A multi-criteria optimisation model for humanitarian and distribution. *Journal of Global Optimisation* 51, pp. 189-208.

Von Thunen. 1966. *Von Thunen's Isolated State*.Oxford: Pergamon Press.

Wang, G., Li, Q., Guoxue, L. and Lijun, C. 2009. Landfill site selection using spatial information technologies and AHP: a case study in Beijing, China. *Journal of Environmental Management* 90(8), pp. 2414-2421.

Wang, J.J. and Yang, D.L. 2007. Using a hybrid multi-criteria decision aid method for information systems outsourcing. *Computers and Operation Research* 34, pp. 3691-3700.

Wang, T.C., and Chang, T.H. 2007. Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment. *Expert Systems with Applications* 33, pp. 870-880.

Wang, T.C. and Lee, H.D. 2009. Developing fuzzy TOPSIS approach based on subjective weights and objective weights. *Expert Systems with Applications* 36, pp. 8980-8985.

Wang, Y.M. and Elhag, T.M.S. 2006. Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment. *Expert Systems with Applications* 31, pp. 309-319.

Waugh, D. 2002. *Geography: An Integrated Approach*, Cheltenham: Thomas Nelson.

Weber, A. 1929. *Uber den Standort der Industrien (Alfred Weber's Theory of the Location of Industries)*, University of Chicago.

Weber, S.F. 1993. A modified analytic hierarchy process for automated manufacturing decisions. *Interfaces* 23(4), pp. 75-84.

Whitcom, C.A., Palli, N. and Azarm, S. 1999. A prescriptive production-distribution approach for decision making in new product design. *IEEE Transaction of systems, Man, and Cybernetics – Part C: Applications and Reviews* 29(3), pp. 336-348.

Whitning, M. 2010. The Haiti earthquake January 2010. *Logistics and Transport Focus* 12(4), pp. 26-29.

Whittow, J.B. 1980. *Disasters: The Anatomy of Environmental Hazards*. London: Penguin Books.

Whybark, D.C. 2007. Issues in managing disaster relief inventories. *International Journal of Production Economics* 108(1-2), pp. 228-235.

Wichmann, L. 1999. Many Companies Still Ignoring Supply-chain Risks. *Business Insurance* 37(43), pp. 21.

Widener, M.J. and Horner, M.W. 2010. A hierarchical approach to modelling hurricane disaster relief goods distribution. *Journal of Transport Geography*

Wijkman, A. and Timberlake, L. 1988. *Natural Disasters: Acts of God or Acts of Man?*. Lodon: Earthscan Publications.

Wilhelm, W.E. and Srinivasa, A.V. 1996. A strategic, area-wide contingency planning model for oil spill cleanup oprations with application demonstrated to the Galveston Bay area. *Decision Sciences*, 43(3), pp. 4314-4317.

Williamson, O.E. 1985. *The Economic Institution of Capitalism.* New York: Free Press

WFP (World Food Programme) 2011. *United Nations Humanitarian Response Depot (UNHRD) Network*, internal report

Wu, C.R., Lin, C.T., and Chen, H.C. 2007. Optimal selection of location for Taiwanese hospitals to ensure a competitive advantage by suing the analytic hierarchy process and sensitivity analysis. *Building and Environment* 42, pp. 1431-1444.

Wu, C.S., Lin, C.T. and Lee, C. 2010. Optimal marketing strategy: A decision-making with ANP and TOPSIS. *International Journal of Production Economics* 127, pp. 190-196.

Yahaya, S., Ilori, C., Whanda, S. and Edicha, J. 2010. Landfill site selection for municipal solid waste management using geographic information system and multicriteria evaluation. *American Journal of Scientific Research* 10, pp. 34-49.

Yang, Y. and Chou 2005. Solving a multiresponse simulation-optimisation problem with discrete variables using a multi-attribute decision making method. *Mathematical Computerisation Simluation.* pp. 9-21.

Yang, J. and Lee, H. 1997. An AHP decision model for facility location selection. *Facilities* 15(9/10), pp. 241-254.

Yang, T. and Hung, C.C. 2007. Multiple-attribute decision-making methods for plant layout design problem. *Robotics and Computer-integrated manufacturing* 23, pp. 126-137.

Yin, R. 1994. *Case Study Research: Design and Methods*, 2nd ed. London: Sage.

Yong, D. 2006. Plant location selection based on fuzzy TOPSIS. *International Journal of Advanced Manufacturing Technology* 28, pp. 839-844.

Yoon, K.P. and Hwang, C.L. 1995. *Multiple Attribute Decision Making – An Introduction.* London: Sage Publications, Thousand Oaks.

Yu, C.S. 2002. A GP-AHP method for solving group decision-making fuzzy AHP problems. *Computers and Operations Research* 29, pp. 1969-2001.

Yu, X., Guo, S., Guo, J. and Huang, X. 2011. Rank B2C e-commerce websites in e-alliance based on AHP and fuzzy TOPSIS. *Expert Systems with Applications* 38, pp. 3550 – 3557.

Yurimoto, S. and Masui, T. 1995. Design of a decision support system for overseas plant location in the EC. *International Journal of Production Economics* 41, pp. 411-418.

Zanakis, S.H., Solomon, A., Wishart, N. and Dublish, S. 1998. Multi-attribute decision making: A simulation comparison of selection methods. *European Journal of Operational Research* 107, pp. 507-529.

Zadeh, L.A. 1965. Fuzzy sets. *Information and Control* 8, pp. 338-353.

Zadeh, L.A. 1973. Outline of a new approach to the analysis of complex systems and decision process. *IEEE Transport Systems, Management and Cybernetics* 3, pp. 28 44.

Zadeh, L.A. 1975. Fuzzy logic and approximate reasoning. *Synthese* 30, pp. 407-428.

Zadeh, L.A. and Kacpryzk J. 1999. *Computing with Words in Information/Intelligent Systems 1. Foundations.* Heidelberg: Physica-Verlag.

Zahir, S. 1999. Clusters in a group: decision making in the vector space formulation of the analytic hierarchy process. *European Journal of Operational Research*. 112, pp. 620-634.

Zeleny, M. 1982. *Multiple Criteria Decision Making.* New York: McGraw-Hill.

Zhang, G. and Lu, J. 2003. An integrated group decision-making method dealing with fuzzy preferences for alternatives and individual judgements for selection criteria. *Group Decision and Negotiation* 12, pp. 501-515.

Zheng, H.A., Chen, Z.M., and You, J.X. 2009. Decision making model of distribution centres location based on simulation tool for chain retail enterprises. *Xitong Gongcheng Lilun yu Shijian/System Engineering Theory and Practice* 29(5), pp. 17-26.

Zimmerman, H. J. 1996. *Fuzzy sets theory and its applications*, Boston: Kluwer Academic Publisher.

Zionts, S. 1979. A survey of multiple criteria integer programming methods. *Annual Discrete Mathematics* 5, pp. 389-398.

Appendices

Appendix A

A.1 Exploratory Survey

Dear Sir/Madam

Re: Humanitarian Ailed Logistics Questionnaire

May name is Saeyeon Roh and I am currently a full time student on the Postgraduate Research Study Programme at Cardiff Business School, Cardiff University.

The title of my thesis is "An analysis of Pre-Positioned Warehouse in Humanitarian Relief Transport" and as part of my research and fieldwork studies I am inviting you to participate and support my work. The work is purely academic and will not be used for any commercial purposes.

I am attaching a Questionnaire and your opinions and support in completing and returning this will be invaluable to my research. Your participation in this survey is entirely voluntary and the information obtained will be treated in the strictest confidence. No individual person will be identifiable from the survey. The questionnaire and interview should take no more than thirty minutes to complete.

Your cooperation is vital to the success of my research and your participation would therefore be extremely welcome.

If you wish to contact my supervisors regarding any aspect of this research they are Dr Anthony Beresford (Beresford@cardiff.ac.uk) or Dr Stephen Pettit (pettit@cardiff.ac.uk).

Yours faithfully,

Saeyeon Roh

MPhil/PhD student

Interview Questions

1. Background of implementing pre-positioned warehouse

1.1 Can you briefly explain about your organisation’s humanitarian operation?

1.2 Why do you operate pre-positioning warehouse strategy?

1.3 What are the implicated reasons for the locations of the warehouses?

1.4 What are the advantages?

2. Determining factors

What are the important factors for pre-positioned warehouse?

3. Priority of the factors

What are the priorities of the factors that you have provided? List them from the most important to the least important.

4. Difficulties and imitation

4.1 What are the disadvantages of the pre-positioned warehouse?

4.2 What are the constraints and limitations?

A.2 Cardiff Business School Ethical Approval Form

CARDIFF BUSINESS SCHOOL ETHICAL APPROVAL FORM:

PHD THESIS RESEARCH

(For guidance on how to complete this form, please see http://www.cf.ac.uk/carbs/research/ethics.html)

For Office Use: Ref Meeting

Does your research involve human participants? Yes ☒ No ☐

If you have answered 'No' to this question you do not need to complete the rest of this form, otherwise please proceed to the next question

Does your research have any involvement with the NHS? **Yes** ☐ **No** ☒

If you have answered **Yes** to this question, then your project should firstly be submitted to the NHS National Research Ethics Service. Online applications are available on http://www.nres.npsa.nhs.uk/applicants/ . It could be that you may have to deal directly with the NHS Ethics Service and bypass the Business School's Research Ethics Committee.

Name of Student: SAEYEON ROH

Student Number: 0742100

Section: CARBS Logistics Operations and Management

Email: RohS1@cf.ac.uk, rohsae@hotmail.com

Names of Supervisors: Dr. Anthony Beresford
Dr. Stephen Pettit
Dr. Andrew Potter

Supervisors' Email Addresses: Beresford@cardiff.ac.uk
Pettit@cf.ac.uk
PotterAT@cf.ac.uk

Title of Thesis: Analysis of Humanitarian relief pre-positioned warehouse

Start and Estimated End Date of Research: September 2008 – September 2011

Please indicate any sources of funding for this research: Self-funded

1. Describe the Methodology to be applied in the research

The research will be conducted by interviewing the experts of the logistician in humanitarian aid relief. The interview will be done through individually by face-to-face or via telephone if needed. Questions will be also asked through electronic mail.

Questionnaires will also be used in the research. They will be sent through by post and emails to the participants.

2. Describe the participant sample who will be contacted for this Research Project. You need to consider the number of participants, their age, gender, recruitment methods and exclusion/inclusion criteria

Participants are mainly logisticians and academics who have experience or researched in humanitarian aid. Field managers of warehouse and their clients will be the sample of the research. The number of the participants will be approximately from 30 to 50. The age will range from 20 to 60 years old. They are both male and females and the cultural background will vary. The recruitment method will be sending emails and post to the participants meet them through workshops and conferences and ask them permission for participating is also one of the recruiting methods that I am looking for.

The questions that will be asked to the field managers and the academics will vary slightly because of the difference of knowledge they have. The academics will not know about the problems in the field that the field managers face. The participants will be able to read and understand English or Korean

3. Describe the consent and participant information arrangements you will make, as well as the methods of debriefing. If you are conducting interviews, you must attach a copy of the consent form you will be using.

The consent form will attached when conducting interviews and briefly explained about the interview. When the interviews are conducted through the telephone, the consent form will be explained and ask permission for recording. If the questions are asked through post or email, the form will be sent in attached file to the participants.

The obtained information will be destroyed after the research is finished. The person that could access to the information is the experimenter, the supervisors and the participants. The data will be destroyed immediately if the participant wants to.

The consent forms (attached) will include:
- participation is voluntary
- participation had the opportunity to consider the information, ask questions and have these answered satisfactorily
- participant's information and data will be protected confidentially and will put into anonymity
- participant can withdraw anytime from the study at any time without giving a reason
- participant can ask any question at any time and free to discuses or withdraw concerns with the supervisor
- and agree to participate in this research

4. Please make a clear and concise statement of the ethical considerations raised by the research and how you intend to deal with them throughout the duration of the project

My research will have ethical of 'confidentiality' and anonymity'. Code of Ethics of Academic of Management (AOM 2005) states that written informed consent (attached form) must be obtained in the first place. This will provide clear understanding to the participants

Personal files and names will be deleted as well as the organisation before the work is published or control disclosure of the identities.

PLEASE NOTE that you should include a copy of your questionnaire

NB: Copies of your signed and approved Research Ethics Application Form together with accompanying documentation must be bound into your Dissertation or Thesis.

5. Please complete the following in relation to your research:

		Yes	No	n/a
(a)	Will you describe the main details of the research process to participants in advance, so that they are informed about what to expect?	☒	☐	☐
(b)	Will you tell participants that their participation is voluntary?	☒	☐	☐
(c)	Will you obtain written consent for participation?	☒	☐	☐
(d)	Will you tell participants that they may withdraw from the research at any time and for any reason?	☒	☐	☐
(e)	If you are using a questionnaire, will you give participants the option of omitting questions they do not want to answer?	☒	☐	☐
(f)	Will you tell participants that their data will be treated with full confidentiality and that, if published, it will not be identifiable as theirs?	☒	☐	☐
(g)	Will you offer to send participants findings from the research (e.g. copies of publications arising from the research)?	☒	☐	☐

PLEASE NOTE:
If you have ticked **No** to any of 5(a) to 5(g), please give an explanation on a separate sheet.
(Note: N/A = not applicable)
There is an obligation on the lead researcher to bring to the attention of Cardiff Business School Ethics Committee any issues with ethical implications not clearly covered by the above checklist.

Two copies of this form (and attachments) should be submitted to Ms Lainey Clayton, Room F09, Cardiff Business School.

Signed

Print Name
SAEYEON ROH

Date
14/06/11

SUPERVISOR'S DECLARATION

As the supervisor for this research I confirm that I believe that all research ethical issues have been dealt with in accordance with University policy and the research ethics guidelines of the relevant professional organisation.

Signed
(Secondary supervisor)

Print Name
Stephen Pettit

Date

STATEMENT OF ETHICAL APPROVAL

This project has been considered using agreed School procedures and is now approved.

Signed
(Chair, School Research Ethics Committee)

Print Name

Date

A.3 Cardiff Business School Research Ethics Consent form

CARDIFF BUSINESS SCHOOL
RESEARCH ETHICS

Consent Form –

I understand that my participation in this project will involve completing questionnaires and interviews about my organisation and my attitudes towards humanitarian aid logistics.   The completion of the questionnaire and interview should take no more than 30 minutes. .

I understand that participation in this study is entirely voluntary and that I can withdraw from the study at any time without giving a reason.

I understand that I am free to ask any questions at any time.   If for any reason I have second thoughts about my participation in this project, I am free to withdraw or discuss my concerns with my supervisors Dr. Anthony Beresford (Beresord@cardiff.ac.uk) or Dr. Stephen Pettit (pettit@cardiff.ac.uk).

I understand that the information provided by me will be held confidentially and securely, that only the researcher can trace this information back to me individually. The information will be retained for up to 5 years and will then be deleted or destroyed. I understand that if I withdraw y consent I can ask for the information I have provides to be deleted or destroyed in accordance with the Data Protection Act 1998.

I, ___________________________________(NAME) consent to participate in the study conducted by Saeyeon Roh (rohs1@cardiff.ac.uk) PhD/Mphil student of Cardiff Business School, Cardiff University, under the supervision of Dr. Anthony Beresford, Dr. Stephen Pettit,.

Signed:

Date:

Appendix B AHP/TOPSIS Survey Question

B.1 AHP/TOPSIS Survey of Case Study A

CARDIFF BUSINESS SCHOOL ETHICAL APPROVAL FORM: PHD THESIS RESEARCH

(For guidance on how to complete this form, please see http://www.cf.ac.uk/carbs/research/ethics.html)

For Office Use: **Ref** **Meeting**

Does your research involve human participants? **Yes** ☒ **No** ☐

If you have answered 'No' to this question you do not need to complete the rest of this form, otherwise please proceed to the next question

Does your research have any involvement with the NHS? **Yes** ☐ **No** ☒

If you have answered **Yes** to this question, then your project should firstly be submitted to the NHS National Research Ethics Service. Online applications are available on http://www.nres.npsa.nhs.uk/applicants/ . It could be that you may have to deal directly with the NHS Ethics Service and bypass the Business School's Research Ethics Committee.

Name of Student: SAEYEON ROH

Student Number: 0742100

Section: CARBS Logistics Operations and Management

Email: RohS1@cf.ac.uk, rohsae@hotmail.com

Names of Supervisors: Dr. Anthony Beresford
Dr. Stephen Pettit
Dr. Andrew Potter

Supervisors' Email Addresses: Dr. Anthony Beresford: Beresford@cardiff.ac.uk
Dr. Stephen Pettit: Pettit@cf.ac.uk
Dr. PotterAT@cf.ac.uk

Title of Thesis: Analysis of Humanitarian relief pre-positioned warehouse

Start and Estimated End Date of Research: Oct 2008 – Oct 2012

Please indicate any sources of funding for this research: None

1. Describe the Methodology to be applied in the research

Semi-structured interviews will be conducted with humanitarian aid experts to determine the prioritisation of factors, and the best location for pre-positioned warehouses for humanitarian relief aid in Dubai. The data will be analysed using both AHP (Analytical Hierarchy Process) and TOPSIS.

The basis of the interviews will be attached (Humanitarian Pre-positioned warehouse survey).

2. Describe the participant sample who will be contacted for this Research Project. You need to consider the number of participants, their age, gender, recruitment methods and exclusion/inclusion criteria

The participants will be senior officers/managers of the supply division in the humanitarian relief sector. Primarily warehouse managers for the United Nations and International NGOs. As there are only a few organisations operating pre-positioned warehouses for their logistics, these organisations' managers will be selected from Dubai where the largest warehouses facilities are located compared to other places.
The number of participants will be around 15 – 20 managers, around 40 – 55 years of age, male and female, and they will be interviewed face-to-face.

6. Describe the consent and participant information arrangements you will make, as well as the methods of debriefing. If you are conducting interviews, you must attach a copy of the consent form you will be using.

I will explain to the participants the consent and confidentiality form with the guarantee that they can withdraw at any time. Complete information will be provided to the participants explaining the purpose of the study, why they have been invited to participate, the anticipated benefits of the study, an assurance of confidentiality, and the promise of a summary of results if they wish to receive them.
The consent form will attached with this form.

7. Please make a clear and concise statement of the ethical considerations raised by the research and how you intend to deal with them throughout the duration of the project

The main ethical issues are concerned with the confidentiality and openness in respect of the study findings. Any information I receive from the respondents will confirmed with them and sought their approval. As all the questionnaires will be conducted face-to-face, the consent and confidentiality explanation for the information will be confirmed with them Furthermore, the summary of the results will be shared with the respondents when they complete questionnaire and an explanation given that the information will be used only for academic research.
The respondents will be invited to make contact at any stage for further information.

PLEASE NOTE that you should include a copy of your questionnaire

NB: Copies of your signed and approved Research Ethics Application Form together with accompanying documentation must be bound into your Dissertation or Thesis.

8. Please complete the following in relation to your research:

		Yes	No	n/a
(a)	Will you describe the main details of the research process to participants in advance, so that they are informed about what to expect?	☒	☐	☐
(b)	Will you tell participants that their participation is voluntary?	☒	☐	☐
(c)	Will you obtain written consent for participation?	☒	☐	☐
(d)	Will you tell participants that they may withdraw from the research at any time and for any reason?	☒	☐	☐
(e)	If you are using a questionnaire, will you give participants the option of omitting questions they do not want to answer?	☒	☐	☐
(f)	Will you tell participants that their data will be treated with full confidentiality and that, if published, it will not be identifiable as theirs?	☒	☐	☐
(g)	Will you offer to send participants findings from the research (e.g. copies of publications arising from the research)?	☒	☐	☐

PLEASE NOTE:
If you have ticked **No** to any of 5(a) to 5(g), please give an explanation on a separate sheet.
(Note: N/A = not applicable)
There is an obligation on the lead researcher to bring to the attention of Cardiff Business School Ethics Committee any issues with ethical implications not clearly covered by the above checklist.

Two copies of this form (and attachments) should be submitted to Ms Lainey Clayton, Room F09, Cardiff Business School.

Signed

Print Name
SAEYEON ROH

Date
14/06/11

SUPERVISOR'S DECLARATION

As the supervisor for this research I confirm that I believe that all research ethical issues have been dealt with in accordance with University policy and the research ethics guidelines of the relevant professional organisation.

Signed
(Secondary supervisor)

Print Name
Stephen Pettit

Date

STATEMENT OF ETHICAL APPROVAL

This project has been considered using agreed School procedures and is now approved.

Signed
(Chair, School Research Ethics Committee)

Print Name

Date

Consent Form - Anonymous data

I understand that my participation in this project will involve completing a set of questionnaires about locating factors for pre-positioning warehouse in humanitarian relief logistics which will require approximately 20 minutes of my time.

I understand that participation in this study is entirely voluntary and that I can withdraw from the study at any time without giving a reason.

I understand that I am free to ask any questions at any time.

I understand that the information provided by me will be held totally anonymously, so that it is impossible to trace this information back to me individually. I understand that, in accordance with the Data Protection Act, this information may be retained indefinitely.

I, ___________________________________(NAME) consent to participate in the study conducted by Saeyeon Roh, Business School, Logistics Operations and Management Section, Cardiff University with the supervision of Dr. Anthony Beresford, Dr. Stephen Pettit, and Dr. Andrew Potter.

Signed:

Date:

Consent Form - Confidential data

I understand that my participation in this project will involve completing a set of questionnaires about locating factors for pre-positioning warehouse in humanitarian relief logistics which will require approximately 20 minutes of my time.

I understand that participation in this study is entirely voluntary and that I can withdraw from the study at any time without giving a reason and without loss of payment (or course credit).

I understand that I am free to ask any questions at any time. I am free to withdraw or discuss my concerns with Dr. Anthony Beresford and Dr. Stephen Pettit, and Dr. Andrew Potter.

I understand that the information provided by me will be held confidentially, such that only the Experimenter can trace this information back to me individually. The information will be retained for up to 3 years when it will be deleted/destroyed. I understand that I can ask for the information I provide to be deleted/destroyed at any time and, in accordance with the Data Protection Act, I can have access to the information at any time.

I also understand that at the end of the study I will be provided with additional information and feedback about the purpose of the study.

I, ___________________________________(NAME) consent to participate in the study conducted by Saeyeon Roh, Business School, Cardiff University with the supervision of Dr. Anthony Beresford, Dr. Stephen Pettit, and Dr. Andrew Potter.

Signed:

Date:

Humanitarian pre-positioned warehouse survey

(Analytical Hierarchy Process for United Nations High Commission for Refugees)

Dear Sir/Madam,

Above all, many thanks for your time complete this survey. I am currently undertaking a PhD research programme in Cardiff Business School, Cardiff University, researching the priority of factors in locating humanitarian pre-positioned warehouses using quantitative, analytical techniques. As part of this process, I am conducting a survey which aims to rank pre-positioned warehouse location indicators. It is expected that data collected through this survey will help to develop an appropriate framework for deciding humanitarian pre-positioned warehouse location. As a senior manager in the supply division in humanitarian relief logistics, you are invited to provide your perceptions of pre-positioning warehouses for humanitarian. Your opinions are extremely important to this research; the attached survey is part of the research. There are no right or wrong answers.

Your participation in this survey is entirely voluntary. The information gathered will be treated in the **strictest confidence**. This survey will only be used for academic research purpose and you are entitled to withdraw your answer at anytime.

This survey will take about 20 minutes to complete. It would be very helpful to the research if you could provide your opinions to the questions. If you consent to participate in this survey, please complete the survey. If you request the research result, please indicate this at the end of the questionnaire or e-mail us and I will be happy to send the summary to you when the research is complete.

If you have any queries regarding to the survey, please contact either myself or my supervisors, Dr. Anthony Beresford (Beresford@cardiff.ac.uk) and Dr. Stephen Pettit (Pettit.cf.ac.uk).

Please accept my thanks for your anticipated co-operation.

Yours faithfully,

SAEYEON ROH
Postgraduate Research Student
Logistics and Operations Management Section
Room D46 Aberconway Building
Cardiff Business School
Cardiff University, Cardiff CF10 3EU, UK
Tel: 44(0)78 0422 0334
Email:rohs1@cardiff.ac.uk, rohsae@hotmail.com

Questionnaire Explanation

In this survey you will be asked to compare the following criteria which are used to locate the pre-positioned warehouse, such as global stockpile. The description of the criteria is described in the following tables.

Main criteria	Sub-criteria	Description of criteria
Location	Geographical location	The physical geographical location of the warehouse
	Proximity to beneficiaries	The proximity and accessibility to the beneficiaries
	Disaster free location	The safe area not easily affected by disasters (natural/man-made)
	Donor's opinion	The opinion of donors on the locations importance
	Climate	The impact of climate on the area
	Closeness to other warehouses	The geographical distance to other regional/local warehouses
	Proximity to disaster prone area	The geographical distance to frequent disaster occurrence area
Logistics	Airport	Considering the capacity to handle large aircraft, air national carriers connections, availability of air cargo companies, and operational ability
	Seaport	Considering accessibility to seaport, frequency of shipping services, quality of the seaport, handling capacity, and distance from the warehouse
	Road	Road infrastructure considering the trucking service, countries connected and road conditions
	Warehouse	Warehouse infrastructure considering the facility, security, capacity and proximity to urban facilities
National Stability	Political stability	Stable political decisions or political change
	Social stability	Risk of riots or protest towards the government
	Economic stability	Important level of output growth and low and stable inflation
Cost	Labour	Labour cost
	Land	Cost of land
	Storage	Maintenance cost of storage
	Replenishment	Impact of change in replenishment cost due to competitive prices, productivity, and access of relief items
	Logistics	Logistics cost from the warehouse to the aid recipients and within the country
Cooperation	Host government	Accessibility of the nation's and military assets, financial aid and incentives
	Int'l NGOs	Cooperation in information, facilities, and personnel sharing, etc in the country
	Local NGOs	
	UN	
	Neighbour countries	Aid support of the neighbour countries in relief items, facilities, etc
	Logistics agents	Logistics training and lease of logistics facilities

How to complete the questionnaire

Tick the most appropriate box according to your opinion on how important one criterion over another when you are evaluating the humanitarian pre-positioned warehouse. If you preference is between two levels of importance, e.g. between Strong Importance and Very Strong Importance, please tick the intermediate box between them.

Intensity of influence	Definition
EI	Equal Importance
MI	Moderate Importance for one over another
SI	Strong Importance
VSI	Very Strong Importance
ExI	Extreme Importance

Examples

Each row has a single comparison for you to make. As stated above, between two criteria “EI” means that both criteria are of Equal Importance. If you think, for example, the importance of *Location* over *Infrastructure* is Strong Importance, your answer should be placed on the left side subject to the degree of relative importance, and then you would tick as follows:

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Location	☐	☐	☐	☐	√	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Infrastructure

Tick √ or X means: the importance of *Location* over the criterion *Infrastructure* is a Strong Importance.

If, however, you think the importance of *Location* over the criterion Infrastructure is an Extreme Influence, then you should thick as follow:

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Location	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	√	Infrastructure

If the importance is the same, tick Equal Importance will be the answer.

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Location	☐	☐	☐	☐	☐	☐	☐	☐	√	☐	☐	☐	☐	☐	☐	☐	☐	Infrastructure

The Survey of Main Criteria

1. Comparison of the relative importance of each criterion in the first hierarchy

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Location	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Logistics
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Stability
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cost
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cooperation
Logistics	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Stability
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cost
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cooperation
Stability	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cost
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cooperation
Cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cooperation

The survey of sub-criteria

1. Comparison of the relative importance of each criterion in the second hierarchy: Logistics

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Airport	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Seaport
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Road
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Warehouse
Seaport	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Road
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Warehouse
Road	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Warehouse

2. Comparison of the relative importance of each criterion in the second hierarchy: Cost

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Labour	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Land
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Storage
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Replenish
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Logistics
Land	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Storage
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Replenish
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Logistics
Storage	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Replenish
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Logistics
Replenish	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Logistics

3. Comparison of the relative importance of each criterion in the second hierarchy: Stability

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Political stability	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Social stability
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Economic stability
Social stability	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Economic stability

4. Comparison of the relative importance of each criterion in the second hierarchy: Location

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Geographical location	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Proximity to beneficiaries
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Disaster free location
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Donor's opinion
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Climate
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Closeness to other warehouses
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Proximity to disaster prone area
Proximity to beneficiaries	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Disaster free location
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Donor's opinion
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Climate
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Closeness to other warehouses
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Proximity to disaster prone area
Disaster free location	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Donor's opinion
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Climate
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Closeness to other warehouse
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Proximity to disaster prone area
Donor's opinion	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Climate
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Closeness to other warehouses
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Proximity disaster prone area
Climate	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Closeness to other warehouses
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Proximityto disaster pron area
Closeness to other warehouses	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Proximity to disaster prone area

5. Comparison of the relative importance of each criterion in the second hierarchy: Stakeholder cooperation

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Host government	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Int’l NGOs
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Local NGOs
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	UN
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Neighbour countries
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Logistics agents
Int’l NGOs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Local NGOs
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	UN
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Neighbour countries
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Logistics agents
Local NGOs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	UN
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Neighbour countries
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Logistics agents
UN	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Neighbour countries
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Logistics agents
Neighbour countries	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Logistics agents

Personal Information
This information will be used to enable clusters to be formed from the response. However, individual responses will not be identifiable.

A. Gender (   )
1. Male   2. Female

B. What is your position in your organisation?

____

C. How long have you worked in humanitarian logistics related sector? ___________ years

D. What additional critical criteria that could be included or excluded in this survey?

If you would like to receive a summary of the results of this research, please contact us by e-mail so that we can send the report to you.

Thank you for your patience and help

Humanitarian pre-positioned warehouse survey

(TOPSIS for United Nations High Commission for Refugees)

Dear Sir/Madam,

Above all, many thanks for your time complete this survey. I am currently undertaking a PhD research programme in Cardiff Business School, Cardiff University, researching the priority of factors in locating humanitarian pre-positioned warehouses using quantitative, analytical techniques. As part of this process, I am conducting a survey which aims to rank pre-positioned warehouse location indicators. It is expected that data collected through this survey will help to develop an appropriate framework for deciding humanitarian pre-positioned warehouse location. As a senior manager in the supply division in humanitarian relief logistics, you are invited to provide your perceptions of pre-positioning warehouses for humanitarian. Your opinions are extremely important to this research; the attached survey is part of the research. There are no right or wrong answers.

Your participation in this survey is entirely voluntary. The information gathered will be treated in the **strictest confidence**. This survey will only be used for academic research purpose and you are entitled to withdraw your answer at anytime.

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Please accept my thanks for your anticipated co-operation.

Yours faithfully,

SAEYEON ROH
Postgraduate Research Student
Logistics and Operations Management Section
Room D46 Aberconway Building
Cardiff Business School
Cardiff University, Cardiff CF10 3EU, UK
Tel: 44(0)78 0422 0334
Email:rohs1@cardiff.ac.uk, rohsae@hotmail.com

Questionnaire Explanation

In this survey you will be asked to compare the following criteria which are used to locate the pre-positioned warehouse. The description of the criteria is described in the following tables.

Main criteria	Sub-criteria	Description of criteria
Location	Geographical location	The physical geographical location of the warehouse
	Proximity to beneficiaries	The proximity and accessibility to the beneficiaries
	Disaster free location	The safe area not easily affected by disasters (natural/man-made)
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Cooperation	Host government	Accessibility of the nation's and military assets, financial aid and incentives
	Int'l NGOs	Cooperation in information, facilities, and personnel sharing, etc in the country
	Local NGOs	
	UN	
	Neighbour countries	Aid support of the neighbour countries in relief items, facilities, etc
	Logistics agents	Logistics training and lease of logistics facilities

How to complete the questionnaire

Tick the most appropriate box according to your opinion on the rating of one criterion according to the stockpile location when you are rating the humanitarian pre-positioned warehouse. If your opinion is Good, please tick or circle around number 4.

Ratings	Definition
1	Very Poor
2	Poor
3	Fair
4	Good
5	Very Good

Examples

As stated above, number "3" means that the criteria are of Fair rating. If you think, for example, the rating of *Dubai* stockpile Good relating to the Location, your answer should be numbered 4 in the box. Circle number 4 or mark anything (tick: √) that could represent your opinion on top of the number.

Stockpiles	Location	Logistics	Stability	Cost	Cooperation
Dubai	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Copenhagen	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Cameroon	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Jordan	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Tanzania	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

The rating can be done with other factors over the stockpiles. The rating can be duplicated to fill out your opinion. To assist you infilling out the box, the definition of the rating number will be marked below the table.

Stockpiles	Location	Logistics	Stability	Cost	Cooperation
Dubai	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Copenhagen	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Cameroon	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Jordan	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Tanzania	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
1 – Very Poor	2 – Poor	3 - Fair	4 – Good	5 – Very Good	

The Survey

1. The rating of the main criteria (Part 1)

Stockpiles	Location					Logistics					Stability				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Dubai	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Copenhagen	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cameroon	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Jordan	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Tanzania	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

1 – Very Poor 2 – Poor 3 - Fair 4 – Good 5 – Very Good

1. The rating of the main criteria (Part 2)

Stockpiles	Cost					Cooperation				
	1	2	3	4	5	1	2	3	4	5
Dubai	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Copenhagen	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cameroon	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Jordan	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Tanzania	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

1 – Very Poor 2 – Poor 3 - Fair 4 – Good 5 – Very Good

2-1. The rating of the criteria of Location (Part 1)

Stockpiles	Geographical location					Proximity to beneficiaries					Disaster free location					Donors opinion				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Dubai	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Copenhagen	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cameroon	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Jordan	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Tanzania	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

1 – Very Poor 2 – Poor 3 - Fair 4 – Good 5 – Very Good

2-1. The rating of the criteria of Location (Part 2)

Stockpiles	Climate					Closeness to warehouse					Proximity to disaster prone area				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Dubai	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Copenhagen	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cameroon	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Jordan	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Tanzania	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

1 – Very Poor 2 – Poor 3 - Fair 4 – Good 5 – Very Good

2-2. The rating of the criteria of Logistics

Stockpiles	Airport					Seaport					Road					Warehouse				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Dubai	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Copenhagen	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Cameroon	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Jordan	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Tanzania	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

1 – Very Poor 2 – Poor 3 - Fair 4 – Good 5 – Very Good

2-3. The rating of the criteria of Cost

Stockpiles	Labour	Land	Storage	Replenish	Logistics
	1 2 4 5	1 2 3 4 5	12 34 5	1 2 3 4 5	1 2 3 4 5
Dubai	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Copenhagen	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Cameroon	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Jordan	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Tanzania	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
1 – Very Poor 2 – Poor 3 - Fair 4 – Good 5 – Very Good					

2-4. The rating of the criteria of Cooperation

Stockpiles	Host government	Int'l NGOs	Local NGOs	UN	Neighbour countries	Logistics agents
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Dubai	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐
Copenhagen	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐
Cameroon	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐
Jordan	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐
Tanzania	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐	☐☐☐☐☐
1 – Very Poor 2 – Poor 3 - Fair 4 – Good 5 – Very Good						

2-5. The rating of the criteria of Stability

Stockpiles	Political Stability	Social Stability	Economic Stability
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Dubai	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Copenhagen	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Cameroon	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Jordan	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Tanzania	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
1 – Very Poor 2 – Poor 3 - Fair 4 – Good 5 – Very Good			

Personal Information

This information will be used to enable clusters to be formed from the response. However, individual responses will not be identifiable.

A. Gender (   )

1. Male   2. Female

B. What is your position in your organisation?

____

C. How long have you worked in humanitarian logistics related sector? ____________ years

If you would like to receive a summary of the results of this research, please contact us by e-mail so that we can send the report to you.

Thank you for your patience and help

B.2 AHP/TOPSIS Survey of Case Study B

Humanitarian pre-positioned warehouse questionnaire

Dear Sirs/Madam,

Above all, many thanks for your time to this survey. I am currently undertaking a PhD research programme in Cardiff Business School, Cardiff University, finding the priority of factors in locating humanitarian warehouse in Dubai using quantitative, analytical techniques. As part of this process, I am conducting a questionnaire survey which aims to rank pre-positioned warehouse location indicators in Dubai. It is expected that data collected through this questionnaire will help to develop an appropriate framework for deciding humanitarian pre-positioned warehouse location. As a involved party in the organisation, you are invited to provide your perceptions of evaluating the new compound. Your opinions are extremely crucial to this research; the attached questionnaire is part of the research. There are no right or wrong answers.

Your participation in this questionnaire survey is entirely voluntary. The information gathered will be treated in the **strictest confidence**. This survey will only be used for academic research purpose and you are entitled to withdraw your answer at anytime.

This survey will take about 20 minutes to complete. It would be very helpful to the research if you could provide your opinions to the questions. If you consent to participate in this survey, please fill out the questionnaire. If you request for the research result, please indicate this at the end of the questionnaire or e-mail us and I will be happy to send the summary to you when the research is over.

If you have any queries regarding to the survey, please contact either myself or my supervisors, Dr. Anthony Beresford (Beresford@cardiff.ac.uk) and Dr. Stephen Pettit (Pettit.cf.ac.uk).

Please accept my thanks for your anticipated co-operation.

Yours faithfully,

SAEYEON ROH
Postgraduate Research Student
Logistics and Operations Management Section
Room D46 Aberconway Building
Cardiff Business School
Cardiff University, Cardiff CF10 3EU, UK
Tel: 44(0)78 0422 0334
Email:rohs1@cardiff.ac.uk, rohsae@hotmail.com

Questionnaire Explanation

A. In this questionnaire you will be asked to compare the following criteria which are used to locate the IHC compound. The description of the criteria is described in the following tables.

Main criteria	Description of criteria
Distance	Distance to airports, seaports, and MOFA
Security	Security of the warehouse, road safety, and related facilities around the area (fire, police station, hospital)
Office facilities	Includes the facilities for suitable administrative office works
Warehouse facilities	Includes the suitable infrastructure for loading, storage and general operations
Convenience	Convenience of the compound facility in welfare for the staffs

Main Criteria	Sub-criteria	Description
Distance	Jebel Ali seaport	The importance of Jebel Aili seaport for operation in Dubai
	Dubai Int'l airport	The importance of Dubai Int'l airport for operation in Dubai
	Al Maktoum airport	The importance of Al Maktoum airport for operation in Dubai
	Sharjah airport	The importance of to Sharjah airport for operation in Dubai
	Abu Dhabi airport	The importance of to Abu Dhabi airport for operation in Dubai
	MOFA	The importance of Ministry of Foreign Affairs for operation in Dubai
Security	Warehouse	Warehouse equipped with CCTV and alarm system
	Fire fighting station	Availability of fire fighting station
	Police station	Availability of police station
	Hospital	Availability of Hospital
	Road safety	Road safety for any traffic accident threat around the compound
Office facilities	Suitability for diplomatic work	Office convenience for diplomatic work
	IT/Communication infrastructure	Office equipped with standard IT/communication infrastructure
	Warehouse distance	Office distance close to the warehouse
	Modular office space	Enough office space
Warehouse facilities	Capacity	Space of the warehouse
	Open storage	Availability of open storage area
	Office facility	Office space , air-conditioner, and sanitation facilities in the warehouse
	General spill-over area	Additional area of the warehouse to store surplus items
	Height of ceiling	Maximum height of the ceiling of the warehouse
	Loading bays	Available for the loading bays
	Flood lights	Available of lights for night operation
	Suitable openings	Openings suitable for 40' high-cube container and flatbed trucks
	Doors at both ends	Available of doors at the both ends of the warehouse
Convenience	Cafeteria	Availability of cafeteria within the compound
	Mini-mart	Availability of mini-mart within/around compound
	ATM	Availability of ATM within/around compound
	Main City	Easy Access to the main city
	Residential accommodation	Close to residential accommodation
	Transportation	Available of public bus, metro station, and taxi

How to complete the questionnaire

Tick the most appropriate box according to your opinion on how important one criterion over another when you are evaluating the IHC compound. If you preference is between two levels of importance, e.g. between Strong Importance and Very Strong Importance, please tick the intermediate box between them.

Intensity of influence	Definition
EI	Equal Importance
MI	Moderate Importance for one over another
SI	Strong Importance
VSI	Very Strong Importance
ExI	Extreme Importance

Examples

Each row has a single comparison for you to make. As stated above, between two criteria "EI" means that both criteria are of Equal Importance. If you think, for example, the importance of *Distance* over *Security* is Strong Importance, your answer should be placed on the left side subject to the degree of relative importance, and then you would tick as follows:

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Distance	☐	☐	☐	☐	√	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Security

Tick √ or X means: the importance of *Distance* over the criterion *Security* is a Strong Importance.

If, however, you think the importance of *Distance* over the criterion *Security* is an Extreme Influence, then you should thick as follow:

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Distance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	√	Security

If the importance is the same, Equal Importance will be the answer.

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Distance	☐	☐	☐	☐	☐	☐	☐	☐	√	☐	☐	☐	☐	☐	☐	☐	☐	Security

The Survey of Main Criteria

1. Comparison of the relative importance the main criteria

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Distance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Security
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Office facilities
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Warehouse facilities
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Convenience
Security	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Office facilities
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Warehouse facilities
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Convenience
Office facilities	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Warehouse facilities
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Convenience
Warehouse facilities	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Convenience

The survey of sub-criteria

1. Comparison of the relative importance of each sub-criterion in second hierarchy: Distance

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Jebel Ali seaport	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Dubai Int'l airport
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Al Maktoum airport
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Sharjah airport
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Abu Dhabi airport
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	MOFA
Dubai Int'l airport	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Al Maktoum airport
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Sharjah airpot
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Abu Dhabi airport
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	MOFA
Al Maktoum airport	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Sharjah airport
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Abu Dhabi airport
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	MOFA
Sharjah airport	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Abu Dhabi airport
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	MOFA
Abu Dhabi airport	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	MOFA

3. Comparison of the relative importance of each sub-criterion in second hierarchy: Office facilities

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Suitability for diplomatic work	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	IT/Communication infrastructure
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Warehouse distance
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Modular office space
IT/Communication infrastructure	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Warehouse distance
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Modular office space
Warehouse distance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Modular office space

3. Comparison of the relative importance of each sub-criterion in second hierarchy: Security

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Warehouse	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Fire fighting station
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Police station
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Hospital
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Road safety
Fire fighting station	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Police station
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Hospital
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Road safety
Police station	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Hospital
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Road safety
Hospital	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Road safety

4. Comparison of the relative importance of each sub-criterion in second hierarchy: Convenience

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Cafeteria	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Mini-mart
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Residential accommodation
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Main City
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Transportation
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	ATM
Mini-mart	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Residential accommodation
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Main City
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Transportation
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	ATM
ATM	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Residential accommodation
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Main City
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Transportation
Residential accommodation	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Main City
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Transportation
Main City	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Transportation

5. Comparison of the relative importance of each sub-criterion in second hierarchy: Warehouse facilities

Criterion	Intensity of Importance																	Criterion
	ExI		VSI		SI		MI		EI		MI		SI		VSI		ExI	
Capacity	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Open storage
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Office facility
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	General spill-over area
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Height of ceiling
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Loading bays
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Flood lights
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Suitable openings
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Doors at both ends
Open storage	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Office facility
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	General spill-over area
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Height of ceiling
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Loading bays
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Flood lights
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Suitable openings
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Doors at both ends
Office facility	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	General spill-over area
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Height of ceiling
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Loading bays
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Flood lights
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Suitable openings
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Doors at both ends
General spill-over area	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Height of ceiling
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Loading bays
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Flood lights
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Suitable openings
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Doors at both ends
Height of ceiling	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Loading bays
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Flood lights
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Suitable openings
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Doors at both ends
Loading bays	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Flood lights
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Suitable openings
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Doors at both ends
Flood lights	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Suitable openings
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Doors at both ends
Suitable openings	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Doors at both ends

Personal Information

This information will be used to enable clusters to be formed from the response. However, individual responses will not be identifiable.

A. Gender (   )

1. Male   2. Female

B. What is your position in your organisation?

____

C. How long have you worked in humanitarian logistics related sector? ___________ years

If you would like to receive a summary of the results of this research, please contact us by e-mail so that we can send the report to you.

Thank you for your patience and help

Humanitarian pre-positioned warehouse survey

(TOPSIS for United Nations High Commission for Refugees)

Dear Sir/Madam,

Above all, many thanks for your time complete this survey. I am currently undertaking a PhD research programme in Cardiff Business School, Cardiff University, researching the priority of factors in locating humanitarian pre-positioned warehouses using quantitative, analytical techniques. As part of this process, I am conducting a survey which aims to rank pre-positioned warehouse location indicators. It is expected that data collected through this survey will help to develop an appropriate framework for deciding humanitarian pre-positioned warehouse location. As a senior manager in the supply division in humanitarian relief logistics, you are invited to provide your perceptions of pre-positioning warehouses for humanitarian. Your opinions are extremely important to this research; the attached survey is part of the research. There are no right or wrong answers.

Your participation in this survey is entirely voluntary. The information gathered will be treated in the **strictest confidence**. This survey will only be used for academic research purpose and you are entitled to withdraw your answer at anytime.

This survey will take about 20 minutes to complete. It would be very helpful to the research if you could provide your opinions to the questions. If you consent to participate in this survey, please complete the survey. If you request the research result, please indicate this at the end of the questionnaire or e-mail us and I will be happy to send the summary to you when the research is complete.

If you have any queries regarding to the survey, please contact either myself or my supervisors, Dr. Anthony Beresford (Beresford@cardiff.ac.uk) and Dr. Stephen Pettit (Pettit.cf.ac.uk).

Please accept my thanks for your anticipated co-operation.

Yours faithfully,

SAEYEON ROH
Postgraduate Research Student
Logistics and Operations Management Section
Room D46 Aberconway Building
Cardiff Business School
Cardiff University, Cardiff CF10 3EU, UK
Tel: 44(0)78 0422 0334
Email:rohs1@cardiff.ac.uk, rohsae@hotmail.com

Questionnaire Explanation

In this questionnaire you will be asked to compare the following criteria which are used to locate the pre-positioned warehouse. The description of the criteria is described in the following tables.

Main criteria	Description of criteria
Distance	Distance to airports, seaports, and MOFA
Security	Security of the warehouse, road safety, and related facilities around the area (fire, police station, hospital)
Office facilities	Facilities for suitable administrative office works
Warehouse facilities	Suitable infrastructure for loading, storage and general operations
Convenience	Convenience of the compound facility in welfare for the staffs

Main Criteria	Sub-criteria	Description
Distance	Jebel Ali seaport	Distance to Jebel Aili seaport
	Dubai Int'l airport	Distance to Dubai Int'l airport
	Al Maktoum airport	Distance to Al Maktoum airport
	Sharjah airport	Distance to Sharjah airport
	Abu Dhabi airport	Distance to Abu Dhabi airport
	MOFA	Distance to Ministry of Foreign Affairs
Security	Warehouse	Warehouse equipped with CCTV and alarm system
	Fire fighting station	Availability of fire fighting station
	Police station	Availability of police station
	Hospital	Availability of Hospital
	Road safety	Road safety for any traffic accident threat around the compound
Office facilities	Suitability for diplomatic work	Office convenience for diplomatic work
	IT/Communication infrastructure	Office equipped with standard IT/communication infrastructure
	Warehouse distance	Office distance close to the warehouse
	Modular office space	Enough office space
Warehouse facilities	Capacity	Space of the warehouse
	Open storage	Availability of open storage area
	Office facility	Office space , air-conditioner, and sanitation facilities
	General spill-over area	Additional area of the warehouse to store surplus items
	Height of ceiling	Maximum height of the ceiling of the warehouse
	Loading bays	Availability for the loading bays
	Flood lights	Availability of lights for night operations
	Suitable openings	Openings suitable for 40' high-cube container and flatbed trucks
	Doors at both ends	Availability of doors at the both ends of the warehouse
Convenience	Cafeteria	Availability of cafeteria within the compound
	Mini-mart	Availability of mini-mart within/around compound
	ATM	Availability of ATM within/around compound
	Main City	Easy Access to the main city
	Residential accommodation	Close to residential accommodation
	Transportation	Availability of public bus, metro station, and taxi

B. Locations of the warehouse for are listed below to evaluate your preference for the criteria.

Current warehouse location	Alternative warehouse locations
International Humanitarian City (IHC)	Dubai Industrial City (DIC) Hellmann by JAFZA (Hellmann) JAFZA by JAFZA (JAFZA) RSA Logistics, DLC (RSA)

How to complete the questionnaire

Tick the most appropriate box according to your opinion on the rating of one criterion according to the stockpile location when you are rating the humanitarian pre-positioned warehouse. If your opinion is Good, please tick or circle around number 4.

Ratings	Definition
1	Very Poor
2	Poor
3	Fair
4	Good
5	Very Good

Examples

As stated above, number "3" means that the criteria are of Fair rating. If you think, for example, the rating of *IHC* stockpile Good relating to the Distance, your answer should be numbered 4 in the box. Mark in the box of number 4 (√ or X) that could represent your opinion on top of the number. (This could be done electronically as well).

Stockpiles	Distance	Security	Office facilities	Warehouse facilities	Convenience
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
IHC	☐ ☐ ☐ ☒ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
DIC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Hellmann	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
JAFZA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
RSA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐

The rating can be done with other factors over the stockpiles. The rating can be duplicated to fill out your opinion. To assist you infilling out the box, the definition of the rating number will be marked below the table.

Stockpiles	Distance	Security	Office facilities	Warehouse facilities	Convenience
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
IHC	☐ ☐ ☐ ☒ ☐	☐ ☐ ☐ ☐ ☒	☐ ☐ ☐ ☒ ☐	☐ ☐ ☐ ☐ ☒	☐ ☐ ☐ ☐ ☒
DIC	☐ ☐ ☒ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Hellmann	☐ ☒ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
JAFZA	☐ ☐ ☒ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
RSA	☐ ☐ ☒ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
1 – Very Poor	2 – Poor	3 - Fair	4 – Good	5 – Very Good	

The Survey

1. The rating of the main criteria.

Locations	Distance	Security	Office facilities	Warehouse facilities	Convenience
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
IHC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
DIC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Hellmann	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
JAFZA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
RSA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
1 – Very Poor	2 – Poor	3 - Fair	4 – Good	5 – Very Good	

2-1. The rating of the criteria of Distance

Locations	Jebel Ali seaport	Dubai Int'l airport	Al Maktoum airport	Sharjah airport	Abu Dhabi airport	MOFA
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
IHC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
DIC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Hellmann	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
JAFZA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
RSA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
1 – Very Poor	2 – Poor	3 - Fair	4 – Good	5 – Very Good		

2-2. The rating of the criteria of Security

Locations	Warehouse	Fire fighting station	Police station	Hospital	Road safety
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
IHC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
DIC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Hellmann	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
JAFZA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
RSA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
1 – Very Poor	2 – Poor	3 - Fair	4 – Good	5 – Very Good	

2-3. The rating of the criteria of Office facilities

Locations	Suitability for diplomatic work	IT/Communication infrastructure	Warehouse distance	Modular office space
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
IHC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
DIC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Hellmann	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
JAFZA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
RSA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
1 – Very Poor	2 – Poor	3 - Fair	4 – Good	5 – Very Good

2-4. The rating of the criteria of Warehouse facilities (part 1)

Locations	Capacity	Open storage	Office facilities	General spill-over area	Height of ceiling
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
IHC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
DIC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Hellmann	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
JAFZA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
RSA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
1 – Very Poor	2 – Poor	3 - Fair	4 – Good	5 – Very Good	

2-4. The rating of the criteria of Warehouse facilities (part 2)

Locations	Loading bays	Flood lights	Suitable openings	Doors at both ends
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
IHC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
DIC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Hellmann	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
JAFZA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
RSA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
1 – Very Poor	2 – Poor	3 - Fair	4 – Good	5 – Very Good

2-5 The rating of the criteria of Convenience

Locations	Cafeteria	Mini-mart	ATM	Main city	Residential accommodation	Transportation
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
IHC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
DIC	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Hellmann	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
JAFZA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
RSA	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
1 – Very Poor	2 – Poor	3 - Fair	4 – Good	5 – Very Good		

Personal Information
This information will be used to enable clusters to be formed from the response. However, individual responses will not be identifiable.

A. Gender (   )
1. Male   2. Female

B. What is your position in your organisation?

____

C. How long have you worked in humanitarian logistics related sector? ___________ years

If you would like to receive a summary of the results of this research, please contact us by e-mail so that we can send the report to you.

Thank you for your patience and help

APPENDIX C SUMMARY OF SURVEY RESULTS

C.1 Matrix for Criteria for Overall Results of Case Study A

Major attributes

	C_1	C_2	C_3	C_4	C_5
C_1	1	1/3	1	1/3	1/3
C_2	3	1	1/2	1	2
C_3	1	2	1	1/2	2
C_4	3	1	2	1	2
C_5	3	1/2	1/2	1/2	1

Attributes	**NW**	**λ_{max}**	**CI**	**RI**	**CR**
Location (C_1)	0.1015	5.3948	0.0987	1.12	0.0881
National stability (C_2)	0.2282				
Cost (C_3)	0.2270				
Cooperation (C_4)	0.2908				
Logistics (C_5)	0.1525				
Total Weight	1.000				

Location (C_1) attributes

	SC_{11}	SC_{12}	SC_{13}	SC_{14}	SC_{15}	SC_{16}	SC_{17}
SC_{11}	1	1/2	1/2	1/2	2	1	1/3
SC_{12}	2	1	1/2	1	5	1	1
SC_{13}	2	2	1	1	2	1	1
SC_{14}	2	1	1	1	6	1	1
SC_{15}	1/2	1/5	1/2	1/6	1	1/2	1/4
SC_{16}	1	1	1	1	2	1	1/4
SC_{17}	3	1	1	1	4	4	1

Attributes	**NW**	**λ_{max}**	**CI**	**RI**	**CR**
Geographical location (SC_{11})	0.0864	7.2358	0.0393	1.32	0.0298
Proximity to beneficiaries(SC_{12})	0.1604				
Disaster free location (SC_{13})	0.1826				
Donor's opinion (SC_{14})	0.1790				
Climate (SC_{15})	0.0447				
Closeness to other warehouses (SC_{16})	0.1194				
Proximity to disaster prone areas (SC_{17})	0.2275				
Total Weight	1.000				

National Stability (C_2) attributes

	SC_{21}	SC_{22}	SC_{23}
SC_{21}	1	2	2
SC_{22}	1/2	1	2
SC_{23}	1/2	1/2	1

Attributes	**NW**	**λ_{max}**	**CI**	**RI**	**CR**
Political (SC_{21})	0.4934	3.1032	0.0516	0.58	0.0890
Economical (SC_{22})	0.3108				
Social (SC_{23})	0.1958				
Total Weight	1.0000				

Cost (C_3) attributes

	SC_{31}	SC_{32}	SC_{33}	SC_{34}	SC_{35}
SC_{31}	1	2	1	1	2
SC_{32}	1/2	1	2	2	2
SC_{33}	1	1/2	1	2	2
SC_{34}	1	1/2	1/2	1	1
SC_{35}	1/2	1/2	1/2	1	1

Attributes	**NW**	**λ_{max}**	**CI**	**RI**	**CR**
Storage (SC_{31})	0.1884	5.0864	0.0216	1.12	0.0193
Logistics (SC_{32})	0.3281				
Replenish (SC_{33})	0.2164				

Labour (SC_{34})	0.1428				
Land (SC_{35})	0.1243				
Total Weight	1.000				

Cooperation (C_4) attributes

	SC_{41}	SC_{42}	SC_{43}	SC_{44}	SC_{45}	SC_{46}
SC_{41}	1	1	5	4	4	5
SC_{42}	1	1	5	1	2	3
SC_{43}	1/5	1/5	1	1/2	2	1
SC_{44}	1/4	1	2	1	2	3
SC_{45}	1/4	1/2	1/2	1/2	1	1
SC_{46}	1/5	1/3	1	1/3	1	1

Attributes	**NW**	λ_{max}	**CI**	**RI**	**CR**
Host government (SC_{41})	0.3678	6.2325	0.0465	1.24	0.0375
United Nations (SC_{42})	0.2442				
Neighbour countries (SC_{43})	0.0804				
Logistics agents (SC_{44})	0.1620				
International NGOs (SC_{45})	0.0764				
Local NGOs (SC_{46})	0.0692				
Total Weight	1.0000				

Logistics (C_5) attributes

	SC_{51}	SC_{52}	SC_{53}	SC_{54}
SC_{51}	1	1	1	1
SC_{52}	1	1	2	2
SC_{53}	1	1/2	1	1
SC_{54}	1	1/2	1	1

Attributes	**NW**	λ_{max}	**CI**	**RI**	**CR**
Airport (SC_{51})	0.2463	4.0681	0.0227	0.90	0.0252
Seaport (SC_{52})	0.3465				
Road (SC_{53})	0.2036				
Warehouse (SC_{54})	0.2036				
Total Weight	1.000				

Source: Author

C.2 Group Pairwise Comparison Result of Attributes of Case Study A

Attributes	UN Agency 1					UN Agency 2					UN Agency 3				
Major	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
C_1	0.0689	5.5336	0.0841	1.12	0.0751	0.0846	5.2428	0.0607	1.12	0.0542	0.0824	5.1228	0.0307	1.12	0.0274
C_2	0.2394					0.2564					0.2564				
C_3	0.2166					0.1481					0.2114				
C_4	0.2869					0.3286					0.2975				
C_5	0.1883					0.1823					0.1523				
Location	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{11}	0.0824	7.4332	0.0722	1.32	0.0547	0.0868	7.1884	0.0314	1.32	0.0238	0.0799	7.432	0.0720	1.32	0.0545
SC_{12}	0.2419					0.1752					0.1788				
SC_{13}	0.1641					0.1625					0.1614				
SC_{14}	0.1502					0.2028					0.1442				
SC_{15}	0.0391					0.0461					0.0659				
SC_{16}	0.1310					0.1076					0.1367				
SC_{17}	0.1913					0.2190					0.2331				
National stability	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{21}	0.5936	3.1032	0.0516	0.58	0.0890	0.6250	3.0352	0.0176	0.58	0.0303	0.5936	3.1032	0.0516	0.58	0.0890
SC_{22}	0.2493					0.2385					0.2493				
SC_{23}	0.1571					0.1365					0.1571				
Cost	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{31}	0.2384	5.1188	0.0297	1.12	0.0265	0.1932	5.0692	0.0173	1.12	0.0154	0.1884	5.0864	0.0216	1.12	0.0193
SC_{32}	0.2166					0.2880					0.3281				
SC_{33}	0.1948					0.2498					0.2164				
SC_{34}	0.2384					0.1440					0.1428				
SC_{35}	0.1118					0.1250					0.1243				
Cooperation	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{41}	0.3853	6.251	0.0502	1.24	0.0405	0.3866	6.174	0.0348	1.24	0.0281	0.4440	6.2855	0.0571	1.24	0.0460
SC_{42}	0.2900					0.2982					0.1702				
SC_{43}	0.0909					0.0809					0.0914				
SC_{44}	0.1070					0.1091					0.1538				
SC_{45}	0.0633					0.0639					0.0626				
SC_{46}	0.0635					0.0613					0.0780				
Logistics	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{51}	0.2389	4.2085	0.0695	0.90	0.0772	0.2463	4.0681	0.0227	0.90	0.0252	0.2389	4.2085	0.0695	0.90	0.0772
SC_{52}	0.3427					0.3465					0.4039				
SC_{53}	0.1448					0.2036					0.1665				
SC_{54}	0.2735					0.2036					0.1907				

C.3 Sensitivity Analysis Conditions of Sub-attributes (Case Study A)

	Conditions																								
Weights	Main	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
w_1	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042	0.074	0.049	0.032	0.028	0.107	0.071	0.023	0.047	0.022	0.020	0.037	0.052	0.031	0.031
w_2	0.016	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042	0.074	0.049	0.032	0.028	0.107	0.071	0.023	0.047	0.022	0.020	0.037	0.052	0.031
w_3	0.018	0.018	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042	0.074	0.049	0.032	0.028	0.107	0.071	0.023	0.047	0.022	0.020	0.037	0.052
w_4	0.018	0.018	0.018	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042	0.074	0.049	0.032	0.028	0.107	0.071	0.023	0.047	0.022	0.020	0.037
w_5	0.004	0.004	0.004	0.004	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042	0.074	0.049	0.032	0.028	0.107	0.071	0.023	0.047	0.022	0.020
w_6	0.012	0.012	0.012	0.012	0.012	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042	0.074	0.049	0.032	0.028	0.107	0.071	0.023	0.047	0.022
w_7	0.023	0.023	0.023	0.023	0.023	0.023	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042	0.074	0.049	0.032	0.028	0.107	0.071	0.023	0.047
w_8	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042	0.074	0.049	0.032	0.028	0.107	0.071	0.023
w_9	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042	0.074	0.049	0.032	0.028	0.107	0.071
w_{10}	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042	0.074	0.049	0.032	0.028	0.107
w_{11}	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042	0.074	0.049	0.032	0.028
w_{12}	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042	0.074	0.049	0.032
w_{13}	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042	0.074	0.049
w_{14}	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042	0.074
w_{15}	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044	0.042
w_{16}	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.107	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071	0.044
w_{17}	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112	0.071
w_{18}	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.008	0.016	0.018	0.018	0.004	0.012	0.023	0.112
w_{19}	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.008	0.016	0.018	0.018	0.004	0.012	0.023
w_{20}	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.008	0.016	0.018	0.018	0.004	0.012
w_{21}	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.008	0.016	0.018	0.018	0.004
w_{22}	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.008	0.016	0.018	0.018
w_{23}	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.008	0.016	0.018
w_{24}	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.008	0.016
w_{25}	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.008

Note: *w* - weight

Source: Author

C.4 Fuzzy evaluation matrix of sub-attributes for case study A

Attribute	Location A	Location B	Location C	Location D	Location E
SC_{11}	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)	P (0.15, 0.30, 0.45)
SC_{12}	F (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)	F (0.35, 0.50, 0.65)
SC_{13}	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)
SC_{14}	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)	P (0.15, 0.30, 0.45)
SC_{15}	P (0.15, 0.30, 0.45)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)
SC_{16}	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)	F (0.35, 0.50, 0.65)
SC_{17}	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)
SC_{21}	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	P (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)	F (0.35, 0.50, 0.65)
SC_{22}	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)	F (0.35, 0.50, 0.65)
SC_{23}	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)
SC_{31}	F (0.35, 0.50, 0.65)	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)
SC_{32}	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)	P (0.15, 0.30, 0.45)
SC_{33}	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)
SC_{34}	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)	F (0.35, 0.50, 0.65)
SC_{35}	F (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)	F (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)	F (0.35, 0.50, 0.65)
SC_{41}	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)
SC_{42}	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)
SC_{43}	F (0.35, 0.50, 0.65)	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)
SC_{44}	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)
SC_{45}	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)	F (0.35, 0.50, 0.65)
SC_{46}	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)
SC_{51}	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)
SC_{52}	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)
SC_{53}	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)	P (0.15, 0.30, 0.45)
SC_{54}	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)	P (0.15, 0.30, 0.45)

Note: F – Fair, P - Poor

Source: Author

Fuzzy weighted evaluation matrix for sub-attributes for case study A

Attribute	Location A	Location B	Location C	Location D	Location E
SC_{11}	(0.003, 0.004, 0.005)	(0.003, 0.004, 0.005)	(0.001, 0.002, 0.003)	(0.003, 0.004, 0.005)	(0.001, 0.002, 0.003)
SC_{12}	(0.005, 0.008, 0.010)	(0.002, 0.004, 0.007)	(0.002, 0.004, 0.007)	(0.002, 0.004, 0.007)	(0.005, 0.008, 0.010)
SC_{13}	(0.006, 0.009, 0.012)	(0.006, 0.009, 0.012)	(0.006, 0.009, 0.012)	(0.006, 0.009, 0.012)	(0.006, 0.009, 0.012)
SC_{14}	(0.006, 0.009, 0.011)	(0.006, 0.009, 0.011)	(0.002, 0.005, 0.008)	(0.006, 0.009, 0.011)	(0.002, 0.005, 0.008)
SC_{15}	(0.000, 0.001, 0.001)	(0.001, 0.002, 0.002)	(0.001, 0.002, 0.002)	(0.001, 0.002, 0.002)	(0.000, 0.001, 0.001)
SC_{16}	(0.004, 0.006, 0.007)	(0.001, 0.003, 0.005)	(0.004, 0.006, 0.007)	(0.004, 0.006, 0.007)	(0.004, 0.006, 0.007)
SC_{17}	(0.011, 0.014, 0.039)	(0.011, 0.014, 0.039)	(0.011, 0.014, 0.039)	(0.011, 0.014, 0.039)	(0.011, 0.014, 0.039)
SC_{21}	(0.039, 0.056, 0.073)	(0.039, 0.056, 0.073)	(0.016, 0.033, 0.050)	(0.016, 0.033, 0.050)	(0.039, 0.056, 0.073)
SC_{22}	(0.024, 0.035, 0.046)	(0.024, 0.035, 0.046)	(0.010, 0.021, 0.031)	(0.010, 0.021, 0.031)	(0.024, 0.035, 0.046)
SC_{23}	(0.015, 0.022, 0.028)	(0.015, 0.022, 0.028)	(0.006, 0.013, 0.020)	(0.006, 0.013, 0.020)	(0.006, 0.013, 0.020)
SC_{31}	(0.019, 0.021, 0.027)	(0.019, 0.021, 0.027)	(0.019, 0.021, 0.027)	(0.006, 0.012, 0.019)	(0.019, 0.021, 0.027)
SC_{32}	(0.026, 0.037, 0.048)	(0.026, 0.037, 0.048)	(0.026, 0.037, 0.048)	(0.026, 0.037, 0.048)	(0.011, 0.022, 0.033)
SC_{33}	(0.017, 0.002, 0.031)	(0.017, 0.002, 0.031)	(0.007, 0.014, 0.022)	(0.017, 0.002, 0.031)	(0.017, 0.002, 0.031)
SC_{34}	(0.011, 0.016, 0.021)	(0.004, 0.009, 0.014)	(0.011, 0.016, 0.021)	(0.011, 0.016, 0.021)	(0.011, 0.016, 0.021)
SC_{35}	(0.009, 0.014, 0.018)	(0.004, 0.008, 0.012)	(0.009, 0.014, 0.018)	(0.004, 0.008, 0.012)	(0.009, 0.014, 0.018)
SC_{41}	(0.037, 0.053, 0.069)	(0.037, 0.053, 0.069)	(0.016, 0.032, 0.048)	(0.016, 0.032, 0.048)	(0.016, 0.032, 0.048)
SC_{42}	(0.024, 0.035, 0.016)	(0.024, 0.035, 0.016)	(0.010, 0.021, 0.031)	(0.024, 0.035, 0.016)	(0.024, 0.035, 0.016)
SC_{43}	(0.008, 0.011, 0.015)	(0.008, 0.011, 0.015)	(0.008, 0.011, 0.015)	(0.035, 0.007, 0.010)	(0.008, 0.011, 0.015)
SC_{44}	(0.016, 0.023, 0.030)	(0.016, 0.023, 0.030)	(0.007, 0.014, 0.021)	(0.016, 0.023, 0.030)	(0.016, 0.023, 0.030)
SC_{45}	(0.007, 0.011, 0.014)	(0.003, 0.006, 0.009)	(0.007, 0.011, 0.014)	(0.007, 0.011, 0.014)	(0.007, 0.011, 0.014)
SC_{46}	(0.007, 0.011, 0.013)	(0.007, 0.011, 0.013)	(0.007, 0.011, 0.013)	(0.007, 0.011, 0.013)	(0.007, 0.011, 0.013)
SC_{51}	(0.013, 0.018, 0.024)	(0.013, 0.018, 0.024)	(0.005, 0.011, 0.016)	(0.005, 0.011, 0.016)	(0.005, 0.011, 0.016)
SC_{52}	(0.018, 0.026, 0.034)	(0.018, 0.026, 0.034)	(0.007, 0.015, 0.023)	(0.007, 0.015, 0.023)	(0.007, 0.015, 0.023)
SC_{53}	(0.010, 0.015, 0.020)	(0.010, 0.015, 0.020)	(0.004, 0.009, 0.013)	(0.010, 0.015, 0.020)	(0.004, 0.009, 0.013)
SC_{54}	(0.017, 0.021, 0.031)	(0.010, 0.015, 0.020)	(0.004, 0.009, 0.013)	(0.004, 0.009, 0.013)	(0.004, 0.009, 0.013)

Source: Author

C.5 Matrix for Criteria for Overall Result of Case Study B

Major attributes

	C_a	C_b	C_c	C_d	C_e
C_a	1	2	4	1/2	6
C_b	1/2	1	4	1/2	4
C_c	1/4	1/4	1	1/4	3
C_d	2	2	4	1	6
C_e	1/6	1/4	1/3	1/6	1

Attributes	**NW**	**λ_{max}**	**CI**	**RI**	**CR**
Distance (C_a)	0.2875	5.172	0.0430	1.12	0.0383
Security (C_b)	0.2032				
Office facilities (C_c)	0.0843				
Warehouse facilities (C_d)	0.3797				
Convenience (C_e)	0.0453				
Total Weight	1.000				

Distance (C_a) attributes

	SC_{a1}	SC_{a2}	SC_{a3}	SC_{a4}	SC_{a5}	SC_{a6}
SC_{a1}	1	2	1/4	1/3	4	4
SC_{a2}	1/2	1	1/2	1/2	4	2
SC_{a3}	4	2	1	1/2	2	5
SC_{a4}	3	2	2	1	6	6
SC_{a5}	1/4	1/4	1/2	1/6	1	1/2
SC_{a6}	1/4	1/2	1/5	1/6	2	1

Attributes	**NW**	**λ_{max}**	**CI**	**RI**	**CR**
Jebel Ali seaport (SC_{a1})	0.1575	6.4275	0.0855	1.24	0.0689
Dubai Int'l airport (SC_{a2})	0.1272				
Al Maktoum airport (SC_{a3})	0.2615				
Sharjah airport (SC_{a4})	0.3446				
Abu Dhabi airport (SC_{a5})	0.0520				
MOFA (SC_{a6})	0.0572				
Total Weight	1.000				

Security (C_b) attributes

	SC_{b1}	SC_{b2}	SC_{b3}	SC_{b4}	SC_{b5}
SC_{b1}	1	2	3	5	3
SC_{b2}	1/2	1	2	2	1/2
SC_{b3}	1/3	1/2	1	2	1/2
SC_{b4}	1/5	1/2	1/2	1	1/2
SC_{b6}	1/3	2	2	2	1

Attributes	**NW**	**λ_{max}**	**CI**	**RI**	**CR**
Warehouse (SC_{b1})	0.4178	5.1384	0.0346	1.12	0.0308
Fire fighting station (SC_{b2})	0.1717				
Police station (SC_{b3})	0.1183				
Hospital (SC_{b4})	0.0804				
Road Safety (SC_{b5})	0.2118				
Total Weight	1.0000				

Office facilities (C$_c$) attributes

	SC_{c1}	SC_{c2}	SC_{c3}	SC_{c4}	
SC_{c1}	1	1/2	1/2	1/2	
SC_{c2}	2	1	1	2	
SC_{c3}	2	1	1	4	
SC_{c4}	2	1/2	1/4	1	

Criteria	**NW**	**λ_{max}**	**CI**	**RI**	**CR**
Diplomatic work (SC_{c1})	0.1356	4.2085	0.0695	0.90	0.0105
IT/Communication (SC_{c2})	0.3106				
Warehouse distance (SC_{c3})	0.3894				
Modular space (SC_{c4})	0.1644				
Total Weight	1.000				

Warehouse facilities (C$_d$) attributes

	SC_{d1}	SC_{d2}	SC_{d3}	SC_{d4}	SC_{d5}	SC_{d6}	SC_{d7}	SC_{d8}	SC_{d9}
SC_{d1}	1	7	7	7	5	5	8	5	7
SC_{d2}	1/7	1	3	3	1/2	1/2	5	1/3	1/2
SC_{d3}	1/7	1/3	1	1/4	1/5	1/5	6	1/3	1/2
SC_{d4}	1/7	1/3	4	1	1/3	1/2	2	1/2	1/2
SC_{d5}	1/5	2	5	3	1	1/2	6	1/2	3
SC_{d6}	1/5	2	5	2	2	1	7	1	1
SC_{d7}	1/8	1/5	1/6	1/2	1/6	1/7	1	1/3	1/4
SC_{d8}	1/5	3	3	2	2	1	3	1	1
SC_{d9}	1/7	2	2	2	1/3	1	4	1	1

Attributes	**NW**	**λ_{max}**	**CI**	**RI**	**CR**
Floor capacity (SC_{d1})	0.3949	9.708	0.0885	1.45	0.0610
Open storage (SC_{d2})	0.0690				
Office facility (SC_{d3})	0.0378				
Spill-over area (SC_{d4})	0.0516				
Ceiling height (SC_{d5})	0.1154				
Loading bays (SC_{d6})	0.1193				
Flood lights (SC_{d7})	0.0208				
Openings (SC_{d8})	0.1109				
Doors at both ends (SC_{d9})	0.0803				
Total Weight	1.0000				

Convenience (C$_e$) attributes

	SC_{e1}	SC_{e2}	SC_{e3}	SC_{e4}	SC_{e5}	SC_{e6}
SC_{e1}	1	1	3	1/3	1/3	1/3
SC_{e2}	1	1	1/3	1/3	1/3	1/3
SC_{e3}	1/3	3	1	1/3	1/3	1/4
SC_{e4}	3	3	3	1	2	1/2
SC_{e5}	3	3	3	1/2	1	1/3
SC_{e6}	3	3	4	2	3	1

Attributes	**NW**	**λ_{max}**	**CI**	**RI**	**CR**
Cafeteria (SC_{e1})	0.1024	6.4255	0.0851	1.24	0.0686
Mini-mart (SC_{e2})	0.0684				
ATM (SC_{e3})	0.0832				
Main City (SC_{e4})	0.2327				
Residential (SC_{e5})	0.1790				
Transportation (SC_{e6})	0.3343				
Total Weight	1.000				

Source: Author

C.6 Group Pairwise Comparison for Group Results of Case Study B

Attributes	UN Agency 1					UN Agency 2					UN Agency 3				
Major	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
C_a	0.3328	5.1096	0.0274	1.12	0.0253	0.1876	5.31	0.0775	1.12	0.0691	0.2372	5.0868	0.0217	1.12	0.0193
C_b	0.1165					0.2915					0.1923				
C_c	0.0892					0.0743					0.0828				
C_d	0.4023					0.4055					0.4347				
C_e	0.0592					0.0411					0.0530				
Distance	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{a1}	0.1366	6.4885	0.0977	1.24	0.0787	0.1249	6.459	0.0918	1.24	0.0740	0.1789	6.3741	0.0928	1.24	0.0748
SC_{a2}	0.0393					0.2921					0.2100				
SC_{a3}	0.4375					0.1441					0.1880				
SC_{a4}	0.3020					0.3431					0.2714				
SC_{a5}	0.0307					0.0410					0.0472				
SC_{a6}	0.0539					0.0548					0.1045				
Security	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{b1}	0.3630	5.2524	0.0631	1.12	0.0563	0.4316	5.2075	0.0581	1.12	0.0518	0.3805	5.1368	0.0342	1.12	0.0305
SC_{b2}	0.1297					0.1837					0.1820				
SC_{b3}	0.1510					0.0984					0.1281				
SC_{b4}	0.1452					0.0445					0.1065				
SC_{b5}	0.2110					0.2418					0.2029				
Office facilities	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{c1}	0.2855	4.2085	0.0695	0.90	0.0772	0.0705	4.1557	0.0519	0.9	0.0576	0.1671	5.1216	0.0304	0.9	0.0377
SC_{c2}	0.2050					0.3572					0.3131				
SC_{c3}	0.3461					0.4387					0.4085				
SC_{c4}	0.1634					0.1336					0.1113				
Warehouse facilities	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{d1}	0.3591	9.792	0.0990	1.45	0.0682	0.3585	9.7408	0.0926	1.45	0.0638	0.3132	9.7488	0.0936	1.45	0.0654
SC_{d2}	0.0959					0.0476					0.0774				
SC_{d3}	0.0537					0.0319					0.0402				
SC_{d4}	0.0958					0.0417					0.0515				
SC_{d5}	0.1175					0.0928					0.1529				
SC_{d6}	0.1236					0.1295					0.1216				
SC_{d7}	0.0326					0.0263					0.0294				
SC_{d8}	0.0770					0.1812					0.1264				
SC_{d9}	0.0448					0.0905					0.0874				
Convenience	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{e1}	0.1436	6.49	0.0980	1.24	0.0790	0.1102	6.4655	0.0931	1.24	0.0750	0.1098	6.379	0.0758	1.24	0.0611
SC_{e2}	0.1631					0.0942					0.0687				
SC_{e3}	0.1069					0.0735					0.0561				
SC_{e4}	0.1958					0.2044					0.2598				
SC_{e5}	0.2305					0.1701					0.1892				
SC_{e6}	0.1698					0.3476					0.3164				

C.6 Group Pairwise Comparison for Group Results of Case Study B (Cont'd)

Attributes	UN Agencies					NGO					Company				
Major	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
C_a	0.2388	5.1236	0.0309	1.12	0.0275	0.2042	5.302	0.0755	1.12	0.0674	0.2617	5.2356	0.0589	1.12	0.0525
C_b	0.1804					0.2841					0.2702				
C_c	0.0824					0.1157					0.0899				
C_d	0.4416					0.3492					0.3295				
C_e	0.0568					0.0468					0.0487				
Distance	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{a1}	0.1301	6.4945	0.0989	1.24	0.0797	0.1381	6.468	0.0936	1.24	0.0754	0.1210	6.2455	0.0491	1.24	0.0395
SC_{a2}	0.1811					0.1605					0.2104				
SC_{a3}	0.2494					0.1942					0.2030				
SC_{a4}	0.3168					0.3216					0.3702				
SC_{a5}	0.0457					0.0689					0.0400				
SC_{a6}	0.0769					0.1167					0.0554				
Security	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{b1}	0.3878	5.156	0.0390	1.12	0.0348	0.4436	5.2296	0.0574	1.12	0.0512	0.4659	5.2828	0.0707	1.12	0.0631
SC_{b2}	0.1848					0.1981					0.1807				
SC_{b3}	0.1491					0.0936					0.1019				
SC_{b4}	0.1226					0.0595					0.0550				
SC_{b5}	0.1557					0.2052					0.1965				
Office facilities	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{c1}	0.2046	4.0681	0.0227	0.90	0.0252	0.1064	4.1326	0.0442	0.90	0.0491	0.1021	4.1572	0.0524	0.90	0.0588
SC_{c2}	0.2879					0.3940					0.3532				
SC_{c3}	0.3384					0.2948					0.4157				
SC_{c4}	0.1691					0.2048					0.1290				
Warehouse facilities	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{d1}	0.3558	9.7208	0.0901	1.45	0.0621	0.3661	9.7336	0.0917	1.45	0.0632	0.3920	9.7512	0.0939	1.45	0.064
SC_{d2}	0.0790					0.0512					0.0462				
SC_{d3}	0.0379					0.0388					0.0388				
SC_{d4}	0.0464					0.0457					0.0456				
SC_{d5}	0.1349					0.1278					0.1243				
SC_{d6}	0.1428					0.1368					0.1303				
SC_{d7}	0.0181					0.0249					0.0242				
SC_{d8}	0.1209					0.1291					0.1159				
SC_{d9}	0.0642					0.0796					0.0827				
Convenience	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR	NW	λ_{max}	CI	RI	CR
SC_{e1}	0.1264	6.6476	0.0952	1.24	0.0767	0.0997	6.4685	0.0937	1.24	0.0755	0.0997	6.4685	0.0937	1.24	0.0755
SC_{e2}	0.0911					0.0664					0.0664				
SC_{e3}	0.1023					0.0627					0.0627				
SC_{e4}	0.2075					0.2370					0.2370				
SC_{e5}	0.1839					0.2048					0.2048				
SC_{e6}	0.2888					0.3294					0.3294				

C.7 Sensitivity Analysis Conditions of Sub-attributes (Case Study B)

Weights	Conditions																													
	Main	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
0.045	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}	w_{19}	w_{20}	w_{21}	w_{22}	w_{23}	w_{24}	w_{25}	w_{26}	w_{27}	w_{28}	w_{29}	w_{30}
0.036	w_{2}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}	w_{19}	w_{20}	w_{21}	w_{22}	w_{23}	w_{24}	w_{25}	w_{26}	w_{27}	w_{28}	w_{29}
0.075	w_{3}	w_{3}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}	w_{19}	w_{20}	w_{21}	w_{22}	w_{23}	w_{24}	w_{25}	w_{26}	w_{27}	w_{28}
0.093	w_{4}	w_{4}	w_{4}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}	w_{19}	w_{20}	w_{21}	w_{22}	w_{23}	w_{24}	w_{25}	w_{26}	w_{27}
0.014	w_{5}	w_{5}	w_{5}	w_{5}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}	w_{19}	w_{20}	w_{21}	w_{22}	w_{23}	w_{24}	w_{25}	w_{26}
0.016	w_{6}	w_{6}	w_{6}	w_{6}	w_{6}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}	w_{19}	w_{20}	w_{21}	w_{22}	w_{23}	w_{24}	w_{25}
0.084	w_{7}	w_{7}	w_{7}	w_{7}	w_{7}	w_{7}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}	w_{19}	w_{20}	w_{21}	w_{22}	w_{23}	w_{24}
0.034	w_{8}	w_{8}	w_{8}	w_{8}	w_{8}	w_{8}	w_{8}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}	w_{19}	w_{20}	w_{21}	w_{22}	w_{23}
0.024	w_{9}	w_{9}	w_{9}	w_{9}	w_{9}	w_{9}	w_{9}	w_{9}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}	w_{19}	w_{20}	w_{21}	w_{22}
0.016	w_{10}	w_{10}	w_{10}	w_{10}	w_{10}	w_{10}	w_{10}	w_{10}	w_{10}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}	w_{19}	w_{20}	w_{21}
0.043	w_{11}	w_{11}	w_{11}	w_{11}	w_{11}	w_{11}	w_{11}	w_{11}	w_{11}	w_{11}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}	w_{19}	w_{20}
0.012	w_{12}	w_{12}	w_{12}	w_{12}	w_{12}	w_{12}	w_{12}	w_{12}	w_{12}	w_{12}	w_{12}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}	w_{19}
0.026	w_{13}	w_{13}	w_{13}	w_{13}	w_{13}	w_{13}	w_{13}	w_{13}	w_{13}	w_{13}	w_{13}	w_{13}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}	w_{18}
0.032	w_{14}	w_{14}	w_{14}	w_{14}	w_{14}	w_{14}	w_{14}	w_{14}	w_{14}	w_{14}	w_{14}	w_{14}	w_{14}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}	w_{17}
0.013	w_{15}	w_{15}	w_{15}	w_{15}	w_{15}	w_{15}	w_{15}	w_{15}	w_{15}	w_{15}	w_{15}	w_{15}	w_{15}	w_{15}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}	w_{16}
0.015	w_{16}	w_{16}	w_{16}	w_{16}	w_{16}	w_{16}	w_{16}	w_{16}	w_{16}	w_{16}	w_{16}	w_{16}	w_{16}	w_{16}	w_{16}	w_{16}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}	w_{15}
0.026	w_{17}	w_{17}	w_{17}	w_{17}	w_{17}	w_{17}	w_{17}	w_{17}	w_{17}	w_{17}	w_{17}	w_{17}	w_{17}	w_{17}	w_{17}	w_{17}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}	w_{14}
0.014	w_{18}	w_{18}	w_{18}	w_{18}	w_{18}	w_{18}	w_{18}	w_{18}	w_{18}	w_{18}	w_{18}	w_{18}	w_{18}	w_{18}	w_{18}	w_{18}	w_{18}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}	w_{13}
0.019	w_{19}	w_{19}	w_{19}	w_{19}	w_{19}	w_{19}	w_{19}	w_{19}	w_{19}	w_{19}	w_{19}	w_{19}	w_{19}	w_{19}	w_{19}	w_{19}	w_{19}	w_{19}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}	w_{12}
0.043	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{20}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}	w_{11}
0.045	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{21}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}	w_{10}
0.009	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{22}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}	w_{9}
0.041	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{23}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}	w_{8}
0.030	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{24}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}	w_{7}
0.006	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{25}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}	w_{6}
0.003	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{26}	w_{1}	w_{2}	w_{3}	w_{4}	w_{5}
0.004	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{27}	w_{1}	w_{2}	w_{3}	w_{4}
0.011	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{28}	w_{1}	w_{2}	w_{3}
0.009	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{29}	w_{1}	w_{2}
0.015	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{30}	w_{1}

Source: Author

C.8 Fuzzy Evalution Matrix of Sub-Attributes for Case Study B

	V	W	X	Y	Z
SC_{a1}	P (0.15, 0.30, 0.45)\	P (0.15, 0.30, 0.45)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)
SC_{a2}	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)	F (0.35, 0.50, 0.65)
SC_{a3}	P (0.15, 0.30, 0.45)	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)
SC_{a4}	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)	F (0.35, 0.50, 0.65)
SC_{a5}	P (0.15, 0.30, 0.45)	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)
SC_{a6}	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)	F (0.35, 0.50, 0.65)
SC_{b1}	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)	F (0.35, 0.50, 0.65)
SC_{b2}	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)	P (0.15, 0.30, 0.45)
SC_{b3}	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)
SC_{b4}	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)
SC_{b5}	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)
SC_{c1}	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)	F (0.35, 0.50, 0.65)
SC_{c2}	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)
SC_{c3}	F (0.35, 0.50, 0.65)	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)
SC_{c4}	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)	P (0.15, 0.30, 0.45)
SC_{d1}	P (0.15, 0.30, 0.45)	P (0.15, 0.30, 0.45)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)
SC_{d2}	F (0.35, 0.50, 0.65)	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)
SC_{d3}	F (0.35, 0.50, 0.65)	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)
SC_{d4}	F (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)	F (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)	F (0.35, 0.50, 0.65)
SC_{d5}	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)	F (0.35, 0.50, 0.65)
SC_{d6}	P(0.15, 0.30, 0.45)\	P (0.15, 0.30, 0.45)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)
SC_{d7}	F (0.35, 0.50, 0.65)	VP (0.00, 0.10, 0.25)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)
SC_{d8}	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)	F (0.35, 0.50, 0.65)
SC_{d9}	F (0.35, 0.50, 0.65)	VP(0.00, 0.10, 0.25)	F (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)	F (0.35, 0.50, 0.65)
SC_{e1}	F (0.35, 0.50, 0.65)	VP (0.00, 0.10, 0.25)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	P (0.15, 0.30, 0.45)
SC_{e2}	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)	P (0.15, 0.30, 0.45)
SC_{e3}	G (0.55, 0.70, 0.85)	VP (0.00, 0.10, 0.25)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)
SC_{e4}	G(0.55, 0.70, 0.85)	P (0.15, 0.30, 0.45)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)
SC_{e5}	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)	F (0.35, 0.50, 0.65)
SC_{e6}	F (0.35, 0.50, 0.65)	VP (0.00, 0.10, 0.25)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)	F (0.35, 0.50, 0.65)

Source: Author

Fuzzy weighted evaluation matrix of sub-attributes case study B

	V	W	X	Y	Z
SC_{a1}	(0.006, 0.013, 0.020)	(0.006, 0.013, 0.020)	(0.015, 0.022, 0.029)	(0.015, 0.022, 0.029)	(0.015, 0.022, 0.029)
SC_{a2}	(0.012, 0.018, 0.023)	(0.005, 0.010, 0.016)	(0.012, 0.018, 0.023)	(0.012, 0.018, 0.023)	(0.012, 0.018, 0.023)
SC_{a3}	(0.011, 0.022, 0.033)	(0.026, 0.037, 0.048)	(0.026, 0.037, 0.048)	(0.026, 0.037, 0.048)	(0.026, 0.037, 0.048)
SC_{a4}	(0.032, 0.046, 0.060)	(0.013, 0.027, 0.041)	(0.032, 0.046, 0.060)	(0.032, 0.046, 0.060)	(0.032, 0.046, 0.060)
SC_{a5}	(0.002, 0.004, 0.006)	(0.005, 0.007, 0.009)	(0.005, 0.007, 0.009)	(0.005, 0.007, 0.009)	(0.005, 0.007, 0.009)
SC_{a6}	(0.005, 0.008, 0.010)	(0.002, 0.004, 0.007)	(0.005, 0.008, 0.010)	(0.005, 0.008, 0.010)	(0.005, 0.008, 0.010)
SC_{b1}	(0.029, 0.042, 0.055)	(0.012, 0.025, 0.038)	(0.029, 0.042, 0.055)	(0.029, 0.042, 0.055)	(0.029, 0.042, 0.055)
SC_{b2}	(0.012, 0.017, 0.022)	(0.012, 0.017, 0.022)	(0.012, 0.017, 0.022)	(0.012, 0.017, 0.022)	(0.005, 0.010, 0.015)
SC_{b3}	(0.008, 0.012, 0.015)	(0.008, 0.012, 0.015)	(0.008, 0.012, 0.015)	(0.008, 0.012, 0.015)	(0.008, 0.012, 0.015)
SC_{b4}	(0.005, 0.008, 0.010)	(0.005, 0.008, 0.010)	(0.005, 0.008, 0.010)	(0.005, 0.008, 0.010)	(0.005, 0.008, 0.010)
SC_{b5}	(0.015, 0.021, 0.027)	(0.015, 0.021, 0.027)	(0.015, 0.021, 0.027)	(0.015, 0.021, 0.027)	(0.015, 0.021, 0.027)
SC_{c1}	(0.004, 0.006, 0.008)	(0.009, 0.013, 0.016)	(0.009, 0.013, 0.016)	(0.009, 0.013, 0.016)	(0.009, 0.013, 0.016)
SC_{c2}	(0.009, 0.013, 0.016)	(0.009, 0.013, 0.016)	(0.009, 0.013, 0.016)	(0.009, 0.013, 0.016)	(0.009, 0.013, 0.016)
SC_{c3}	(0.011, 0.016, 0.021)	(0.011, 0.016, 0.021)	(0.011, 0.016, 0.021)	(0.004, 0.009, 0.014)	(0.011, 0.016, 0.021)
SC_{c4}	(0.004, 0.006, 0.008)	(0.004, 0.006, 0.008)	(0.004, 0.006, 0.008)	(0.004, 0.006, 0.008)	(0.002, 0.004, 0.006)
SC_{d1}	(0.022, 0.045, 0.067)	(0.022, 0.045, 0.067)	(0.052, 0.075, 0.097)	(0.052, 0.075, 0.097)	(0.052, 0.075, 0.097)
SC_{d2}	(0.009, 0.013, 0.017)	(0.009, 0.013, 0.017)	(0.009, 0.013, 0.017)	(0.003, 0.007, 0.011)	(0.009, 0.013, 0.017)
SC_{d3}	(0.004, 0.007, 0.009)	(0.002, 0.004, 0.006)	(0.004, 0.007, 0.009)	(0.002, 0.004, 0.006)	(0.004, 0.007, 0.009)
SC_{d4}	(0.006, 0.009, 0.012)	(0.002, 0.005, 0.008)	(0.006, 0.009, 0.012)	(0.002, 0.005, 0.008)	(0.006, 0.009, 0.012)
SC_{d5}	(0.015, 0.021, 0.002)	(0.006, 0.013, 0.019)	(0.015, 0.021, 0.002)	(0.015, 0.021, 0.002)	(0.015, 0.021, 0.002)
SC_{d6}	(0.015, 0.022, 0.029)	(0.006, 0.013, 0.020)	(0.015, 0.022, 0.029)	(0.015, 0.022, 0.029)	(0.015, 0.022, 0.029)
SC_{d7}	(0.003, 0.004, 0.005)	(0.000, 0.000 ,0.002)	(0.003, 0.004, 0.005)	(0.003, 0.004, 0.005)	(0.003, 0.004, 0.005)
SC_{d8}	(0.014, 0.020, 0.027)	(0.006, 0.012, 0.018)	(0.014, 0.020, 0.027)	(0.014, 0.020, 0.027)	(0.006, 0.012, 0.018)
SC_{d9}	(0.010, 0.015, 0.019)	(0.000, 0.003, 0.007)	(0.010, 0.015, 0.019)	(0.004, 0.009, 0.013)	(0.010, 0.015, 0.019)
SC_{e1}	(0.002, 0.003, 0.004)	(0.000, 0.001, 0.001)	(0.001, 0.001, 0.002)	(0.001, 0.001, 0.002)	(0.000, 0.001, 0.001)
SC_{e2}	(0.001, 0.002, 0.003)	(0.000, 0.001, 0.001)	(0.001, 0.001, 0.002)	(0.001, 0.001, 0.002)	(0.000, 0.001, 0.001)
SC_{e3}	(0.002, 0.003, 0.003)	(0.000, 0.000, 0.001)	(0.001, 0.002, 0.002)	(0.001, 0.002, 0.002)	(0.001, 0.002, 0.002)
SC_{e4}	(0.006, 0.007, 0.009)	(0.001, 0.003, 0.005)	(0.003, 0.005, 0.007)	(0.003, 0.005, 0.007)	(0.003, 0.005, 0.007)
SC_{e5}	(0.003, 0.004, 0.006)	(0.001, 0.002, 0.004)	(0.003, 0.004, 0.006)	(0.003, 0.004, 0.006)	(0.003, 0.004, 0.006)
SC_{e6}	(0.005, 0.007, 0.009)	(0.000, 0.001, 0.003)	(0.005, 0.007, 0.009)	(0.005, 0.007, 0.009)	(0.005, 0.007, 0.009)

Source: Author

Appendix D.1Analysis Methods Used in AHP Location Decision Problem

No.	Year	Authors	Application	Other tools used
1	1995	Aguilar-Manjarrez and Ross	Aquaculture	GIS
2	1999	Akash *et al.*	Plant	-
3	2000	Alberto	Warehouse	-
4	1997	Alphonce	Store	-
5	2010	Amiri	Plant	Fuzzy TOPSIS
6	2010	Aragones-Beltran *et al.*	Landfill	ANP
7	2004	Aras *et al.*	Wind observation	-
8	1999	Badri	Plant	Goal programming
9	2011	Bottero and Ferretti	Landfill	ANP
10	2006	Burnaz and Topcu	Retail store	ANP
11	1997	Charnpratheep *et al.*	Landfill	Fuzzy set theory, GIS
12	2008	Chou *et al.*	Hotel	Fuzzy set theory
13	2001	Chuang	General	QFD
14	2009	Cinar	Bank	Fuzzy set theory, TOPSIS
15	2010	Demirel *et al.*	Warehouse	Fuzzy set theory, Choquet Integral
16	2008	Dey and Ramcharan	Plant	-
17	2010	Ekmekcioglu *et al.*	Landfill	Fuzzy set theory, Fuzzy TOPSIS
18	1991	Erkut and Moran	Landfill	-
19	2009	Fernandez and Ruiz	Industry	-
20	2007	Gemitzi *et al.*	Landfill	GIS
21	1990	Hegde and Tadikamalla	Service terminal	-
22	1987	Hussein *et al.*	Plant	-
23	2006	Javaheri *et al.*	Landfill	GIS
24	2007	Kaboli *et al.*	General	Fuzzy set theory
25	2003	Kahraman *et al.*	Plant	Fuzzy set theory
26	2010	Kahraman *et al.*	General	Fuzzy set theory, Fuzzy TOPSIS
27	2008	Kannan *et al.*	Collecting centre	Fuzzy set theory, Reverse logistics
28	1989	Kashani	Landfill	GIS
29	1987	Kathawala and Gholamnezhad	General	-
30	2010	Kayikci	Logistics centre	Fuzzy set theory, Artificial neural network
31	2004	Kengpol	Distribution centre	Fuzzy set theory, Capital Investment model,
32	2003	Kontos *et al.*	Landfill	GIS
33	1996	Korpela and Tuominen	Warehouse	-
34	2011	Kuo	Distribution centre	Fuzzy set theory, ANP, TOPSIS, Fuzzy DEMATEL
35	1999	Kuo *et al.*	Store	Fuzzy set theory, Artificial neural network
36	2002	Kuo *et al.*	Store	Fuzzy set theory, Artificial neural network
37	2011	Kuo and Liang	Distribution centre	Fuzzy set theory, ANP, TOPSIS, DEMATEL
38	2009	Lee *et al.*	Wind observation	-
39	1991	Levine	General	-
40	2010a	Lin and Tsai	Hospital	ANP, TOPSIS
41	2010b	Lin and Tsai	Hospital	ANP, TOPSIS, Porter's diamond framework
42	2004	Lirn *et al.*	Port	-
43	1994	Min	Airport	-
44	1999	Min and Melachrinoudis	Distribution centre	-
45	2010	Moeindannini *et al.*	Landfill	GIS
46	2010	Mohajeri and Amin	Railway station	DEA
47	2010	Moshen *et al.*	Plant	-
48	1995	Mummolo	Landfill	-
49	2009	Naghadehi *et al.*	Plant	Fuzzy set theory
50	2010	Önut *et al.*	Shopping centre	Fuzzy set theory, Fuzzy TOPSIS
51	2008	Önut and Soner	Landfill	Fuzzy set theory, Fuzzy TOPSIS
52	2011	Özcan *et al.*	Warehouse	TOPSIS, ELECTRE, Grey Theory
53	2006	Partovi	General	ANP, QFD
54	2002	Sarkis and Sundarraj	Warehouse	ANP, Transhipment model
55	2006	Sener *et al.*	Landfill	GIS
56	2010	Sener *et al.*	Landfill	GIS
57	2011	Sener *et al.*	Landfill	GIS
58	1996	Siddiqui *et al.*	Landfill	GIS
59	1995	Sinuany-Stern *et al.*	Hospital	-
60	2011	Suarez-Vega *et al.*	Market	GIS
61	2001	Tseng *et al.*	Artificial reef	GIS
62	2002	Tzeng *et al.*	Restaurant	-
63	2006	Ugboma *et al.*	Port	-
64	2009	Vahidnia *et al.*	Hospital	Fuzzy set theory, GIS, *a*-cut based method
65	2003	Van der Kleij *et al.*	Airport	Monte Carlo
66	2009	Wang *et al.*	Landfill	GIS
67	2010	Yahaya *et al.*	Landfill	GIS
68	2007	Wu *et al.*	Hospital	-
69	1997	Yang and Lee	General	-
70	1995	Yurimoto and Masui	Plant	-
71	2009	Zheng *et al.*	Distribution centre	TOPSIS

Source: Author

D.2 Distribution of AHP Location Decision Problem

Journal title	Author name and published date	
Agricultural Systems	Alphonce (1997)	1
American Journal of Scientific Research	Yahaya *et al.* (2010)	1
Applied Geography	Srarez-Vega *et al.* (2011)	1
Aquaculture International	Aguilar-Manjarrez and Ross (1995)	1
Building and Environment	Wu *et al.* (2007)	1
Computers and Industrial Engineering	Kuo *et al.* (1999), Mohajeri and Amin (2010)	2
Computers in Industry	Kuo *et al.* (2002)	1
Electric Power Systems Research	Akas iet al. (1999)	1
Environment Monitory Assessment	Sener *et al.* (2011	1
Environmental Geology	Gemitzi *et al.* (2007), Sener *et al.* (2006)	2
Environmental Management	Kashani (1989)	1
European Journal of Operational Research	Hegde and Tadikamalla (1990), Sarkis and Sundarraj (2002)	2
Expert Systems with Applications	Amiri (2010), Demirel *et al.* (2010), Kuo (2011), Naghadehi *et al.* (2009), Özcan *et al.* (2011), Önut *et al.* (2010),	6
Facilities	Yang and Lee (1997)	1
Fisheries Science	Tseng *et al.* (2001)	1
Information Sciences	Karahaman *et al.* (2003)	1
International Journal of Advance Manufacturing Technology	Chuang (2001)	1
International Journal of Engineering Transactions A: Basics	Kaboli *et al.* (2007)	1
International Journal of Hospitality Management	Chou *et al.* (2008), Tzeng *et al.* (2002)	2
International Journal of Logistics	Alberto (2000)	1
International Journal of Management and Decision Making	Kannan *et al.* (2008)	1
International Journal of Management Science	Partovi (2006)	1
International Journal of Production Economics	Badri (1999), Kengpol (2004), Korpela and Tuominen (1996), Yurimoto and Masui (1995)	4
International Journal of Systems Sciences	Kathawala and Gholamnezhad (1987)	1
Iranian Journal of Environment Health Science Engineering	Javaheri *et al.* (2006)	1
Journal of Cleaner Production	Fernandez and Ruiz (2009)	1
Journal of Environmental Engineering	Siddiqui *et al.* (1996)	1
Journal of Environmental Management	Aragones-Beltran *et al.* (2010), Dey and Ramcharan (2008), Wang *et al.* (2009), Vahidnia *et al.* (2009)	4
Journal of Environmental Systems	Mummolo (1995)	1
Journal of Testing and Evaluation	Lin and Tsai (2010b)	1
Journal of Multi-Criteria Decision Analysis	Bottero and Ferretti (2011), Burnaz and Topcu (2006)	2
Location Science	Sinuany-Stern *et al.* (1995)	1
Logistics and Transportation Review	Min (1994)	1
Maritime Economics and Logistics	Lirn *et al.* (2004), Ugboma *et al.* (2010)	2
Mathematical and Computer Modelling	Kuo and Liang (2011)	1
Mining Science and Technology	Moshen *et al.* (2010)	1
Nuclear Technology	Hussein *et al.* (1987)	1
Ocean and Coastal Management	Van der Kleij *et al.* (2003)	1
Omega: International Journal of Management Science	Min and Melachrinoudis (1999)	1
Plant Location	Levine (1991)	1
Procedia Social and Behavioural Sciences	Kayikci (2010)	1
Proceedings of World Academy of Science, Engineering and Technology	Cinar (2009)	1
Qualitative and Quantitative	Lin and Tsai (2010a)	1
Renewable Energy	Aras *et al.* (2004), Lee *et al.* (2009)	2
Socio-economics Planning Science	Erkut and Moran (1991)	1
Studies in Fuzziness and Soft Computing	Kahraman *et al.* (2010)	1
Waste Management	Ekmekcioglu *et al.* (2010), Moeindanni *et al.* (2010), Önut and Soner (2008), Sener *et al.*(2010),	4
Waste Management and Research	Charnpratheep *et al.* (1997), Kontos *et al.* (2003)	2
System Engineering Theory and Practice	Zheng *et al.* (2009)	1
Total number of journals: 46	Total number of papers: 69	

Source: Author

D.3 Analysis Methods Used in TOPSIS Location Decision Problem

No.	Year	Authors	Application	Other tools used
1	2010	Amiri	Plant	Fuzzy set theory, AHP
2	2011	Awasthi *et al.*	Distribution centre	Fuzzy set theory
3	1992	Bhattacharya *et al.*	General	Fuzzy goal
4	1993	Bhattacharya *et al.*	General	Bi-criteria analysis, Fuzzy goal
5	2011	Boran	General	Intuitionist fuzzy set
6	2002	Cheng *et al.*	Landfill	SAW, Weighted Product method, Cooperative game theory, ELECTRE
7	2003	Cheng *et al.*	Landfill	Inexact mixed integer linear programming, SAW, Product method, Cooperative game theory, ELECTRE
8	2002a	Chu	Manufacturing	Fuzzy set theory, interval arithmetic
9	2002b	Chu	Manufacturing	Fuzzy set theory, interval arithmetic
10	2009	Cinar	Bank	AHP
11	2010	Ekmekcioglu *et al.*	Landfill	Fuzzy set theory, Fuzzy AHP
12	2010	Ertuğrul	Factory	Fuzzy set theory
13	2010	Gligoric *et al.*	Plant	Fuzzy set theory, Kruskal's algorithm, Steiner points
13	2010	Karimi *et al.*	Investment company	-
14	2010	Kucas	Administrative location	Simple Additive Weighting (SAW)
15	2011	Kuo	Distribution centre	ANP, Fuzzy AHP, Fuzzy DEMATEL
16	2007	Kuo *et al.*	General	Fuzzy set theory
17	2011	Kuo and Liang	Distribution centre	ANP, Fuzzy AHP, DEMATEL
18	2011	Li *et al.*	Logistic centre	Axiomatic fuzzy set
19	2009	Liao	Passenger station	Fuzzy set theory
20	2010a	Lin and Tsai	Hospital	AHP, ANP
21	2010b	Lin and Tsai	Hospital	AHP, ANP, Porter's diamond framework
22	2010	Önut *et al.*	Shopping centre	Fuzzy set theory, Fuzzy AHP
23	2008	Önut and Soner	Landfill	Fuzzy set theory, Fuzzy AHP
24	2011	Özcan *et al.*	Warehouse	AHP, ELECTRE, Grey Theory
25	2010	Safari *et al.*	Plant	Fuzzy set theory
26	2006	Yong	Manufacturing	Fuzzy set theory
27	2009	Zheng *et al.*	Distribution centre	AHP

Source: Author

D.4 Distribution of TOPSIS Location Decision Problem

Journal title	Author name and published date	No.
China railway Science	Liao (2009)	1
Engineering Applications of Artificial Intelligence	Cheng *et al.* (2003)	1
Expert Systems with Applications	Amiri (2010), Gligoric *et al.* (2010), Kuo (2011), Li *et al.* (2011), Önut *et al.* (2010), Özcan *et al.* (2011)	6
Fuzzy Sets and Systems	Bhattacharya *et al.* (1992), Bhattacharya *et al.* (1993)	2
Group Decision Negotiation	Ertuğrul (2010)	1
International Journal of Advance Manufacturing Technology	Chu (2002b)	1
International Journal of Manufacturing and Technology	Yong (2006)	1
International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems	Chu. (2002a)	1
International Research Journal of Finance and Economics	Karimi *et al.* (2010)	1
Journal of Environmental Engineering and Landscape Management	Kucas (2010)	1
Journal of Environmental Science and Health, Part A	Cheng *et al.* (2002)	1
Journal of Testing and Evaluation	Lin and Tsai (2010b)	1
Mathematical and Computational Applications	Boran (2011)	1
Mathematical and Computer Modelling	Awasthi *et al.* (2011), Kuo and Liang (2011), Kuo *et al.* (2007)	3
Qualitative and Quantitative	Lin and Tsai (2010a)	1
Proceedings of World Academy of Science, Engineering and Technology	Cinar (2009)	1
Waste Management and Research	Ekmekcioglu *et al.* (2010), Önut and Soner (2008)	2
System Engineering Theory and Practice	Zheng *et al.* (2009)	1
Total number of journals: 17	Total number of papers: 27	

Source: Author

D.5 Attributes for Warehouse Location 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 demands	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 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	

Key attributes for Distribution/Logistics centre selection

Author	Application	Location	Criteria	Sub-criteria
Awasthi *et al.* (2011)	Distribution centre		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	
			Quality of service	
Kayikci (2010)	Logistics centre	Austria	Economical scale	Socio-economic development Spatial development Transhipment volume Import/Export volume Mobility
			National stability	Political stability Economic stability Social stability
			Intermodal operation and management	Information technology infrastructure Transport cost Transport time Service availability Coordination Quality Connectivity Interoperability
			International market location	Accessibility International consumption market International manufacturing market Border crossing Customs European corridor
			Environmental effect	Congestion Energy use Emissions Land use Accident Hazardous materials
Kengpol (2004)	Distribution centre	Thailand	Cost	
			Comfortability in truck management	Inventory Supplier Staff
			Preparation moving time	
			Comfortability in product distribution	North North-East East Central South West
Kuo (2011)	Distribution centre	Asia	Cost	Port rate Transhipment time Port and warehouse facilities
			Convenience	Information abilities One stop service Extension transportation convenience
			Port's conditions	Port operation system Location resistance
			Operating capability	Density of shipping lines Import/Export volume
Kuo and Liang (2011)	Distribution centre	Asia	Cost	Port rate Import/Export volume Location resistance Transhipment time Port and warehouse facilities
			Information/Transportation convenience	Extension transportation convenience Information abilities Density of shipping lines
			Service quality of port	One stop service Port operation system

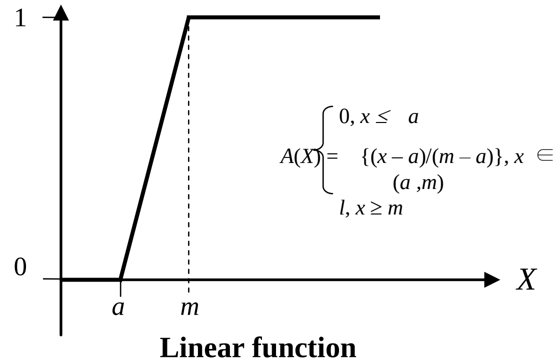
Key attributes for Distribution/Logistics centre selection (Cont'd)

Author	Application	Location	Criteria	Sub-criteria
Li *et al.*(2011)	Logistics centre	-	Weather condition	
			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	
			Fundamental construction investment	
Min and Melachrinoudis (1999)	Distribution centre	USA	Site characteristics	Capacity Compatibility Deed, Building Expansion Soil
			Cost	Start-up Operating
			Traffic access	Highway Rail Terminal Waterway
			Market opportunity	Customer Supplier Competitor Alpha Market potential
			Quality of living	Climate Crime Living expense Congestion
			Local incentives	Union Skilled labour Tax incentives Park services
Sarkis and Sundarraj (2002)	Distribution centre	Asia	Cost	Initial cost Capital cost Operations and administrative cost Labour cost Freight rate
			Accessibility	Supplier accessibility Customer accessibility infrastructure Transport service
			Time	Replenishment time Delivery time Start-up time
			Regulatory	Tax structure Government incentives Government restrictions Trade policy Repatriation allowances
			Risk	Foreign exchange bank Government intervention Political risk Economic risk Legal risk
			Labour	Skilled workforce Education system Unionisation Training support
			Strategic issues	Competition Current facilities Market size and penetration Expansion capabilities

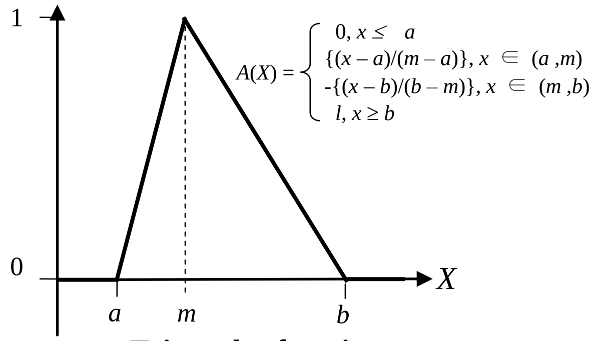
Key attributes for facility location selection

Author	Location	Criteria	Sub-criteria
Chuang (2001)	-	Information technology of requirement	
		Energy/utilities	
		Labour conditions	
		Community and working environment	
		Political regulation and law	
		Closeness to suppliers and customers	
		Transportation conditions	
		Initial and operating costs	
		Land features	
Kahraman *et al*. (2003)	Turkey	Environmental regulation	
		Host community	
		Competitive advantage	
		Political risk	
Levine (1991)	-	Access to markets/distribution centres	Cost of serving markets Trends in sales by areas Penetrate local market by plant presence
		Access to supplies/resources	Transportation costs Trends in supplier by sea
		Community/government access	Ambience/cost of living Co-operation with established local industry Community pride Housing/churches Schools and colleges
		Competitive considerations	Location of competitors Likely reacting to the new site
		Labour	Prevailing wage rates Extent and militancy of unions in the area Productivity Availability Skills levels available
		Taxes and financing	State income tax/local property and income taxes Unemployment and compensation premiums Tax incentive concessions Industrial pollution control revenue bonds
		Transportation	Trucking service Rail service Air freight service
		Utility services	Quality and price of water and sewerage Availability and price of electric and natural gas Quality of police, fire, medical services
Yang and Lee (1997)		Market	Market growth potential Proximity to market Proximity to raw materials
		Transportation	Land Air Water
		Labour	Cost of labour Availability of skilled workers Availability of semi-skilled workers
		Community	Housing g Business climate Education

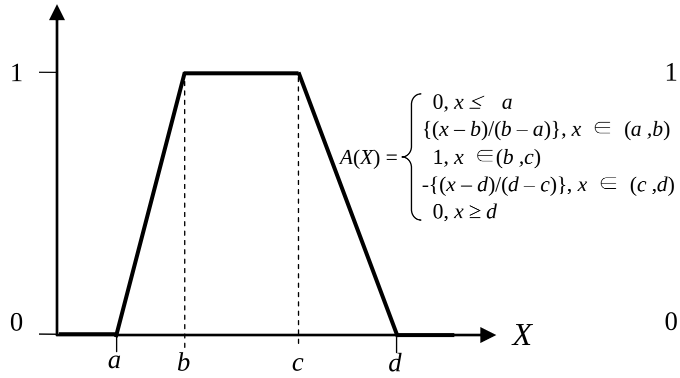
D.6 Kinds of Fuzzy Function



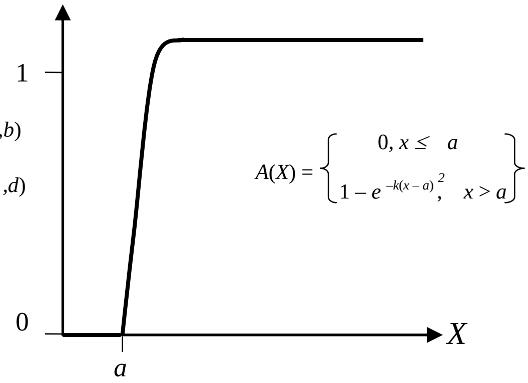
Linear function



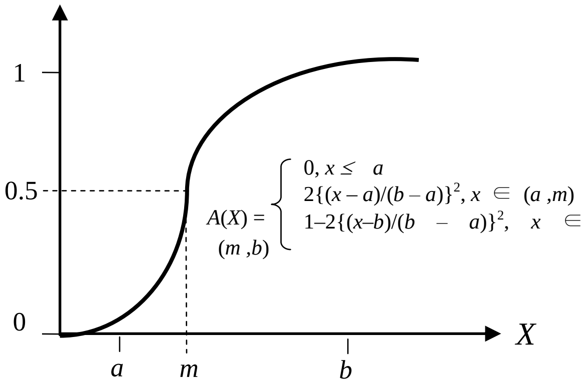
Triangular function



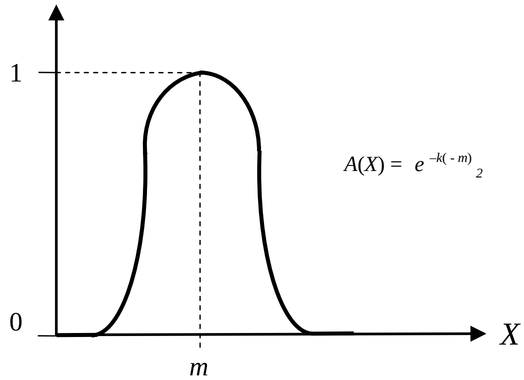
Trapezium function



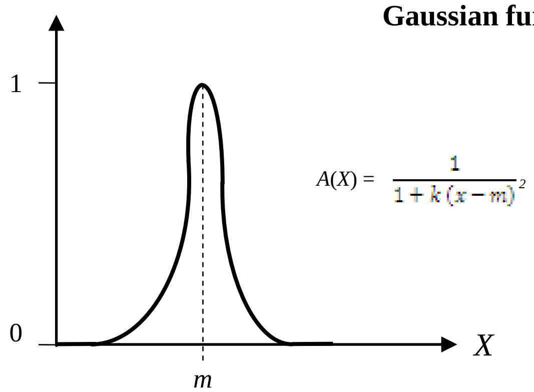
Gamma function



S function



Gaussian function



Pseudo-exponential function

Source: Fernandez and Ruiz (2009)

D.7 Definition of "persons of concerns"

Population group	**Definition**	**Additional explanation**
Refugees	Individuals recognised under 1951 Convention relating to the *Status of Refugees*: its 1967 protocol; the 1969 *OAU Convention Governing the Specific Aspects of Refugee Problems in Africa*; those recognised in accordance with the UNHCR Statue; individuals granted complementary forms of protection[1], or, those enjoying temporary protection[2] including people in a refugee-like situation[3].	1. Complementary protection refers to protection provided under national or regional law I countries which do not grant 1951 *Convention refugee status* to people who are in need of international protection against serious, but indiscriminate risks. 2. Temporary protection refers to arrangements developed by States to offer protection of a temporary nature to people arriving from situations of conflict or generalised violence without the necessity for formal or individual status determination. This usually applies to situations of large-scale influx. 3. The terms is descriptive in nature and includes groups of people who are outside their country or territory of origin and who face protection risks similar to refugees, but for whom refugee status has, for practical or other reasons, not been ascertained.
Asylum-seekers	Individuals who have sought international protection and whose claims for refugee status have not yet been determined.	
Internally displaced persons	People or groups of individuals who have been forced to leave their homes or places of habitual residence, in particular as a result of, or in order to avoid the effects of armed conflict, situations of generalised violence, violations of human rights, or natural- or human-made disasters, and who have not crossed an international border. This includes people in an IDP-like situation[4].	4. The term is descriptive in nature and includes groups of people who are inside their country of nationality or habitual residence and who face protection risks similar to IKPs but who, for practical or other reasons, could not be reported as such.
Returned refugees (Returnees)	Refer to refugees who have returned voluntarily to their country of origin or habitual residence.	
Returned IDP	Refer to those IDPs who were beneficiaries of the protection and assistance activities and who returned to their areas of origin or habitual residence.	
Stateless persons	Individuals not considered as citizen of any State under national laws including *de facto* stateless persons and persons with undetermined nationality.	

Source: UNHCR (2009)

D.8 Characteristics of IHC members

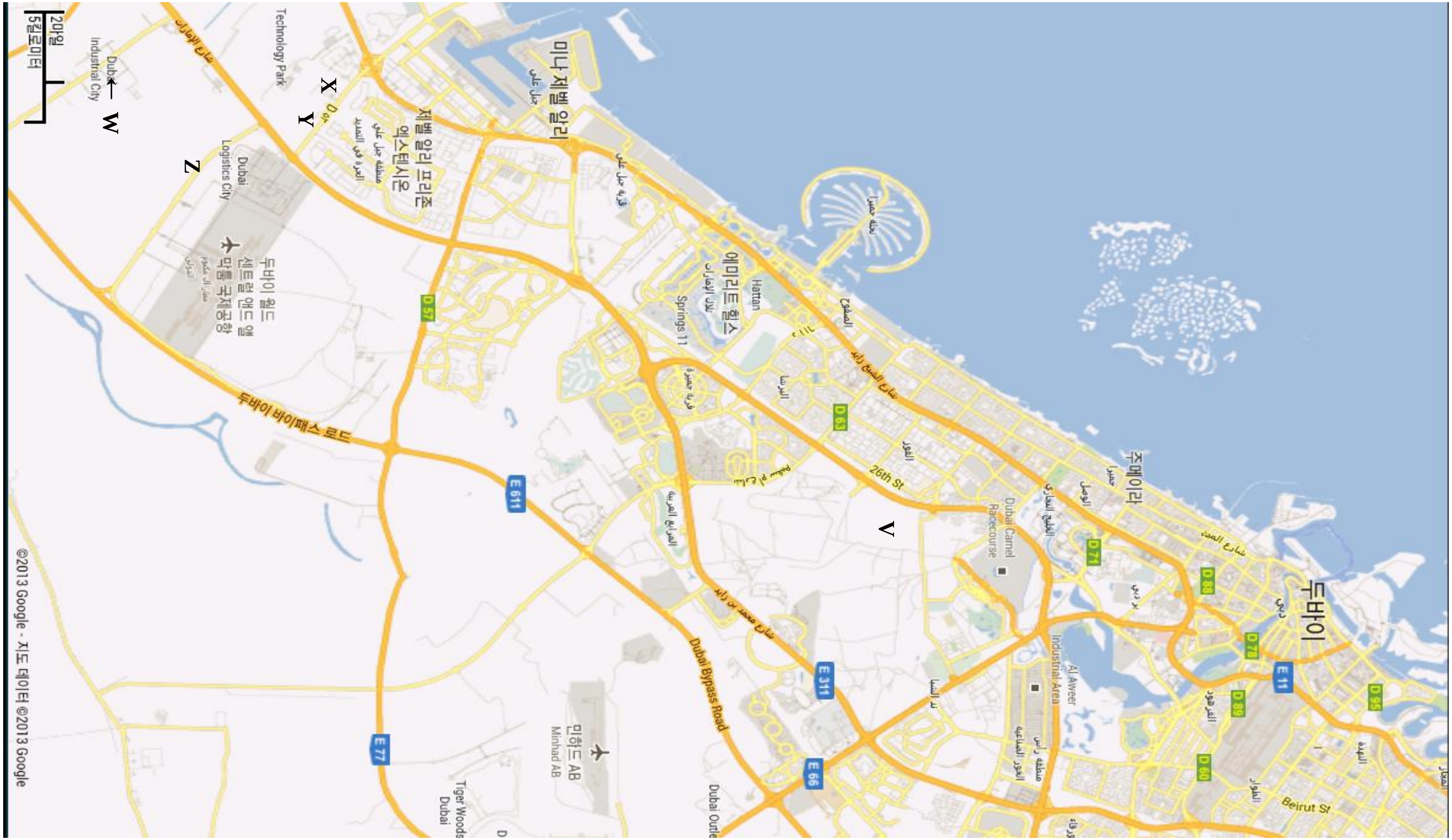
Type	Organisation Name	Main Focus
Company	Aga Khan Planning and Construction Management	Construction & Engineering, Water & Sanitation
	Automotive Management Services FZE	Logistics, Vehicles & Supply Chain
	Bukkehave	Logistics, Vehicles & Supply Chain
	Bukkehave Global Spareparts (BGS) FZE	Logistics, Vehicles & Supply Chain
	Emerging Markets Communications	IT & Telecommunications
	Global Relief Solutions	Tents, Shelters & Prefab
	Grameen-Jameel Pan-Arab Microfianacne Ltd.	Economic Development & Mircofinance
	IMGC Global	Emergency Response
	Intertrade International Services Middle East	Logistics, Vehicles & Supply Chain
	Microtech International	IT & Telecommunications
	Middle East Petroleum Services	Construction & Engineering, Logistics, Vehicle & Supply Chain
	RA International	Construction & Engineering
	UXB Inernational	Landmines
	Western Auto	Logistics, Vehicles & Supply Chain
NGO	ACTED	Children, Construction & Engineering, Economic Development & Mircofinance, Education, Emergency Response, Food & Nutrition, Human Vales Advocacy, Refugees & Displaced Population, Tents, Shelters & Prefab, Water & Sanitation, Women
	Al Basar International Foundation	Blindness
	Al-Muntada Al-Islami	Education, Water & Sanitation
	All As One	Children, Education, Orphans
	Child Foundation	Children, Education, Health, Pharmaceuticals & Medical Equipment
	Children's Hope Foundation	Children, Education, Health, Pharmaceuticals & Medical Equipment
	Gulf for Good	Human Values Advocacy
	Humanity First Middle East	Blindness, Children, Education, Emergency Response, Food & Nutrition, Human Values Advocacy, Orphans, Water & Sanitation
	International Association for Human Values	Education, Human Values Advocacy
	International Federation of Red Cross & Red Crescent Societies Regional Logistics Unit & Fleet Base	Children, Construction & Engineering, Coordination of Human Efforts, Economic Development & Mircofinance, Emergency Response, Food & Nutrition, Health, Pharmaceuticals & Medical Equipment, Human Values Advocacy, IT & Telecommunications, Logistics, Vehicles & Supply Chain, Policy Advocacy, Refugees & Displaced Population, Water & Sanitation, Women
	International Islamic Relief Organisation	Children, Construction & Engineering, Coordination of Humanitarian Efforts, Economic Development & Microfinance, Education, Emergency Response, Food & Nutrition, Health, Pharmaceuticals & Medical Equipment, Orphans, Refugees & Displaced Populations, Special needs, Water & Sanitation, Women
	Kinderhut International	Children, Orphans, Refugees & Displaced Population, Women
	King's Revival International Charitable Trust	Children, Orphans
	Life of Relief & Development	Education, Emergency Response, Health, Pharmaceuticals & Medical Equipment, Human Values Advocacy, Orphans, Refugees & Displaced Population, Special needs, Water & Sanitation, Women
	Make a Wish Foundation	Children, Health, Pharmaceuticals & Medical Equipment
	PlaNet Finance UAE	Economic Development & Mircofinance, Policy Advocacy
	Shaukat Khanum Memorial Trust	Children, Health, Pharmaceuticals & Medical Equipment, Women
	SOS Children's Villages	Children, Orphans
	The Citizens Foundation	Children, Construction & Engineering, Education
	UPFBH	Construction & Engineering, Emergency Response, Special needs
	Waqf Foundation	Children, Education, Women
	World Memom Organisation (Middle East Chapter)	Human Values Advocacy
	World Vision International	Children
	Zia Siddique Foundation	Education, Health, Pharmaceuticals & Medical Equipment, Policy Advocacy, Women
UN Agency	IRIN (United Nations Integrated Regional Information Networkds	Media & Information
	OCHA (United Nations Office for the Coordination of Humanitarian Affairs)	Coordination of Humanitarian Efforts, Emergency Response, Media & Information, Policy Advocacy
	UNDSS (United Nations Department for Safety and Security)	Security
	UNHCR (UN High Commissioner for Refugees)	Education, Emergency Response, Logistics, Vehicles & Supply Chain, Policy Advocacy, Refugees & Displaced Population, Tents, Shelters & Prefab.
	UNICEF (United Nations Children's Fund)	Children, Construction & Engineering, Education, Emergency Response, Health, Pharmaceuticals & Medical Equipment, Law & Human Rights, Logistics, Vehicles & Supply Chain, Orphans, Policy Advocacy, Water & Sanitation, Women
	UNOPS – The Arab Water Reports (AWR)	Water & Sanitation
	UNU – INWEH (United Nations University – International Network on Water Environment and Health)	Water & Sanitation
	WFP (United Nations World Food Programme)	Education, Food & Nutrition, Logistics, Vehicles & Supply Chain, Policy Advocacy

Source: IHC

D.9 Alternative warehouse location comparisons for IHC

	Current Compound	Alternative Warehouse Locations			
Attributes	**IHC (V)**	**W**	**X**	**Y**	**Z**
Distance (C_1)					
Jebel Ali seaport (SC_{11})	30kms	25kms	9kms	9kms	19kms
Dubai Int'l airport (SC_{12})	12kms	75kms	54kms	54kms	58kms
Al Maktoum airport (SC_{13})	15kms	46kms	10kms	10kms	2kms
Sharjah airport (SC_{14})	10kms	90kms	69kms	69kms	74kms
Abu Dhabi airport (SC_{15})	145kms	108kms	112kms	112kms	113kms
Ministry of Foreign Affairs (MOFA) (SC_{16})	10kms	75kms	45kms	45kms	52kms
Security (C_2)					
Warehouse (SC_{21})	yes	Weak secured perimeter	Yes	Yes	Yes
Fire fighting station (SC_{22})	10kms	5kms	3kms	3kms	> 10kms
Police station (SC_{23})	10kms	5kms	3kms	3kms	> 10kms
Hospital (SC_{24})	10kms	25kms	3kms	3kms	3kms
Road safety (SC_{25})	Bad	UNDSS assessed traffic accident threat	Good	Good	Good
Office facilities (C_3)					
Suitability for diplomatic work (SC_{31})	Yes	No	Yes	Yes	Yes
IT/Communication (SC_{32})	Good	Good	Good	Good	Good
Warehouse distance (SC_{33})	Co-located	< 10kms	Co-located	< 5kms	Co-located
Modular office space (SC_{34})	Good	Good	Good	Good	Good
Warehouse facilities (C_4)					
Capacity (SC_{41})	21,500m^2	17,000m^2	36,960m^2	21,000m^2	18,000m^2
Open storage (SC_{42})	18,000 m^2	None	30,000m^2	None	25,000m^2
Office facility (SC_{43})	Good	Good	Poor	Poor	Good
General spill-over area (SC_{44})	Yes	No	No	No	Yes
Height of ceiling (SC_{45})	11.5m	8.5m	10.2m	10.5m	12m
Loading bays (SC_{46})	Yes	No	Yes	Yes	Yes
Flood lights (SC_{47})	Yes	No	Yes	Yes	Yes
Suitable openings (SC_{48})	Yes	Yes	Yes	Yes	Yes
Doors at both ends (SC_{49})	yes	No	No	Yes	No
Convenience (C_5)					
Cafeteria (SC_{51})	In compound	No	In Jebel Ali	In Jebel Ali	In Dubai Logistics City (DLC)
Mini-mart in compound (SC_{52})	No	No	No	No	No
ATM (SC_{53})	In compound	No	No	No	In Dubai Logistics City (DLC)
Distance from main city (SC_{54})	10kms	75kms	54kms	54kms	60kms
Distance from residential area (SC_{55})	< 20kms	< 35kms	< 45kms	< 45kms	< 40kms
Transportation accessibility (SC_{56})	Difficult	Difficult	Convenient	Convenient	Convenient

Source: Author


2마일
5킬로미터
Dubai
Industrial City
W
Technology Park
X
Y
Z
Dubai
Logistics City
두바이 월드
센트럴 앤드 알
막툼 국제공항
미나 제벨 알리
제벨 알리 프리존
엑스텐시온
에미리트 힐스
Hattan
Springs 11
D 57
D 63
두바이 바이패스 로드
E 611
26th St
V
Dubai Camel
Racecourse
주메이라
D 71
D 88
두바이
D 78
E 11
D 89
D 95
D 60
Beirut St
Al Aweer
Industrial Area
E 311
E 66
Dubai Bypass Road
민하드 AB
Minhad AB
E 77
Tiger Woods
Dubai
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