YAŞAR UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

MASTER THESIS

EVALUATING THE COMPARATIVE EFFICIENCY OF UNIT-LOAD THIRD PARTY WAREHOUSES USING AHP AND VIKOR

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Presentation Date: 30.11.2015

Bornova-İZMİR
2015

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ABSTRACT

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November 2015, 75 pages

The selection of supplier has become attentively studied problem over the past several years. In today's competitive environment, among the logistic activities, the importance of warehousing is increasing day by day. With warehousing activities becoming wider and wider in scope, third party logistics service providers became a necessity for manufacturers.

In this study, different supplier measuring methods have been used to evaluate three logistics companies that offer services from same sector. In this thesis, a multi-criteria decision model for evaluation of third party service providers' alternatives has been created. Analytic Hierarchy Process (AHP) and VIKOR methods have been used for evaluating and ranking the suppliers. The aim of this study is selection of the best efficient third party warehouse. The details of evaluating process have been shown. The data is taken from well-known logistic companies in Turkey. The six different main criteria have been detected for application. These are "market", "quality", "operational", "constructional", "service" and "social responsibility or green project". Apparently, warehouse selection is a multi-criteria problem that includes both quantitative and qualitative factors. The outcomes has been compared and discussed in this study.

This thesis consists of eight chapters, which include all of these subjects.

Keywords: Analytic Hierarchy Process (AHP), VIKOR, Supplier Selection, Warehouse and Warehouse Management, Multi-Criteria Decision Analysis Method, Third-Party Warehouse Selection.

ÖZET

AHP VE VİKOR KULLANILARAK BİRİM-YÜK ÜÇÜNCÜ PARTİ DEPOLARIN KARŞILAŞTIRMALI VERİMLİLİK DEĞERLENDİRİLMESİ

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Yüksek Lisans Tezi, Endüstri Mühendisliği Bölümü
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Kasım 2015, 75 sayfa

Son yıllarda, tedarikçi seçimi dikkatlice üzerinde çalışılmakta olan bir problem olmaktadır. Günümüzün rekabet ortamında, lojistik faaliyetleri içerisinde depolamanın önemi gittikçe artmaktadır. Depoculuk faaliyetlerinin daha kapsamlı bir hale gelmesiyle, üreticiler için üçüncü parti lojistik servis sağlayıcıları bir ihtiyaç haline gelmektedir.

Bu çalışma da farklı tedarikçi değerlendirme yöntemleri incelenerek, aynı sektörlerde hizmet veren üç lojistik firmasını ele alınmıştır. Bu tez, çoklu kriterli karar verme modeli üçüncü parti hizmet sağlayıcılarının alternatiflerini oluşturmaktadır. Çok kriterli karar verme problemi olarak değerlendirilebilecek bu problemin çözümünde Analitik Hiyerarşi Süreci (AHS) ve VIKOR yöntemleri kullanılmıştır. Bu çalışmanın amacı en verimli üçüncü parti depo firmasını seçmektir. Sürecin değerlendirilmesi detayları ile gösterilmiştir. Veriler, Türkiye'de tanınmış lojistik şirketlerinden alınmıştır. Altı ana kriter uygulama için tespit edilmiştir. Bunlar "pazar", "kalite", "operasyonel", "yapı", "hizmet" ve "sosyal sorumluluk ya da yeşil projeler" dir. Görünüşe göre, depo seçimi nicel ve nitel faktörleri de içeren çoklu kriterli bir sorundur. Çalışmada, çıktılar karşılaştırıldı ve tartışıldı.

Bu tez, yukarıda bahsedilen konuları içeren sekiz üniteden oluşmaktadır.

Anahtar sözcükler: Analitik Hiyerarşi Süreci (AHS), VIKOR, Tedarikçi Seçimi, Depo ve Depo Yönetimi, Çoklu Kriterli Karar Analizi Metodu, 3.Parti Depo Seçimi.

To my father, Ramazan

ACKNOWLEDGEMENTS

I would like to acknowledge the advice and guidance of Asst. Prof. Ömer Öztürkoğlu and Asst. Prof. Yücel Öztürkoğlu for his/her support and help on my thesis.

I gratefully acknowledge the contributions of my brother, Hasan Oğuzhan Çakal. I would like to thank you my mother, Kadriye Çakal, without them continuous support and encouragement I never would have been able to achieve my goals. I am very thankful to my father, Ramazan Çakal for always protecting me.

I would also like to thank to warehouse logistic employees for their help and support on my study and for allowing me to work inside the warehouses.

I would like to give special thanks to my family and my dearest friends for supporting and encouraging me. Especially without their encouragement, I would not have finished this project.

Ayça ÇAKAL
İzmir, 2015

TEXT OF OATH

I declare and honestly confirm that my study, titled “Evaluating The Comparative Efficiency of Unit-Load Third Party Warehouses Using AHP and VIKOR” and presented as a Master’s Thesis, has been written without applying to any assistance inconsistent with scientific ethics and traditions, that all sources from which I have benefited are listed in the bibliography, and that I have benefited from these sources by means of making references.

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INDEX OF SYMBOLS AND ABBREVIATIONS

Symbols	**Explanations**
CI	Consistency Index
RI	Random Consistency Index
CR	Consistency Ratio
W	Preference (weight) Vector
A	Pair Wise Comparison Matrix
X	Row Averages
n	Amount of items compared
wi	Weight
ci	Sum of column
λmax	Eigenvalue

Abbreviations

AHP	Analytic Hierarchy Process
3PL	Third Party Logistics
DC	Distribution Centre

1. INTRODUCTION

Today, logistics services become more important because it became a need for many sectors in the world. Number of logistic firms expanded systematically in the world. Warehousing was born due to necessity. Warehousing's roots go back to the creation of granaries to store food, which was historically available for purchase during times of scarcity. As European discoverers began to create shipping-trade routes with other nations, warehouses increased in importance for the storage of products and commodities from afar. Ports were the major location for warehouses.

In years passed by, warehouses were used to store imported foods, such as corn, as well as alcohol, valuable commodities and various other materials.

Warehouses are no longer just for storage. In today's cost-conscious, efficiency-driven environment, many manufacturers are revaluating their definition of warehousing. Anything that does not lend itself to a high-speed, highly mechanized, low-labour environment is being sent to the warehouse.

Because of this shift, manufacturers are gradually expanding the services they expect from their warehousing providers, seeking ways to increase flexibility, improve inventory control, manage costs, and streamline the supply chain.

Compared to the past, warehousing activities have become more important. Thus, the companies have been developing many warehousing systems today. These companies' products require greater structure. For this reason, bigger businesses can need higher quantity of warehouses, which are also wider in scale. We take a closer look at some of the biggest and best warehouses below. Table 1.1 below, shows that the largest warehouses in the world (Marpak Extrusions Ltd, As of March 2014).

Table 1.1 The Largest Warehouses in the World

THE LARGEST WAREHOUSES IN THE WORLD	
The Company Name	About Information of Warehouse Volume
NASA Vehicle Assembly Building, USA.	3,664,883 cubic meters. Built in 1966, the NASA Vehicle Assembly Building (VAB) was used to assemble space shuttles for over 30 years.
Meyer Werft GMbH, Germany	167 million cubic feet - 4728913m^3 cubic meters.
Constellation Europe, UK.	With a footprint of 858,000 sq ft and a volume the equivalent of 14,000 double decker buses.
Target Import Warehouse, USA.	The warehouse is used to distribute stock from overseas to local distributors, has a volume of 7.43 million m^3 and is the largest of four warehouses Target owns.
Boeing Everett Factory, USA.	Due to the size of the products created, the warehouse is the largest building in the world by volume, at 13,385,378 m3.
Tesco Distribution centre, Ireland	70,000 square metre footprint.

In the warehousing systems, nowadays it is a significant link in the supply chain. Therefore, it is of great importance in many sectors. Companies have been tried to choose the best warehouse between the logistics firms. Logistics companies have been entered into a competition to give customers better service. In order to serve its customers in all sectors, the logistics industry involves warehousing, material handling, packaging and the integration of information flow through supply chain management software.

Figure 1.1 NASA vehicle assembly building, USA

In Turkey, warehousing history is based on very old times. Anatolia's recorded history begins in the year 5000 B.C. Warehousing gained more importance with Ottoman Empire and in recent history, and then warehousing gained more importance in the Republic of Turkey.

It started with governmental operations. These operations were managed by Government banks. For the purposes of meeting the requirement for storage areas and warehouses, Agricultural Bank (Ziraat Bank) was also authorized and mandated to establish wheat storage facilities under Law No. 2303 enacted on 11/06/1933 governing principles and conditions for construction of silos and warehouses (The Data of the Turkish Grain Board).

On the other hand, Turkish Grain Board was founded in 1938. Turkish Grain Board was formed as a state economic enterprise to deal with wheat affairs under Law No 3491 of 24/ 06/ 1938 published in Official Journal on 13/ 07/ 1938 (The Data of the Turkish Grain Board).

TMO started procurement of barley and oat on 27 October 1939, rye on 28 November 1940, corn and maize on 23 April 1941 and rice, vegetable and animal fats and oils, meat and fish, alfalfa seeds and legumes on 13 August 1941. TMO also organized supply and distribution of gasoline, wheel tires, fried meat, margarine and coffee during and after Second World War and, started procurement of chickpea, millet, beans, lentil, broad bean and cowpea on 3 August 1943 and sesame on 31 October 1947.

Since its foundation, Turkish Grain Board constructed warehouses in various types and tonnages considering ports and intensive production areas in every district of Turkey. Total storage capacity of Turkish Grain Board is 4.5 million tons and 546.700 tons of respective capacity is located in ports. TMO's storage areas (warehouses) corresponding to storage capacity of 3.195.500 tons has ventilation facility. Storage areas of the facilities closed during restructuring process are reclaimed through selling or hiring out. (The Data of the Turkish Grain Board)

Figure 1.2 Warehousing activities in the past in Turkey

Figure 1.3 Transportation activities in the past in Turkey

In the globalizing world, Turkey has gained importance and progressed rapidly in this sector. At the same time, major improvements have happened in the world. The reason is the, time has been the more valuable for people. They have developed a more efficient system for warehousing activities. Thus, third-party logistics systems were born for better service to manufacturers. Competition in the logistics service industry has constantly increased over the last decades (Wallenburg, 2009).

While it is not immediately clear, exactly who coined the term third party-logistics. Its beginnings can be traced to the 70′s and 80′s as companies outsourced more and more logistics services to third parties. Over time, these third party logistics service providers (3PLs) expanded their services to cover specific geographies, commodities, modes of transport and integrated their existing warehousing and transportation services, becoming what we now know today as a “3PL”.

Figure 1.4 Example third party logistic warehouse facility

The radical change the business world has been undergoing from the 1990s has greatly influenced (among other things) logistics and supply chain management. Coyle, et al. (2003) state that supply chain management has progressed in that its development as a response to the macro-level change drivers in the economy.

With changing business environment as a background, Hesse and Rodrigue (2004) claim that evolution of supply chain management is characterized by four main features. Goods merchandizing has been fundamentally restructured by integrating supply chains and thus integrating freight transport demand. Logistics, as opposed to the traditional transportation function, which was oriented on overcoming space, is critical in the terms of time. Supply chains are increasingly managed by the demand and demand-side oriented activities are developing a major roll. Finally, as all this has leaded to the increasing complexity and time sensitivity of the logistics, many companies are forced to outsource logistics functions to the third party logistics providers (TPL) which can benefit from economies of scope and scale in their solution offerings of freight distribution problems.

There has been a rapid growth in Third Party Logistics service providers owning to the emergence of advanced demand of logistics services, which includes the urge to shorten lead-time, customers demand and outsourcing. Nowadays, various firms belonging to other fields have now influenced into the logistics market to compete with the firms whose traditional roles have been transportation and warehousing (Hertz & Alfredsson, 2003). The traditional ways of developing and

structuring logistics and the supply chain are now obsolete to sustaining emerging organizations because of globalization, increasing competition, the desire to enhance reduced order cycle time as well as inventory levels (Bolumole, 2001). Coyle et al. (2003) claim that the term logistics became universally recognized over twenty years ago, and described logistics as a series of integrated enterprises that have to share information, coordinate physical execution to make sure there is a smooth flow of goods, services.

Business today is looking for a single-source solution to manage warehousing and distribution. Constraints on cash flow and floor-space mean that few have the luxury to finance and keep surplus stock on-hand. Finding the happy medium is a challenge that sees many struggles to strike a balance between tying-up too much cash in stock and satisfying the customer off the shelf. In addition, it only gets worse when your business sources products from a large number of different sources, often scattered around the country, if not the world. Co-ordinating your suppliers to observe delivery windows which suit your business is difficult if not impossible.

In the 2015, 19th Annual Third Party Logistics Study, survey results showed the continuing, positive overall nature of shipper-3PL relationships. Advantages of third party logistics firms, both parties view themselves as being successful, and shippers are seeing positive results again this year: an average logistics cost reduction of 9%, an average inventory cost reduction of 5% and an average fixed logistics cost reduction of 15%.

2. PROBLEM STATEMENT

This thesis firstly focuses on supplier selection problem. Various researchers have tried to find the best solution and many methods that have been developed for supplier selection problem in the literature so far. Objective of this thesis is selection of the best efficient warehouse company.

Today, selection of warehouse is an important problem between suppliers' selection problems because manufacturers want to decrease their cost of warehousing and logistics services. Their aim is just focus on production and to take support for warehousing activities and logistic services thus third party warehouses have been a needed for manufactures. In competitive environment, the numbers of the third party warehouses have increased drastically. The producers tried to select the best efficient warehouses.

The application of supplier evaluation process is a huge problem for producers, therefore this topic has been selected and studied as the thesis topic. First, we selected three third party Logistics companies in İzmir. At the same time, they are working internationally and have branches in the other cities. Some questions are prepared about third party logistics services and asked to experts who is working in logistic department. The survey was filled by the companies to gather information. The answers have been used as data in the application.

The goal of this study is to evaluate potential suppliers and determining relative priorities of them in order to help purchase best choice for the companies. It is a multi-criteria decision making problem involving both qualitative and quantitative elements. AHP and VIKOR methods will be used for evaluating the suppliers. First, AHP results have been evaluated and then second methods are used integrated AHP and VIKOR Methods. The details of the evaluation processes will be given for both methods for each company. After the evaluation process outcomes were compared and discussed.

3. WAREHOUSE AND WAREHOUSE MANAGEMENT

3.1. Warehouse and Distribution Centers

Warehouse and distribution centers (DC) are very important parts in a supply chain network. They perform valuable functions that support the movement of materials, storing goods processing products, de-aggregating vehicle loads, creating stock keeping unit assortments, and assembling shipments (Langevin & Riopel, 2005). These are the activities usually performed in warehouses and distribution centres. The major challenge to distribution center and warehouse, both today and tomorrow is related to workforce issues. For example, staffing, training, scheduling and job design (Ackerman & Brewer, 2001-cited in Kotzab & Bjerre, 2005). Moreover, firm must also consider facilities that help the firm to cut handling costs. Coyle at el. (2003) present the definition of warehousing and distribution center that warehousing is the storage of goods, whereas distribution center precedes a post-production warehouse for finished goods held for distribution. Therefore, warehousing and DC have the same function, which is goods and products storage. According to Higginson and Bookbinder (2005), a distribution center is in fact, a specific type of warehouse as well as Frazelle (2002) who refers distribution center as distribution warehouse.

3.1.1 Warehousing

New cars can be stored outside on the dealer's lot, fuel oil can be stored in a specially designed tank, coal and other raw material can be stored in open pits but most products must be stored inside protective building (Perreault & McCarthy, 2003). According to Higginson and Bookbinder (2005), "Warehouses store all products in four cycle (receive, store, pick and ship)". Firm can decide and select among the different kinds of specialized storing facilities, and the right choice might assist the firm reducing costs and serving customer better (Perreault & McCarthy, 2003). The use of specific type of these storing facilities is aimed to reduce/cut costs and smooth the distribution as well as operation to improve service level to the customer.

3.1.2 **Distribution Centers**

Perreault and McCarthy (2003) state that a distribution center is a special type of warehouse which been designed to fasten the flow of goods and avoid unnecessary storing goods. Today the distribution center concept is widely used by firms at all channel levels and also many products buzz through a distribution center without ever tarrying on a shelf, workers and equipment immediately sort the products as they come in handy subsequently move the products to an outgoing loading dock, and then to the vehicle which will take the products to next stop (Perreault & McCarthy, 2003). Seeing the information latter distribution centre speeds up the distribution process and reduces the complication in storing goods. According to Higginson and Bookbinder (2005), DCs handle most products in two ways, receiving and shipping rather than storage and also DCs hold minimum inventories and of predominantly, high-demand items. Nevertheless, many of works cited use interchangeably the two terms, warehouse and DC. Since the 1980s, three supply-chain trends have had a major impact on the distribution center (Higginson & Bookbinder, 2005):

- Reduction in the number of warehouse;
- Greater emphasis on the flow of goods rather than their storage;
- Increases outsourcing of warehouse/distribution center activities.

The basic warehouse operations are movement and storage (Coyle et al., 2003). The cost of physical handling is a major storing cost. Furthermore, goods must be handled once putting them into storage, and removing them again when they are to be sold (Perreault & McCarthy, 2003). Warehouse also contains highly specialized storage facilities such as bean and grain elevators and refrigeration facilities etc. (Coyle et al., 2003) as well as distribution center.

3.1.3 **Differences & similarities between warehouse and distribution center**

A warehouse is designed to accommodate long-term storage, whereas a distribution center is set up to distribute supplies: product comes in and within a week or so, the majority of it is shipped out (to stores, for instance). It is constantly moving through the building. It is received use to fill orders and shipped out as new product is arriving.

Distribution centers are warehouse facilities used for the temporary storage and then distribution. They are typically staffed by employees in charge of the receipt of products into the facility, organization of the products and loading and shipping when the products are shipped following the order. Distribution centers operate separately from a company's main offices or other business buildings since they focus on the distribution process. Current distribution center is managed by external logistics service provider. All operations are outsourced to third party logistics partner (later called 3PL or 3rd party). “3PL, third-party logistics operational model company is outsourcing logistics operations to external service provider. Service provider is managing outsourced services for supply chain, either partly or fully according to contract. Contract may include transportation as well other services like warehousing.

In fact, both of them have differences but in the same time, they have some similarities. These similarities, both have 4 walls, a roof and truck/rail docks. Here differences:

- Warehouse focused on the most efficient and cost effective methods of storing products within its four walls.
- Low inventory velocity
- Provide time utility shift. Sometimes used for speculation.
- Space for storage (e.g. documents, seasonal merchandise)
- Space for protection from environmental impacts (e.g. rain, heat, sun)
- Space for product characteristics change (e.g. wine aging)

Distribution Center

- Provides principal link between suppliers and customers.
- Focused on filling customer orders
- High inventory velocity
- Variety of value added services (e.g. fulfilment, kitting)
- Technology driven

Figure 3.1 Example warehouses facility two

Figure 3.2 Distribution Center - Employees filled customer orders at an Amazon.com distribution center in Phoenix in November.

Although the popularity of warehouses has waxed and waned over the years, warehouses – also known as distribution centres – are an important part of the complete business supply chain. However, they have had to become less dispensable in order to survive, especially in the wake of just-in-time (JIT) manufacturing: Developed in the mid-20th century, this type of manufacturing sees products being sent directly from factories to customers, thus eliminating the need for temporary storage.

Therefore, while warehouses were once used only as storage depots for products, these days they often have other functions too, and as such may be known as third party logistics providers (3PLs). In addition to storing pallets, now warehouses may be suggestion light manufacturing of goods, and they may have call centres, labelling facilities and other stock-related uses. Another recent trend is the emergence of warehouse-style retail stores, where large amounts of products are stored on industrial racks, rather than on conventional retail-type shelving. Customers are able to buy products in bulk, and stock that is ready to be sold is generally placed on bottom racks. Meanwhile, crated inventory, or inventory that has been placed in pallets, is stored higher up, and lowered when required. In this way, these buildings function as both warehouses and retail stores.

3.1.4 **Features of Third Party Warehouse**

Up until the recent past, there were sizeable companies where materials handling, warehousing and distribution were regarded as a self-evident activities and unavoidable cost centres. Today, contracting out those functions is now regarded as a critical part of the effort to drive down costs, reduce stockholding and achieve time-critical deliveries to customers.

Companies entering into third party logistics agreements are generally looking for more added to value services and technology is often the most effective way of providing such benefits. The increased use of IT, for example, offers a potential avenue for providing more benefits to 3PL contracts.

There is no question about the fact that companies are turning to third-party warehousing and logistics companies to reduce their supply chain costs, gain market

share, increase profits, and improve customer satisfaction and retention. Thus, they provide to customers some services.

Some of the services given to provide benefits are assembly, consolidation, co-packing, cross cocking, direct store delivery, fulfilment, import/export, inspection, inventory management, packaging, pallet exchange, pick and pack, pool distribution, reverse logistics, sorting, trans-loading, transportation management, etc.

3.2. Types of Warehouses

There are many types of warehouse, which were mostly born from scope of needs. While selecting the type of warehouse, companies need to take into consideration the factors like the nature of goods, the quality and the climatic condition. From the point of view of structure, the following types of warehouses are found:

Classical Warehouse: It is a big hall of single storey building divided into various big or small rooms to store of general nature.

Silo**:** It is a vertical structure room equipped with mechanical devices. The loading and unloading functions are affected through mechanical devices. These are generally in the shape of big tanks or bunkers.

Bins**:** Bins are small cylindrical cabins of different sizes meant to store varieties of products. These are operated with manually and provide bulk storage facility.

Elevator**:** Elevator is a big vertical premise and is of craned types. These are used for lifting and de-lifting of products. From the elevator goods are directly discharged from wagons.

Portable Warehouse**:** It is a type of temporary warehouse, which can be removed or set in a short time. These warehouses have enough capacity to withstand rains and winds.

On the Basis of Ownership**:** From ownership point of views, there are different types of warehouses. The various types of warehouses are below:

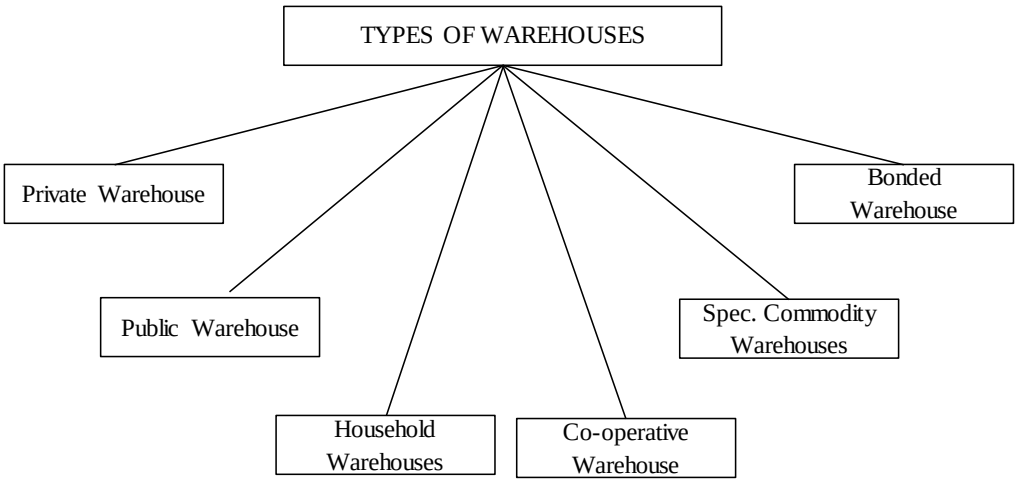

Figure 3.3 Types of warehouses

Private Warehouses: In the eyes of Perreault and McCarthy (2003) depict that firms use private warehouse when a large volume of goods and products must be stored regularly, nonetheless private warehouse can be expensive in dealing with the changes needs as it might be difficult or impossible for the extra space to rent to others.

Public Warehouses: Public warehouse is an independent storing facility. Public warehouse usually provides all services that a company's own warehouse can provide (Perreault & McCarthy, 2003). They also cite that public warehouses are functional and useful for manufacturers who are required to maintain stock in many different locations. The first and most significant reason for using public warehouse is financial; it requires no or limited capital investment by the company (Coyle et al., 2003). Public warehouses are used by general business -men on payment of a rent or charges.

Household Warehouses: These warehouses provide storage facility for household equipment's like furniture, rugs, furs and paintings. These warehouses are found in western countries.

Co-operative Warehouse: these warehouses are organized on co-operative basis and run on joint efforts of the people. These are made in rural areas for storage of agricultural goods. The best example of a co-operative warehouse is cold storage.

Bonded Warehouse: Bonded warehouses are maintained by port trust and custom authorities. These are meant to store imported goods from the foreign countries.

Based on Service Rendered, from the point of view of service rendered, there are different types of warehouses like, these include:

(a) Special Commodity Warehouses
(b) Cold Storages or Refrigerated Warehouses
(c) Institutional Warehouses

Specific Commodity Warehouses: These warehouses are meant to store specific goods like cotton, petroleum products and wool. These warehouses are specially constructed to accommodate the above articles.

Cold Storage: These are meant to store agricultural products of perishable nature. Perishable goods like fruits, vegetables, eggs and butter are stored in these warehouses.

Bank Warehouses: these warehouses are maintained by banks to keep goods as securities. The goods received by banks against credits or loans are kept in these warehouses.

General Merchandise Warehouse; goods, which do not require any special storage facilities are stored in these warehouses. Other type of warehouses below;

- Raw material and component warehouses
- Work-in-process warehouses
- Finished goods warehouses
- Distribution warehouses and distribution centers
- Value-added service warehouses

- Local warehouses
- Customs bonded warehouses

3.3. Warehouse Operations

Each warehouse has its own operations or different steps depending on their industry and product requirements. However, some basic steps can be found on the warehousing literature, below we can see Figure 3.4.

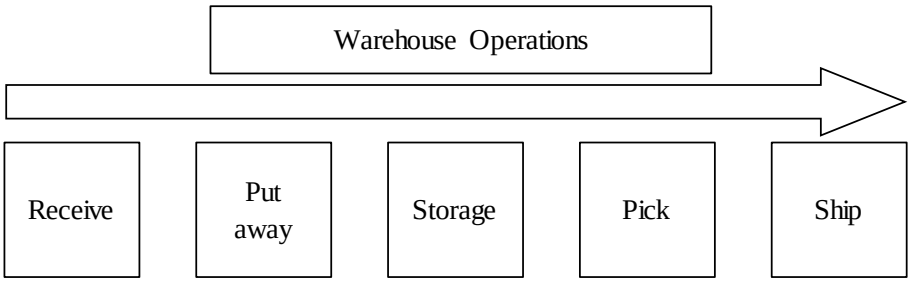

Figure 3.4 Warehouse operations

We can list the operations that are the core processes in the warehousing. First process is receiving and it includes the physical unloading of incoming transport, checking, recording of receipts, and deciding where the received goods are to be put away in the warehouse. It can also include such activities as unpacking and repackaging, quality control checks and temporary quarantine storage for goods awaiting clearance by quality control.

Inspection operation**,** quality and quantity check of the incoming goods for their required characteristics.

Repackaging operation**,** incoming lot may be having non-standard packaging, which may not be stored as it is in the respective location. In those cases, these materials have to be pre packed in unit loads/pallet loads suitable for storage.

Put away operation**,** binning and storing the goods in their respective locations including the temporary locations from the receiving docking area.

Storage operation, storage functions are usually an extension of receiving department duties. The basic functions of storage are the movement of products from the dock area to a holding location, the recording of the location and quantity, and the updating of storage records so that the product can be found easily when it is needed.

Order-Order picking / selection operations, goods are selected from order picking stock in the required quantities and at the required time to meet customer orders. Picking often involves break bulk operations, when goods are received from suppliers in, say, whole pallet quantities, but ordered by customers in less than pallet quantity. Order picking is important for achieving high levels of customer service; it traditionally also takes a high proportion of the total warehouse staff complement and is expensive. The good design and management of picking systems and operations are consequently vital to effective warehouse performance

Sortation operation, this enables goods coming into a warehouse to be sorted into specific customer orders immediately on arrival. The goods then go directly to order collation.

Packing and shipping operations, picked goods as per customer order are consolidated and packed according to customer order requirements. It is shipped according to customer orders and respective destinations.

Cross docking operation, move products directly from receiving to the shipping dock – these products are not at all stored in the specific locations.

Replenishing operation, this is the movement of goods in larger order quantities, for example a whole pallet at a time, from reserve storage to order picking, to ensure that order picking locations do not become empty. Maintaining stock availability for order picking is important for achieving high levels of order fill.

3.4. Warehouses Layout

Storage is an important aspect of economic activity. In the early stages of industrial development, because of low labour rates, manpower was used freely, with little consideration given to efficiency in space utilization, order picking methods or material handling in general.

Warehouse layout is also important in achieve greater efficiencies. Minimizing travel time between picking locations can greatly improve productivity. However, to achieve this increase in efficiency, companies must develop processes to regularly monitor picking travel times and storage locations.

Handling of materials is one of the most important inputs of the warehouse layout especially from the view of planning. There are also varieties of formal definitions for handling of materials in the literature. Handling of material is a system of interrelated handling activities, the other one is the activities of loading, unloading placing and manipulating material and of in process movement. In addition, the physical handling of products and materials between procurement and shipping can describe in other handling types.

Layout planning is necessity for each warehouse. Today, the competition is more intense in the market so every detail is very important in layout planning. If the warehouse area designed correctly, it can provide many benefits. The objectives of layout optimization planning to provide space efficiency, efficient material handling, cost efficiency, flexibility, good housekeeping. Moreover, the other main benefits warehouse planning below explained:

- Reducing travel distance to fast movers
- Balancing the fast movers across aisles/bays to reduce congestion
- Picking very slow movers from reserve storage
- Sizing locations to satisfy required days-on-hand
- Sizing locations to reduce stock-outs
- Maximizing the location cube, resulting in less space required
- Arranging products based on stack ability (for pallet building)
- Developing effective picking zones (category, customer, temperature, etc.)

In addition to the objectives that Salvendy (2001) has defined, Mulcahy (1993) brings forward more objectives. Warehouse layout objectives according to Mulcahy (1993) are as follows:

- Maximizing the space utilization
- Efficient product flow
- Ease of access to positions and inventory rotation

- Reducing annual operation costs
- Improve employee productivity
- Maintain philosophy and direction of the corporate
- Protecting the inventory
- Providing expansion
- Providing safe work environment
- Customer Satisfaction

In figure 3.5, it shows sample warehouse layout design situation. In this layout, the summary of all kinds of buildings are in need of a receptacle is defined. For example uninterruptible power supply, Ethernet connection etc.

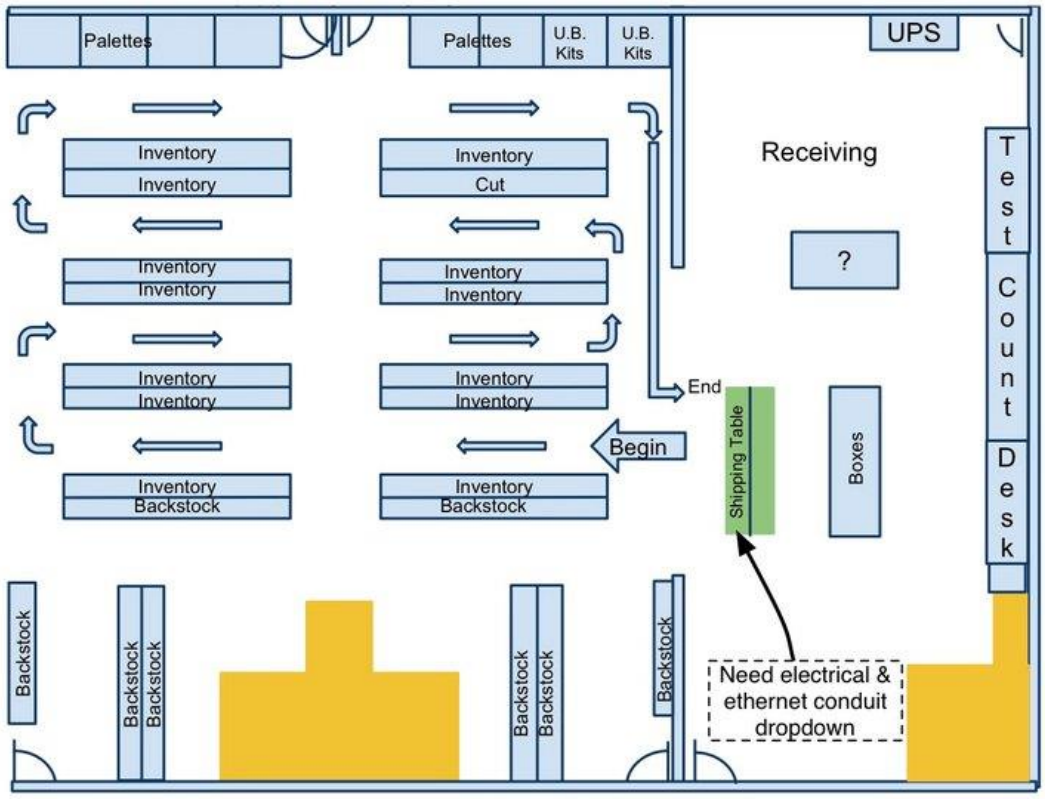

Figure 3.5 Sample warehouse layout design

Source: http://www.philsuslow.com/phil/warehouse-automation/

4. LITERATURE REVIEW

Today, with the globalization of the world it has become feasible to sell the other side of the world's product where have been produced at the other side of the world. Therefore, competition environment has increased between companies so an effective supplier selection process is very important to the success of any manufacturing organization. The supplier selection question has become extremely important (Petroni, 2000).

The main objective of supplier selection process is to reduce purchase risk, maximize overall value to the purchaser, and develop closeness and long-term relationships between buyers and suppliers, which is effective in helping the company to achieve "Just-In-Time" (JIT) production (Li et al., 1997).

Nowadays, supplier selection and evaluation problem is one of the most important topics in industries so there have been many studies on this subject. Researchers have developed many methodologies for solving supplier selection problem. Supplier evaluation has been shown to be multiple criteria decision-making (MCDM) problem (Weber et al 1991). MCDM techniques support the decision-makers (DMs) in evaluating a set of alternatives (Amid et al., 2006). Supplier selection is a multi-criterion problem, which includes both qualitative and quantitative factors (criteria). Looking at the AHP applications over the years, it consists of the many studies in literature. The method has been studied on this subject will be review below.

For supplier selection and evaluation problem have been proposed methodologies and techniques included methods such as Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Data Envelopment Analysis (DEA), Genetic Algorithms (GA) and SMART theory (Simple Multi-Attribute Rating Technique). There are other several supplier selection and benchmarking methods available in the literature such as fuzzy programming model (Sanayei et al., 2010; Wu et al., 2010), artificial intelligence (AI) (Hong et al., 2005; Lau et al., 2006), multiple attribute utility approach (MAUT) (Min, 1994).

The beginning, producers tried to experiments with heuristic methods, but in time they were forced to start academic studies for improvement. To do more

scientific research was needed to process improvements. Furthermore, other approaches was developed such as Fuzzy Logic Approaches (Bevilacqua and Petroni, 2002; Lee, 2008), Mixed Integer Programming (Hartmut, 2007), Real Options Approach (Costantino and Pellegrino, 2010), Supply Base (Choi and Krause, 2006), Simulated Annealing (Chen and Zhang, 2010), Integrated Approach (Ting and Cho, 2008), Total Cost of Ownership Approach (Bhutta and Huq, 2002), Hybrid AHP (Sevkli et al., 2008), etc. for supplier selection problem.

One of the most important methods is Analytic Hierarchy Process that was used in the study of consumer behaviour in 1968 as the first by Myers and Alpert. (Journal of the Academy Marketing Science, Volume 22, No 4, Page 383-392) .After all Analytic Hierarchy Process (AHP) was developed by Saaty in (1977,1980). AHP is used in the solution of multi-criteria problems. Technique allows each criteria evaluation and optimization of the results. Before AHP, DQDA (Dual Questioning Determinant Attribute) developed in 1971; Alpert was using this technique for marketing research applications. This method was evaluating attributes. AHP method allows to decision makers can evaluating alternatives. (Saaty, 1977-1980)

Wind and Saaty (1980) examined various marketing applications of the AHP. Whipple and Simons (1987) used to evaluate the effect of the decision maker's gender making microcomputer vender selections. Javalgi, Armacost and Hosseini (1989) used the AHP to examine bank selection decisions by consumers.

Today, with the help of analytic hierarchy process, many problems can be resolved with a solution. An application made in the military field, "Effective decision-making with AHP in the selection of candidates Turkish Air Force" is work (Levent Erikan, 2002) was published in 2002.

"Prioritization of quality function expansions with the help of analytic hierarchy process" is the book, in 1998, published by Cem Görkem Özarpacı of glory.

"The evaluation of investment projects under uncertainty with fuzzy analytic hierarchy process" Fuzzy AHP approach is to work with management has been added for solutions (Emre Çevik, Cengiz Kahraman, 2009).

In other applications, it has made application made by AHP again, one of the founders of the Saaty in policy areas (Saaty and Vargas, 1994). Strategic researches and strategies in the field of identification, applications were made by Saaty and Wind (1980). Studies on consumer behaviour and consumer preferences were realized at the beginning of the process (Saaty, 1982). In the field of human resources, performance evaluation studies were also made (Chan and Lynn, 1991). The choice of storage locations, while the AHP application, realized Korpela and Tuominen (Korpela and Tuominen, 1996). Applications related to the selection of suppliers in the communication system (Tam and Tummala, 2001). An analysis of the transformational leadership perspectives (Sipahi and Berber, 2002) such studies in the literature.

When we look at our country, which are registered academic studies conducted in universities, 98 pieces of work with AHP has been realized.

Other multi-criteria decision analysis method is Vikor. Serafim Opricovic originally developed it. Vikor method takes into account many criteria used in the literature as a multi-criteria decision-making tools of choice among various alternatives (Cristóbal, 2012, 752). In the literature, Liou and friends (2010) used an adapted Vikor method to improve the quality of domestic airlines service. Chang and Hsu (2009) for Tseng-Wen Reservoir land restriction strategies has been used Vikor metod for prioritizing. Sayadi and friends (2009) have used the Vikor method to solve the problem extended decide spaced numbers (Demirel and Yücenur, 2011, 1128). Büyüközkan and Ruan (2008) to evaluate the software development project Vikor method had been applied (Choi et al., 2014, 161).

Opricovic and Tzeng (2007) have compared the four multi-criteria decision-making methods. Topsis, Promethee, Electra and compared the Vikor methods and found the Vikor method as the best evaluation method (Choi et al., 2014, 161). Vikor method uses linear normalization. Vikor method calculates the ratio of positive and negative ideal solution. However, Vikor method proposes a solution accommodating advantageous ratio (Amir et al., 2011, 68).

In the thesis screening centre, the result of the investigation of the Vikor method, there are seven studies. We examine the study, methods of Vikor is seen in the work that is harmonized with AHP.

In general, subjects studied, our country seems to be made of less practice Vikor method according to AHP method. In general, AHP used more times than Vikor in the literature.

In addition, in this thesis includes warehouse selection. Especially, it refers 3PL selection and evaluation. The literature analysis allows us to classify the several methods of 3PL selection and evaluation. According to literature, there are four main categories. First method is linear weighting model; second is artificial intelligence and statistical/probabilistic approaches, the lastly mathematical programming models. The linear weighting models are the most used approaches for selection of 3PL warehouse.

In the study, there are main criteria and sub-criteria for decision making of warehouse selection. In this decision is complex because it requires the use of several criteria such as service, quality, market, operational, etc. In 1994 and 1999, the top three determinants in selecting a 3PL were service quality, reliability and on-time performance. By 2003, the price became the most important selection criterion (Aicha Aguezzoul, 2007).

A software tool was presented for selection of public warehouse (Colson, G. and Dorigo, F., 2004).Their extensive list of decision criteria includes storage surface and volume, dangerous items, geographical distance to highway connection, certification (ISO 9001/9002, SQAS, HACCP) etc. (Aicha Aguezzoul, 2007). This article also inspires us. The sub-criteria certificate (ISO 9001/9002) used to determine quality score and by other sub-criteria. One study by the American Warehouse Association in 1994 found that the top ten selection criteria for firms choosing public warehouse providers was service quality, reliability, on-time performance, good communication, customer support, speed of service, flexibility, management quality, willingness to customize and order cycle time (Traffic Management 1995). According to these criteria, we are selected some of them such as sub-criteria of service quality and on time performance etc. As a consequence of researches, six main criteria and other sub-criteria are selected and identified in this thesis.

5. MULTI-CRITERIA DECISION MAKING TOOLS

Multi-criteria decision-making (MCDM) is a branch of operation research models and a well-known field of decision-making. These methods can handle both quantitative as well as qualitative criteria and analyse conflict in criteria and decision makers (Pohekar SD, Ramachandran M (2004). Decision maker(s) want to decide fast and true for during selection so some methodologies are used for decision making such as excel. If there are many alternatives and criteria in a problem, decision-making tools are used for selection or decision. Multi-Criteria Analysis (MCA) is a decision-making tool developed for complex problems. Multi criteria decision analysis (MCDA) has made practical methods available for applying scientific decision and theoretical approaches to complex multi-criteria problems. Analytical Hierarchy Process is the most popular weighting method in comprehensive MCDA method. There are other methods such as TOPSIS, VIKOR and Fuzzy AHP etc.

5.1. The Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) is a multi-criteria decision making process that is a structured technique for organizing and analysing complex decisions. It uses a multi-level hierarchical structure of objectives, criteria, sub-criteria and alternatives. Based on the mathematics and psychology, it was developed in 1980 by Thomas L. Saaty and perhaps the most widely used method in the world and has been extensively studied and improved since then. AHP is a tool that helps to find the suitable alternative when problem involves many decision alternatives. The method is similar to the weighted sum model with the exception of the weight allocation process.

In using the AHP, one constructs a hierarchy (consisting of goal, criteria and alternatives), and then makes judgments (or performs measurements) on pairs of elements with respect to a controlling element. Ratio scales are derived from these judgments and then synthesized throughout the structure to selected the best alternative.

The analytic hierarchy process method consists of three levels of hierarchy. The first level of hierarchy is the objective of the decision-making, the second level of hierarchy is how each of the existing criteria contributes to the achievement, and the

last level of hierarchy is to find out how each of the alternatives contributes to each of the criteria.

Taylor (2002) explains that the steps of decision-making process using by the method are as follows:

- Objective determine, main-criteria, sub-criteria, alternatives and construction of the hierarchy
- Make pairwise comparisons of criteria
- Make pairwise comparisons of alternatives for each criteria
- Preparation of pairwise comparison with normalized matrices (each column by dividing the sum of the column)
- Calculation of priority vector (each line is obtained by the taking average)
- Determination of weights and alternative criterion of benchmark scores
- Calculate and check consistency ratio
- Analysis of the AHP scores

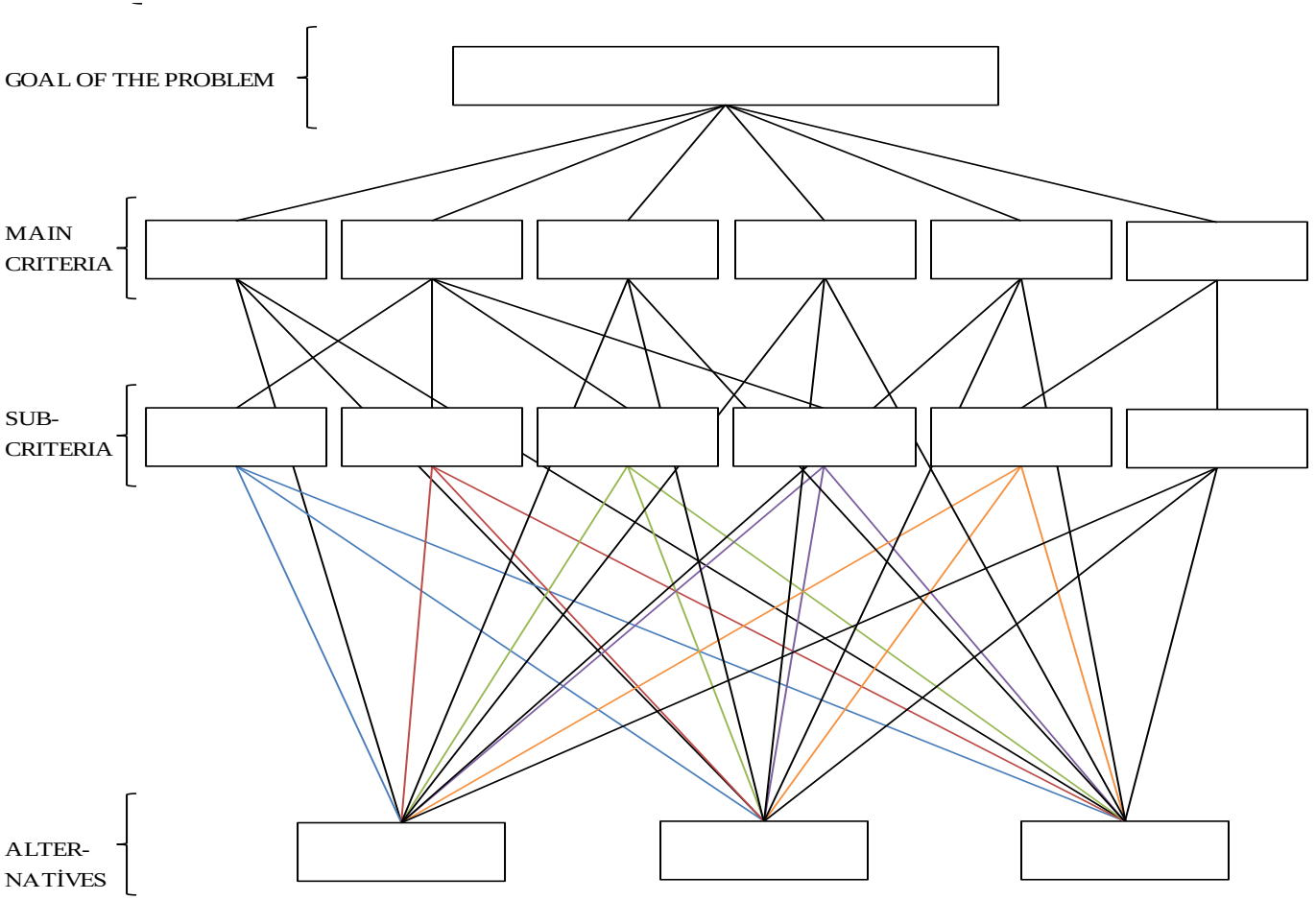

Figure 5.1 The main AHP design

5.1.1 **Basic principles of AHP methodology**

AHP is a successive pairwise comparison process between each criterion and each alternative, rather than a simultaneous process like the weighted sum model. Psychologists have used this technique for a long time to compare affective alternatives (Yokoyama, 1921; Saaty & Ozdemir, 2003).

Saaty (1994) states that there are three basic principles in the AHP method, which are as follows, decomposition.

The decision problem is decomposed into same hierarchical components such as the objective of the problem, performance criteria including sub-criteria and the solution alternatives. Those components are combined to form a hierarchical tree structure.

Comparative Judgement, the essence of AHP method is to make pairwise comparisons between the components of the hierarchical structure. Those comparisons help us to evaluate the relative importance of the components. A special evaluation method is used through pairwise comparisons. The conclusions can be observed in the form of Pairwise Comparison Matrices.

Synthesis of Priority, from each of pairwise comparison matrix, the eigenvector value can be determined to acquire local priority. Because the Pairwise Comparison Matrix is available in each level, the global priority can be acquired by synthesizing between those local priorities. The procedure of synthesizing is different according to each hierarchy. To rank the elements according to its relative importance through synthesizing procedure is called priority setting.

According to Saaty (1994:203), this AHP method is appropriate to be used in making decision that involves decision element comparison, which is difficult to be assessed quantitatively. This matter is based on the assumption that human beings' natural reaction when facing a complex decision-making, is by grouping the decision elements according to its common characteristics. This grouping process includes rank the decision elements, and then comparing between each pair in each group in a

form of matrix. Afterward, inconsistency ratio and weight for each element will be acquired. Thus, it will provide ease in testing the data consistency.

The ratio-scale form is used as an input in the AHP method, which states one's perception when facing the decision-making situation. The values in the ratio are then organized in a matrix, which is called the pairwise comparison matrix. Due to the limitation of human beings' brain capability, the ratio-scale is limited as well. In the AHP method, the scale range 1–9 is assumed sufficiently representing human beings' perception. Either the reason why the AHP method limits the ratio-scale 1–9, is according to the research conducted by a psychologist (Miller, 1956: 256), which shows that human beings cannot simultaneous compare more than seven objects, it increases or decreases two objects. In such condition, human beings will lose their consistency in making the comparison.

A basic, but very reasonable, assumption is that if attribute A is absolutely more important than attribute B and is rated at 9, then B must be absolutely less important than A and is valued at 1/9. These pairwise comparisons are carried out for all factors to be considered, usually not more than seven, and the matrix is completed. The matrix is of a very particular form which neatly supports the calculations which then ensue (Saaty was a very distinguished mathematician). The example scale for comparison (Saaty & Vargas, 1991).

Table 5.1 Preference Scale of Pairwise Comparisons

Intensity of Importance	Definition	Explanation
1	Equally Preferred	Two factors contribute equally to the objective
3	Moderate Preferred	Experience and judgement slightly favour one over the other.
5	Strong Preferred	Experience and judgement strongly favour one over the other.
7	Very Strong Preferred	Experience and judgement very strongly favour one over the other. Its importance is demonstrated in practice.
9	Extreme Preferred	The evidence favouring one over the other is of the highest possible validity
2,4,6,8	Intermediate values between two adjacent scale values	When compromise is needed

5.1.2 **Test of consistency**

AHP method checks the consistency of the pairwise comparisons in order to get a reliable solution. Inconsistency arises in different situations. One example is the following. Assume that three criteria are considered, and the decision maker evaluates that the first criterion is slightly more important than the second criterion, while the second criterion is slightly more important than the third criterion. An evident inconsistency arises if the decision maker evaluates by mistake that the third criterion is equally or more important than the first criterion. On the other hand, a slight inconsistency arises if the decision maker evaluates that the first criterion is also

slightly more important than the third criterion. A consistent evaluation would be, for instance, that the first criterion is more important than the third criterion.

5.1.3 **Pairwise comparison matrix**

To develop the Pairwise Comparison Matrix, the data generated from the questionnaire are used, which are the average measurement given by the respondents arranged in the form of matrix. After constructing the pair-wise comparison matrix and making the normalization computation to form the matrix elements onto a common scale, you can obtain the priority ranking of the criteria through calculating row averages. Meanwhile, doing a consistency check is an essential step of implementing the AHP method. It verifies the consistency, thus the acceptance, of priority judgments. It measures how consistent the judgments have been comparing to large samples of purely random judgments.

The consistency ratio (CR) computation formula is:

CR = Consistency Index (CI) / Random Consistency Index (RI).

The AHP method can tolerate the inconsistency by providing the measurement of assessment inconsistency. This measurement is one of the important elements in priority determination process according to pairwise comparison. The higher consistency ratio, the assessment result becomes more inconsistent. The acceptable consistency ratio is less than or equal to 10 percent, although in some cases the consistency ratio which is higher than 10 percent is still considered acceptable (Forman dan Selly, 2001: 70). As, Ax = λmaxX, where A is denoted as the pair-wise comparison matrix and X as row averages, CI can be calculated by formula (1):

$$CI = \frac{maks.\ eigenvalue - n}{n-1} \qquad (1)$$

If the value of Consistency Ratio is smaller or equal to 10%, the inconsistency is acceptable. If the Consistency Ratio is greater than 10%, we need to consider revising our subjective judgments. According to Taylor III (2002: 379), Consistency Index (CI) can be calculated by using formula as follows.

$$maks.eigenvalue = \sum_{i} wi.ci \quad (2)$$

After acquiring Consistency Index (CI), the next step is calculating Consistency Ratio (CR) by using formula:

$$CR = \frac{CI}{RI} \quad (3)$$

Description:

n = Amount of items compared

wi = Weight

ci = Sum of column

CR = Consistency Ratio

CI = Consistency Index

RI = Random Consistency Index

Table below shows average random consistency: The Reference Values of RI for Different Matrix Sizes (Alsuwehri, 2011; developed by Saaty).

Table 5.2 Random Consistency Indices- (for number of items compared in a matrix)

n	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

If $CR \geq 10\%$, achieved data is inconsistent

If $CR < 10\%$, achieved data is consistent.

Using the responding RI found in the above table, we can receive the consistency ratio CR = CI/RI. If the CR value is less than 0.1, then we say the judgments are consistent and acceptable. The test result is inconsistent if CR ≥ 10%, The RI index is a constant value for an n x n matrix. (Asamoah et al, 2012).

5.2. VIKOR

The compromise ranking method (called VIKOR) has been introduced as a useful technique to implement within MCDM (Opricovic 1998). VIKOR method was developed as a multi-criteria decision making method to solve a discrete decision problem with non-commensurable (different units) and conflicting criteria (Opricovic and Tzeng, 2004).

This method focuses on ranking and selecting from a set of alternatives, and determines compromised solutions for a problem with conflicting criteria, which can help the decision makers to reach a final decision. It presents the multi-criteria ranking index based on the particular measure of ‘‘close-ness’’ to the ‘‘ideal’’ solution (Opricovic, 1998). Assuming that each alternative is evaluated according to all criteria, the compromise ranking could be performed by comparing the measure of closeness to the ideal solution F* (the best values of criteria). The multi-criteria merit for compromise ranking is developed from the Lp-metric used in compromise programming method (Yu, 1973; Zeleny, 1982). The compromised ranking method of VIKOR consists of the following steps:

1) Determination of the positive-ideal solution’s value f_i^* and the negative-ideal solution’s value f_i^- , i = 1, 2,….,n. If the i^{th} function represents a benefit then:

$$fi_{jj}^* = max f_{ij}, \quad f_i^* = min f_{ij}, \tag{4}$$

If the i^{th} function represents a cost then: $f_i^* = minf_{ij}, \quad fi_{jj}^* = maxf_{ij}$

2) Computation of the values S_j and R_j , j = 1, 2,….,J, by the relations, S_j is the optimal solution of schemes' comprehensive evaluation, R_j is most inferior solution of schemes' comprehensive evaluation.

$$S_j = \sum_{i=1}^{n} w_i\left(f_i^* - f_{ij}\right)/(f_i^* - f_i^-) \tag{5}$$

$$R_j = max\left[wi\left(\left(f_i^* - f_{ij}\right)/(f_i^* - f_i^-)\right)\right] \tag{6}$$

where w_i denotes the weights of criteria.

In the function, w_i are weights of each indicator, meaning the relative importance among the indicators.

3) Computation of the values Q_j, j = 1, 2,….,J, by the relation.

$$Q_j = \frac{v(S_j - S^*)}{S^- - S^*} + (1 - v)(R_j - R^*)/(R^- R^*) \tag{7}$$

Where;

$$S^* = minS_j, \;\; S^- = maxS_j, R^* = \min Rj \,, \;\; R^- = \max R_j \tag{8}$$

"v" is introduced as the weight of the strategy of the majority of criteria"" (or the maximum group utility), usually it defines the value, v = 0.5.

4) Rank the alternatives, sorting by the values S, R and Q.

The results are three ranking lists; propose as a' compromise solution, for given criteria weights, the alternative (a'), which is the best ranked by the measure $\mathrm{Q_{min}}$ if the following two conditions are satisfied:

C1 is the acceptable advantage.

$Q(a'') - Q(a') \geq DQ$; Same time DQ =1/(m-1) (9)

Where a´´ is the alternative with second position in the ranking list by

$Q;\ DQ = \frac{1}{m-1}$; m is the number of alternatives.

C2: Acceptable stability in decision-making:

The alternative a´ must also the best ranked by S or/and R. This compromise solution is stable within a decision making process, which could be: "voting by majority rule" (When $v > 0{,}5$ is needed)

On the other hand, by "consensus", $v \approx 0{,}5$ or "with veto" ($v < (0{,}5)$ .As indicated before, v represents the weight of the decision making strategy "the majority of criteria" (or the maximum group utility).

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

(1) If the condition C2 is not satisfied, then (a') and (a'') or

Schemes are both compromise solution.

(2) If the condition C1 is not satisfied, we will get schemes$(a'),(a''),\ldots (a^r)$.

(a^r) It is determined by the relation:

$Q(a'') - Q(a') \geq 1/$ (m-1), for maximum m (the positions of these alternatives are "in closeness") (Opricovic and Tzeng, 2006).

The best alternative, ranked by Q, is the one with the minimum value of Q. The main ranking result is the compromise-ranking list of alternatives, and the compromise solution with the "advantage rate". VIKOR is an effective tool in multi-criteria decision making, particularly in a situation where the decision maker is not able, or does not know to express his/her preference at the beginning of system design (Opricovic and Tzeng, 2002).

5.3. Other Methods

There are several classifications, but in general these methods can be divided into two categories: multi-objective decision-making (MODM) and multi-attribute decision-making (MADM) (Climaco, 1997). In MODM, the decision problem is characterized by the existence of multiple and competitive objectives that should be optimized against a set of feasible and available constraints (Diakaki et al, 2010) rather than, as in MADM, the evaluation of a set of alternatives against a set of criteria. MADM is one of the most popular MCDM methods to be adopted to solve problems associated with different perspectives (Wang et al, 2010). They contain several different methods of which the most important are Analytic hierarchy process (AHP), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) and Elimination Et Choix Traduisant la REalité (ELimination and Choice Expressing REality or more commonly—ELECTRE). The mostly used methods AHP, PROMETHEE, ELECTRE, MAUT, fuzzy methods and decision support systems (DSS) (Pohekar and Ramachandran, 2004) in literature. Other method is widely used the technique for order preference by similarity to ideal solutions (TOPSIS). The basic concept of TOPSIS is that the selected alternative is the one that has the best value for all criteria, i.e. has the shortest distance from the negative ideal solution (Wang et al, 2008). Consequently, it is noticed that AHP is the most used methodology of all MCDM methods.

6. APPLICATION OF THE MODELS IN THIRD PARTY LOGISTIC WAREHOUSE SELECTION

The goal of this study is to evaluate the efficiency of warehouses and ranking them in order to help experts for deciding which supplier should be preferred. This thesis includes two methods in the application. First method is Analytic Hierarchy Process and it will be used for evaluating the alternatives. Moreover, second method is VIKOR and this method used to rank alternative. The VIKOR method provides the maximum group utility for the majority and minimum of an individual regret for the opponent.

6.1. AHP Model

Generally, there are three main components in AHP hierarchy. They are the objective of the model, comparison criteria, sub-criteria and the alternatives to be ranked. Two different models are used for warehouse selection.

The objective of the model is defined as “Selection of the Best Efficient Third-Party Warehouse”. There are three alternatives third-party logistic companies in study. These companies are the leading companies in the sector so their name is not used. Instead of their name Warehouse A, Warehouse B and Warehouse C used.

There are main criteria and sub-criteria in this study. These criteria determined by decision makers who are the managing partners of the logistic firm with consultants in each company. The main-criteria and sub-criteria are defined as shown in table 6.1 comparisons of main criteria used in AHP model.

Table 6.1 Comparisons of Main Criteria Used in AHP Model

Criteria	**Main-Criteria**
Criterion 1	Market
Criterion 2	Quality
Criterion 3	Operational
Criterion 4	Constructional
Criterion 5	Service
Criterion 6	Social Responsibility or Green Projects

6.1.1 **The details of comparison criteria**

Each main criterion has sub-criteria. In this section, the details of the comparison criteria will be showed. Each criterion will be explained in detail. Why these criteria are selected in the model, the reason will be discussed.

6.1.1.1 Main criteria: market

The market main criteria have four Sub-criteria. These criteria are important for the selection of warehouses.

The market criterion is one of the important factors in the logistic sector. The market criterion is defined as the combination of four sub-criteria that are closeness to the market, closeness to the supplier, global marketing capabilities, and market knowledge.

The sub-criterion closeness to the market refers to the distance of customers' location. Where located majority customers and important customers are that is important for decision maker. If the amount of distance increases, cost and elapsed time increase. It is undesirable situation for customer. We asked to an expert who is working in the company: Where are your highly served customers located and how important for you to be close to your customers? According to answers, we determined to sub-criteria score.

Another sub-criterion is the closeness to the supplier. It is critical point for supplier location. It is important to be close to suppliers for customers. If the supplier is close, the customers can save time and cost during transportation. Today, the cost and time are important for companies and especially logistic companies because competition is hard in the sector. Time and cost are valuable for every company. Some question was asked about supplier location: Where are your suppliers located and how important for you to be close to your suppliers and according to answers, we calculated sub-criteria score.

Third sub-criteria is the global marketing capabilities which is important for companies because of sales abilities. Today, the production is no longer determines the sales ability, the sales ability determines by the marketing capabilities. With new

technologies for all companies, world has been market. People now have the ability to shop from the other side of the world. This means that, the larger the targeted markets, it will be available to as many sales turnover for companies.

Market knowledge is important for the warehouse and producers. The warehouse, which has market knowledge, with information of the official papers and laws that, may enter the market with less effort; and they know how to document, which helps the manufacturers' sales operations.

6.1.1.2 Main criteria: quality

The quality criterion is always included in supplier evaluation. Same time, the quality is another factor in warehouse selection. The quality main criteria have four sub-criteria. The quality criterion is defined as the combination of four sub-criteria that are training plan for staff, problem solving, customer follow up and quality certificates. We are used sub-criteria for gather the required information about suppliers because the quality is an important factor in choosing suppliers.

First sub-criteria is training plan for staff. The workers should have necessity information and enough qualified. Customers pay attention to using problem solving tools and training plan of staff because trained staff can do more work in a professional in job. Thus, the staff can make fewer mistakes and the company mistake rate is lower according to other companies. The mistake rate is important to some factor for customers.

The second sub-criteria is problem solving. The problem solving system is important for the success. The major aim is to prevent the errors, if it has occurred to prevent the repetition. The QRQC means Quick Response Quality Control. The ability of the problem solving system is similar of the immune system against the fealties. These processes support the protection from the mistakes and to provide continuous improved for companies.

The third sub-criteria is customer follow-up system. It is necessity factor because it checks the location of the product and follows the recent situation. Thus, customers can learn the final status of the product.

The last sub-criteria is quality certificates. It is better to have quality certificates because it shows application of necessity standards for customer. Quality Certificates, in today's competitive environment, quality plays a very important role for customers. Having the quality management system makes a difference between companies. If the company has quality certificates (ISO 9001 and ISO 10002), it is proven competence.

6.1.1.3 Main criteria: operational

The operational criterion is one of the main factors for selection of warehouse. There are operational activities a critical role for customers.

First sub-criterion is order accuracy. This sub-criterion’s rate shows us performance of the warehouse operations. Nowadays many companies work with Customer Relationship Management (CRM) programs. These programme’s aim provides right order, right time, right place. Miss place orders, missing orders, wrong items order can be doubt to companies by the customers.

Second sub-criterion is return rate. This criterion should be minimised by the warehouses. If this criterion is high, it means that, there are some operational problems in warehouse management system. Return rate can be calculated by total number of pallets divided total number of shipped pallets. With this formula one can calculate the return rate of warehouses.

Third sub-criterion is averages pick time. For warehouse, working performance is important. This performance criterion can improve with pick path optimization or optimization capabilities in storage and picking. For example, if high runner goods placed closed the truck lifting are, at that time company can minimised domestic transportation cost.

The other sub-criterion is turnover rate. This is one of the important criterions. The higher turnover that it is considered to work in a dynamic store. Inventory turns show the number of times the total value of an item is transferred out. Its values display the speed of the goods entering the warehouse.

The last criterion is space utilization. It is so important because there are advantages for warehouses. Thus, companies can also reduce their costs and improve

efficiency of their warehouse by maximizing the space utilization. Moreover, it is possible to store as many items as possible in the most optimum space. When a company has performed some space utilization project, they often find that they do not need as large a warehouse as they had been using. This area is not necessary for their using so their warehouse cost is higher. While warehouse selection, the company should investigate about optimization of space utilization.

6.1.1.4 Main criteria constructional

The constructional criterion is one of the important factors in the logistic sector. The constructional criterion is defined as the combination of five sub-criteria that are resistance to natural disasters, structural condition, and insulation, availability of electric forklifts and Fire Protection.

First sub-criteria is resistance to natural disasters. The resistance to natural disasters sub-criteria is related to warehouse location. The building should not be located in an area that is prone to earthquakes, hurricanes, windstorms, floods or other potentially catastrophic natural events.

Second sub-criteria is structural condition. The building should be in good structural condition. Major components should be inspected regularly and properly maintained. For example, the roof should be examined periodically for damage due to roof traffic, contaminants, poor drainage, windstorms or other environmental or climatic conditions. Any defective areas should be repaired, as needed. A qualified individual/company should perform repair work.

Third sub-criteria is insulation. The warehouse should be isolated because the isolation is necessity for some special materials and some customers can want to wall of building and roof should be isolation. Warehouse located in areas that are subject to snow/ice accumulation should have contingency plans in place for snow/ice removal from the roof, in the event of heavy storm accumulations.

Other sub-criteria is availability of electric forklifts. Electric forklift utilization rate in the transportation process is an important tool for domestic transportation. These sub-criteria can be analysed on different topics. An electric or motorized transport operation has been, will make significant contributions in terms of

productivity, and will help to reduce costs. Operation and maintenance costs of electric forklifts have lower cost according to diesel and gas forklifts. On the other hand, with electric forklift truck loading and unloading operations will also prevent potential product damage problems.

The last sub-criteria is fire protection. Warehouse personnel should be trained in general fire-safety, including specific instruction in the use of portable fire extinguishers. Other important point is that fire department should be nearby with the equipment necessary to respond to an incident. Other point is water control valve(s) and the water control valve(s) should be secured in an open position and equipped with a tamper alarm or should be chain-locked.

6.1.1.5 Main criteria: service

Service is means that in other words, operation quality, process quality, system quality. Of course, that does not have a warehouse with a good quality of service; it will not be able to work in the long term. These main criteria can analyse with some sub-criteria.

First Sub-criteria is on-time performance, same time it means time to response immediate requests. Timely delivery of products and services are of a very serious importance to the consumer. Other than the durable goods which products have short and middle term expired dates, on time delivery is top of major points. None of the manufacturer wants to send expiry date passed products to the customer. Even if can be product is a durable good, on time delivery is major point for success in global competition.

Second sub-criteria is service quality (providing value-added activities, processing standards), value-added activities, Design and recycling of packaging, marking/labelling, billing, call centre activities, customization. All of these are tools for customer satisfaction. Quality is the operational definition in terms of customer satisfaction.

EDI or Electronic order/invoice capability is the other sub-criteria. These systems will help with easy way the operational process. With these systems, firms

can manage their logistic operations within seconds and one centre of the world. For stock management this enterprise resource management are a major topic.

Cost of service or servicing costs are an important factor affecting the final product price. At the same time, the manufacturer is one of the important criteria in the selection of third-party warehouse.

Customer service (Information Technology System) processes today is a decisive criteria selection determined by the customers. For both transparency and information security, it is necessary to develop the system. When the customers are faced with the problems by the organisation, they need to hear their own voice in the organization and they need a channel to understand them. Management of customer service process helps in these terms.

6.1.1.6 Main criteria: social responsibility and green project

Studies for a liveable future, is a criterion of selection criteria among all corporations. Firms should consume resources without damaging the environment. In society, to engage in work fulfil their social responsibilities, it is in ethics. Sub-criteria of Social Responsibility or Green Projects are summarised on the above.

Environmental awareness is a sub-criterion of the social responsibility and green project title. Government and corporate organizations support environmental sensitivity and the entire application appreciates. Some countries have established practices with the law.

Waste management is another sub-criterion of the social responsibility and green project title. Waste management is an important issue in both titles. In this context, it is the responsibility of every business to prevent the release of hazardous waste into the environment.

ISO 14001 certification is given to companies under the name of environmental management system according to ISO standards. If the company has this certification, it means that, this company has suitable management system and makes necessary action for protect environment.

Green public projects, sharing some of their profits with their community of companies, community awareness and social responsibility, they are investments in the future and they are investing in their own future.

Today, the success of the company is linked to how far they can see the vision. Reduction of CO2 (projects) is an important topic for long-term strategical politics for companies. Today's companies, which have solved the today's problem, have the ability to plan for tomorrow.

6.1.2 **Evaluation of the hierarchy**

In this section, it will be showed application of methodology in study. As stated before; the essence of AHP is pairwise comparisons. The synthesis of AHP model is then made by manipulating pairwise comparison matrices. The comparison matrices can include subjective judgments or some direct numerical values. Data are collected from experts. The entries in comparison matrices represent the geometric mean of individual judgments.

In problem, it is used for this thesis following numerical rating and verbal judgment. The first stage starts with the comparisons at the first level, which refer to pairwise comparisons of main criteria see below table. The values represent subjective judgements.

Table 6.2 Pairwise Comparison Matrix for Main Criteria

MAIN CRITERIA	Operational	Service	Market	Quality	Constructional	Social Responsibility
Operational	1,00	2,88	4,22	3,04	7,32	8,65
Service	0,32	1,00	1,44	1,34	2,88	6,87
Market	0,24	0,69	1,00	1,33	3,91	2,92
Quality	0,34	0,75	0,75	1,00	2,00	3,00
Constructional	0,14	0,35	0,26	0,50	1,00	3,56
Social Responsibility	0,12	0,16	0,16	0,23	0,28	1,00
Sum	2,16	5,83	7,83	7,43	17,40	26,00

Pairwise comparison matrix is then normalized and consistency ratio calculated as explain in section 5.2 and normalized matrix is presented in Table 6.3.

Table 6.3 Normalized Matrix of Main Criteria

MAIN CRITERIA	Operational	Service	Market	Quality	Constructional	Social Responsibility
Operational	0,46	0,49	0,54	0,41	0,42	0,33
Service	0,15	0,17	0,18	0,18	0,17	0,26
Market	0,11	0,12	0,13	0,18	0,23	0,11
Quality	0,16	0,13	0,1	0,13	0,11	0,12
Constructional	0,07	0,06	0,03	0,07	0,06	0,14
Social Responsibility	0,05	0,03	0,02	0,03	0,02	0,04
Sum	1	1	1	1	1	1

According to calculation result, the consistency ratio (CR) is 0, 0090. The result is less than 0, 1 and it is consistency.

The relative importance, or weights, or the local priorities of main criteria are then defined by the averages of each row in normalized matrix. These values are presented in Table 6.4.

Table 6.4 Weights of Main Criteria

WEIGHTS	
Operational	0,4429
Service	0,1858
Market	0,1454
Quality	0,1247
Constructional	0,0700
Social Responsibility	0,0312

According above table, the main criteria of operational has the highest score. It shows us, the operational criterion is the most important main criteria and second high score belongs to service criterion between main criteria. Third high score belongs to the market criterion and then quality, constructional the last criterion is social responsibility. It has the lowest score between main criterions.

In the second level of the hierarchy, we need to make pairwise comparisons to find the local priorities of sub-criteria. The first comparison matrix is developed for the sub-criteria of “Market”. The pairwise comparison matrix is presented in Table 6.5.

Table 6.5 Pairwise Comparison Matrix for the sub-criteria of "Market"

MAIN CRITERION: MARKET				
SUB-CRITERIA	Closeness to the market	Closeness to the supplier	Global marketplace	Market knowledge
Closeness to the market	1,00	0,33	0,33	0,20
Closeness to the supplier	3,00	1,00	0,50	0,33
Global marketing capabilities	3,00	2,00	1,00	0,50
Market knowledge	5,00	3,00	2,00	1,00
SUM	12,00	6,33	3,83	2,03

Pairwise comparison matrix is then normalized and consistency ratio is calculated as shown in Table 6.6.

Table 6.6 Normalized Matrix of the sub-criteria of "Market"

SUB-CRITERIA	Closeness to the market	Closeness to the supplier	Global marketplace	Market knowledge
Closeness to the market	0,08	0,05	0,09	0,10
Closeness to the supplier	0,25	0,16	0,13	0,16
Global marketing capabilities	0,25	0,32	0,26	0,25
Market knowledge	0,42	0,47	0,52	0,49
SUM	1,00	1,00	1,00	1,00

This table shows us, the consistency ratio (CR) is 0, 0195.The result is less than 0,1 so it is in consistency.

The relative importance or the local priorities of these sub-criteria are then defined by the averages of each row in normalized matrix. These values are presented in Table 6.7.

Table 6.7 Weights of the sub-criteria of "Market"

WEIGHTS	
Closeness to the market	0,08
Closeness to the supplier	0,18
Global marketing capabilities	0,27
Market knowledge	0,48

In study, there are six main criteria multiple sub-criteria for each one. Above, we calculated weight of the sub-criteria of “Market”. For all other sub-criteria is applied same AHP’ stages and calculated their weights. Moreover, for main criteria and all sub-criteria calculated their consistency ratio. All consistency ratios is calculated less than 0.1 so all results are found in consistent. The other tables and other details is displayed in the Appendix.

The other step is making comparisons according to company for each sub-criteria and calculated the local priorities of alternatives.

The first comparison of alternatives is done with respect to sub-criterion “Closeness to the market”. The comparison matrix is given below in Table 6.8. The comparison matrix includes subjective judgments.

Table 6.8 Pairwise Comparisons Matrix -Sub-Criteria Closeness to the Market

Closeness to the market	Warehouse A	Warehouse B	Warehouse C
Warehouse A	1,00	2,00	3,00
Warehouse B	0,50	1,00	3,00
Warehouse C	0,33	0,33	1,00
Sum	1,83	3,33	7,00

Pairwise comparison matrix is then normalized and consistency ratio is calculated and presented in Table 6.9.

Table 6.9 Normalized Matrix Sub-Criteria “Cloness to the Market”

Closeness to the market	Warehouse A	Warehouse B	Warehouse C
Warehouse A	0,55	0,60	0,43
Warehouse B	0,27	0,30	0,43
Warehouse C	0,18	0,10	0,14
Sum	1,00	1,00	1,00

According to calculation of consistency ratio, result is 0, 04 and it is consistent.

The relative importance or the local priorities of alternatives “Closeness to the Market” are then defined by the averages of each row in normalized matrix. These values are presented in Table 6.10.

Table 6.10 Local Priorities of Alternatives “Closeness to the Market”

WEIGHTS	
Warehouse A	0,52
Warehouse B	0,33
Warehouse C	0,14

The comparison matrix does not include any subjective judgement since this criterion is related with numerical values. The entries in this matrix are calculated by the actual average distances and their values is reached to according in the responses of questionnaire. Local priorities of alternatives are calculated likewise for all of them and their detail tables are displayed in Appendix.

The comparison of alternatives is done with respect to all sub-criteria. The comparison matrix is given for all sub-criteria, then pairwise comparison matrix is normalized, and consistency ratio is calculated and presented in the Appendix. The consistency ratio is less than 0,1 for all calculation so the results are consistent. The values criteria is presented summary table according to every warehouse.

Below, local priorities of alternatives is calculated and presented as summary in Table 6.10. According to results, customer services have the highest value between sub-criteria for Warehouse C. It is 74% and the ratio is very high. It means, Warehouse C has the best customer services between others warehouses. The second high score is 72% with global marketing capabilities and Warehouse A has very big capabilities in the global market according to the others warehouses. There are two sub-criteria in third; they have same value that is 68% with space utilization in the Warehouse A and service quality in the Warehouse C.It means, the Warehouse A have been made efficiently space utilization and the Warehouse C have been provided good service to customers. The others results have been shown in Table 6.11.

Table 6.11 Local Priorities of Alternatives for All Warehouses

MAIN CRITERIA	EVALUATION CRITERIA	Warehouse A	Warehouse B	Warehouse C
Operational	Order accuracy	0,65	0,23	0,12
	Return rate	0,54	0,30	0,16
	Average pick time	0,62	0,24	0,14
	Turnover rate	0,58	0,31	0,11
	Space utilization	0,68	0,20	0,12
Service	On-time performance	0,12	0,23	0,65
	Service quality	0,12	0,20	0,68
	EDI or Electronic order/invoice capability	0,58	0,31	0,11
	Cost of service	0,67	0,23	0,10
	Customer service	0,17	0,09	0,74
Market	Closeness to the market	0,52	0,33	0,14
	Closeness to the supplier	0,58	0,31	0,11
	Global marketing capabilities	0,72	0,19	0,08
	Market knowledge	0,63	0,29	0,08
Quality	Training Plan for staff	0,54	0,30	0,16
	Problem Solving	0,12	0,23	0,65
	Customer Follow-up	0,16	0,30	0,54
	Quality Certificates	0,20	0,49	0,31
Constructional	Resistance to natural disasters	0,20	0,31	0,49
	Structural condition	0,49	0,31	0,20
	Insulation	0,16	0,25	0,59
	Availability of electric forklifts	0,14	0,31	0,55
	Fire Protection	0,54	0,16	0,30
Social Responsibility and Green Porject	Environmental awareness	0,52	0,14	0,33
	Waste management	0,54	0,30	0,16
	ISO 14000 certificate	0,16	0,25	0,59
	Green public projects	0,20	0,31	0,49
	Reduction of CO2	0,62	0,24	0,14

The preferred alternative should have the highest value. AHP results is calculated and found the best efficient warehouse is A with 48%, second warehouse C is with 26% and the lastly, warehouse B is with 25%, which are shown as follows Table 6.12.

Table 6.12 AHP Final Score

WEIGHTS		
WAREHOUSE A	WAREHOUSE B	WAREHOUSE C
0,4836	0,259	0,2614

According to AHP results, Warehouse A has the highest value, second Warehouse is C and third Warehouse is B. The best efficient warehouse is A, because sub-criteria of warehouse A has higher value than others the warehouses. Because warehouse A is operational, activities are better than the other warehouses. With this result under the six main criteria, twenty-five sub-criteria analysed with AHP methods and determined all their score.

6.2. VIKOR Method

In this section, it will be showed application of Vikor Method. Two distinct models are developed for each company. The aims of the models for three companies are defined as “Selection of the Best Supplier”. The alternative suppliers are defined as “Warehouse A”, “Warehouse B” and “Warehouse C” to mask the real names of suppliers.

Pairwise comparison matrices and weights of criteria matrices are calculated using AHP Methodology. In this thesis, two well-known methods, namely AHP and VIKOR, are combined in order to rank alternatives with respect to criteria. The main-criteria of supplier selection same as AHP Methodology as below;

Table 6.13 The Main Criteria Weights

WEIGHTS	
Operational	0,4429
Service	0,1858
Market	0,1454
Quality	0,1247
Constructional	0,0700
Social Responsibility	0,0312

6.1.3 **Application of the VIKOR Method in third-party logistics companies**

First, local priorities of all alternatives is calculated by AHP methods for all main-criteria and AHP' results are used by Vikor Method in the application. First main criteria is "Market", local priorities of alternatives are calculated by AHP.

Table 6.14 Local Priorities of Alternatives "Market"

Warehouse Name	Weights
Warehouse A	0,6367
Warehouse B	0,2720
Warehouse C	0,0913

According to results, the warehouse A has the highest value with 63%, second warehouse is B with 27% and the last warehouse is C with 9%. It means Warehouse A is the best company between the others in the Market.

This method changes the transformation to a linear one and the value before and after transformation are in proportion. For all main criteria are calculated to local priorities of alternatives by AHP method and decision-making matrix values are showed as follows table.

Table 6.15 Local Priorities of Alternatives Main Criteria

fij	Operational	Service	Market	Quality	Constructional	Social Responsibility
Warehouse A	0,6104	0,2253	0,6367	0,3487	0,2734	0,4461
Warehouse B	0,2544	0,2274	0,2720	0,2885	0,2986	0,2264
Warehouse C	0,1353	0,5473	0,0913	0,3629	0,4279	0,3276

(1) Determination of the positive-ideal solution's value f_i^* and the negative-ideal solution's value f_i^- , i = 1, 2,….,n. If the i^{th} function represents a benefit then, in below table is shown the positive-ideal solution's values:

Table 6.16 Positive -Ideal Solution

Main Criteria	Score	Warehouse
Market	0,6367	Warehouse A
Quality	0,3629	Warehouse C
Operational	0,6104	Warehouse A
Constructional	0,4279	Warehouse C
Social Responsibility	0,4461	Warehouse A
Service	0,5743	Warehouse C

The highest values is given positive-ideal solution and the lowest values is given negative-ideal solution between others criteria' values that is selected. In below table is shown the negative-ideal solution's values.

Table 6.17 Negative -Ideal Solutions

Main Criteria	Score	Warehouse
Market	0,288	Warehouse A
Quality	0,323	Warehouse C
Operational	0,244	Warehouse C
Constructional	0,326	Warehouse B
Social Responsibility	0,258	Warehouse C
Service	0,245	Warehouse C

As a result; the positive-ideal solution and negative-ideal solution are shown in the summary Table 6.18.

Table 6.18 Positive and Negative -Ideal Solutions

	Operational	Service	Market	Quality	Constructional	Social Responsibility
f* (positive-idea lsolution)	0,6104	0,5473	0,6367	0,3629	0,4279	0,4461
f^- (negative-ideal solution)	0,1353	0,2253	0,0913	0,2885	0,2734	0,2264

According to Equation (5) and (6) in the VIKOR, calculate each supplier's S, R and Q value, the result is shown in Table 7.7.

Table 6.19 Each Supplier's S and R-Value

	Warehouse A		Warehouse B		Warehouse C	
Main Criteria	R_i	S_i	Ri	Si	Ri	Si
Operational	0,0000	0,0000	0,3319	0,3319	0,4429	0,4429
Service	0,1858	0,1858	0,1846	0,1846	0,0000	0,0000
Market	0,0000	0,0000	0,0972	0,0972	0,1454	0,1454
Quality	0,0229	0,0229	0,1200	0,1200	0,0000	0,0000
Constructional	0,0700	0,0700	0,0586	0,0586	0,0000	0,0000
Social Responsibility	0,0000	0,0000	0,0400	0,0400	0,0216	0,0216
Total	**0,1858**	**0,2787**	**0,3319**	**0,8322**	**0,4429**	**0,6098**

The evaluation value of each supplier was calculated for each warehouse and found "S", "R" and "Q" values following table shows:

Table 6.20 The Evaluation Value of Each Supplier

	Warehouse A	**Warehouse B**	**Warehouse C**
S	0,28	0,61	0,83
R	0,19	0,44	0,33
Q	0,00	0,80	0,78

Rank the alternatives, sorting by the values S, R and Q. The below table, shows ranked values. In this table, all warehouses get their numbers. For example, "Q" value in warehouse A, it shows "0, 00". This is the lowest value in the others. Therefore, this will be first number. With this method warehouse C will called second and the last one is warehouse B. It will be described third.

Table 6.21 Rank the Suppliers by VIKOR

	Warehouse A	**Warehouse B**	**Warehouse C**
S	1	2	3
R	1	3	2
Q	1	3	2

The results are three ranking lists; propose as a' compromise solution, for given criteria weights, the alternative (a'), which is the best ranked by the measure Q_{min} if the following two conditions are met simultaneously, then the scheme with minimum value of Q in ranking is considered the optimal compromise scheme, C1 is the acceptable advantage.

C1 is the acceptable advantage:

According to $Q(a'') - Q(a') \geq DQ$; Same time DQ =1/(m-1).

If m is less than 4, it is taken 0,25(Chen ve Wang, 2009: 237). In thi study m is equal to 3 so we can get it : DQ = 0,78-0 = 0,78 > =0,25.But,

Q (S3)-Q (S1) >=DQ ; 0,7991-0>=0,25 , it is provided this conditions.

C2: Acceptable stability in decision-making:

The best alternative, ranked by Q, is the one with the minimum value of Q. The main ranking result is the compromise-ranking list of alternatives, and the compromise solution with the "advantage rate".According to Q values,Warehouse A has the minimum value of Q,it is equal to zero.And second Warehouse is B with 0,78 and then the third warehouse is C with 0,79.The Warehouse A is in the best ranked by Q , S and R. This compromise solution is stable within a decision making process, by consensus.

Table 6.22 VIKOR Method Results

Supplier	S		R		Q	
	Distance	Rank	Distance	Rank	Distance	Rank
Warehouse A	0,278	1	0,185	1	0	1
Warehouse B	0,832	3	0,331	2	0,784	2
Warehouse C	0,609	2	0,442	3	0,799	3

The best alternative, ranked by Q, is the one with the minimum value of Q. The main ranking result is the compromise ranking list of alternatives, and the compromise solution with the "advantage rate".

Vikor Method result shows us the best efficient warehouse is warehouse A with "0" value. According to Vikor Methods which warehouse has the lowest value of "Q", it means that the best efficent decision it that.

7. SENSITIVITY ANALYSIS

Lastly, we also investigate the efficiency of "v" on the ranking of warehouses. We choose five additional weights. Such as 0, 0.25, 0.50, 0.75, 1.00. These weights are assigned to warehouses to calculate Qi values for each one. Table below shows the results.

Table 7.1 Q Results Depending on "V" Values

Qi				
V	**Warehouse A**	**Warehouse C**	**Warehouse B**	**Ranking**
0	0,02	1	0,57	A,B,C
0,25	0,03	0,9	0,68	A,B,C
0,5	0,02	0,8	0,78	A,B,C
0,75	0,03	0,7	0,89	A,C,B
1	0,02	0,6	1	A,C,B

The v is introduced as the weight of the strategy of the majority of criteria (or the maximum group utility), usually it is taken "0.5." But it is given other values for sensitivity analysis and ranking is changes when v is below and above 0.5 value. If v is bigger than 0.5 value, ranking is taken A,B,C. If v is smaller than 0.5, the ranking is taken A,C,B.

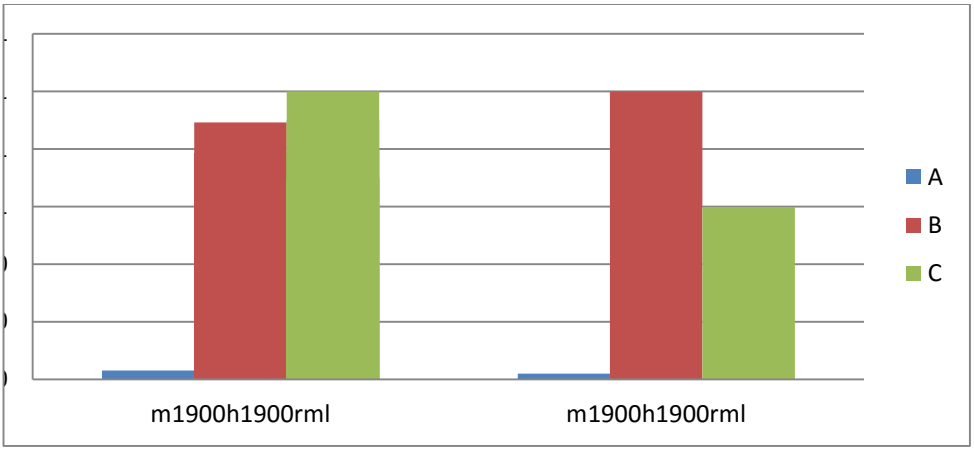

Figure 7.1 Qi-V values for each warehouse

8. CONCLUSION

Supplier selection problem is a well-known problem and it is a popular topic in the literature. Our aim is selection of the best efficient third party warehouse in this thesis. In this thesis, we tested two different methods. For the first method, only the AHP is applied and for the second method, we integrated AHP-VIKOR into a single method. Later, AHP and integrated AHP-VIKOR results are compared. The selection process involves the determination of quantitative and qualitative factors to select the best possible provider with in AHP.

The goal of this study is selection of the best efficient third-party logistics companies. In this thesis, it is discussed the three different international third party warehouse in the logistic sector. Both AHP and VIKOR methods have been performed to identify priorities of alternative suppliers. The results are summarized in Table 8.1.

Table 8.1 Comparison Table of Outcomes for Warehouses

Warehouse	AHP		AHP-VIKOR	
	Rank	Weights	Rank	Weights
A	1	0,483	1	0
B	3	0,259	2	0,784
C	2	0,261	3	0,799

Suppliers' ranking results are close for both methods. The best alternative is same according to both results. It is not surprising since the outcomes of AHP method is fed as inputs of the VIKOR method. The second method emphasizes the best alternative and magnifies the difference in the weights of alternatives.

The criteria set of each company is commonly the same. In the first stage of the application, weight values of the warehouse selection criteria were calculated by AHP. In the second stage, this covered analysis of warehouse companies are listed in order of preference with the help of the VIKOR method in accordance with the predetermined criteria.

As a result of previous calculations, it is determined that warehouse A is ranked as the top of the list and has a distinct advantage compared to other warehouses.

According to this study, Warehouse A is the best alternative for both methods. According to preference ranking Warehouse A, Warehouse C and Warehouse B was determined to follow by AHP method. Second method is, Warehouse A is the best alternative, second Warehouse B and the lastly Warehouse is C according to integrated AHP and VIKOR method.

Moreover, AHP method also calculates main-criteria values for each alternative in this study. Between the criteria the one that has the highest value, "market" criteria is 64% in the Warehouse A. It means, it has an important position in the "market". The second criterion is operational and again warehouse A has best value. The warehouse A has generally high scores according to others and selection of warehouse A has more advantages for customers. The following table presents a comparison for criteria in the three companies.

Table 8.2 AHP Results

Main-criteria	WAREHOUSE A	WAREHOUSE B	WAREHOUSE C	Sum
Operational	0,61	0,25	0,14	1,00
Service	0,23	0,23	0,55	1,00
Market	0,64	0,27	0,09	1,00
Quality	0,35	0,29	0,36	1,00
Constructional	0,27	0,30	0,43	1,00
Social Responsibility	0,45	0,23	0,33	1,00

This thesis aims at designing a multi-criteria decision-making (MCDM) model for evaluation alternatives for selection of best efficient supplier problem. For this purpose, an integrated methodology is structured, where the VIKOR uses the AHP result weights as input weights and then the results are compared between two methods. For further research, it can work on the topic that considers the proposed methodology in a fuzzy environment.

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CURRICULUM VITEA

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APPENDIX 1 TABLES

Table Pairwise Comparison Matrix for Main Criteria

	Operational	Service	Market	Quality	Constructional	Social Responsibility
Operational	1,00	2,88	4,22	3,04	7,32	8,65
Service	0,32	1,00	1,44	1,34	2,88	6,87
Market	0,24	0,69	1,00	1,33	3,91	2,92
Quality	0,34	0,75	0,75	1,00	2,00	3,00
Constructional	0,14	0,35	0,26	0,50	1,00	3,56
Social Responsibility	0,12	0,16	0,16	0,23	0,28	1,00
Sum	2,16	5,83	7,83	7,43	17,40	26,00

Table Normalized Matrix of Main Criteria

	Operational	Service	Market	Quality	Constructional	Social Responsibility
Operational	0,46	0,49	0,54	0,41	0,42	0,33
Service	0,15	0,17	0,18	0,18	0,17	0,26
Market	0,11	0,12	0,13	0,18	0,23	0,11
Quality	0,16	0,13	0,10	0,13	0,11	0,12
Constructional	0,07	0,06	0,03	0,07	0,06	0,14
Social Responsibility	0,05	0,03	0,02	0,03	0,02	0,04
Sum	1,00	1,00	1,00	1,00	1,00	1,00

Table: Weight of Main Criteria

Main Criteria	Wi
Operational	0,44
Service	0,19
Market	0,15
Quality	0,12
Constructional	0,07
Social Responsibility	0,03
Sum	1,00

Pairwise Comparison Matrix "Market"

MAIN CRITERION: MARKET				
SUB-CRITERIA	Closeness to the market	Closeness to the supplier	Global marketplace	Market knowledge
Closeness to the market	1,00	0,33	0,33	0,20
Closeness to the supplier	3,00	1,00	0,50	0,33
Global marketing capabilities	3,00	2,00	1,00	0,50
Market knowledge	5,00	3,00	2,00	1,00
SUM	12,00	6,33	3,83	2,03

Table Normalized Matrix of Sub-Criteria "Market"

SUB-CRITERIA	Closeness to the market	Closeness to the supplier	Global marketplace	Market knowledge
Closeness to the market	0,083	0,052	0,086	0,099
Closeness to the supplier	0,250	0,158	0,131	0,163
Global marketing capabilities	0,250	0,316	0,261	0,246
Market knowledge	0,417	0,474	0,522	0,493
SUM	1,00	1,00	1,00	1,00

Table Weights of Sub-Criteria "Market"

SUB-CRITERIA	**Weight**
Closeness to the market	0,08
Closeness to the supplier	0,18
Global marketing capabilities	0,27
Market knowledge	0,48
SUM	1,00

Table Pairwise Comparison Matrix "Quality"

MAIN CRITERION:QUALITY				
SUB-CRITERIA	Training Plan for staff	Problem Solving(QRQC)	Customer Follow-up	Quality Certificates
Training Plan for staff	1,00	2,00	5,00	7,00
Problem Solving(QRQC)	0,50	1,00	3,00	5,00
Customer Follow-up	0,20	0,33	1,00	3,00
Quality Certificates	0,14	0,20	0,33	1,00
SUM	1,84	3,53	9,33	16,00

Table Normalized Matrix of Sub-Criteria Quality

SUB-CRITERIA	Training Plan for staff	Problem Solving(QRQC)	Customer Follow-up	Quality Certificates
Training Plan for staff	0,54	0,57	0,54	0,44
Problem Solving(QRQC)	0,27	0,28	0,32	0,31
Customer Follow-up	0,11	0,09	0,11	0,19
Quality Certificates	0,08	0,06	0,04	0,06
SUM	1,00	1,00	1,00	1,00

Table Weights of Sub-Criteria "Quality"

SUB-CRITERIA	**Weight**
Training Plan for staff	0,52
Problem Solving(QRQC)	0,30
Customer Follow-up	0,12
Quality Certificates	0,06
SUM	1,00

Table Pairwise Comparison Matrix "Operational"

MAIN CRITERION: OPERATIONAL					
SUB-CRITERIA	Order accuracy	Average turnover rate	Average pick time (avg. number of picks per hour)	Average turnover rate	Space utilization
Order accuracy	1,00	2,00	5,00	7,00	9,00
Return rate	0,50	1,00	3,00	5,00	7,00
Average pick time (avg. number of picks per hour)	0,20	0,33	1,00	3,00	5,00
Average turnover rate	0,14	0,20	0,33	1,00	2,00
Space utilization	0,11	0,14	0,20	0,50	1,00
SUM	1,95	3,68	9,53	16,50	24,00

Table Normalized Matrix of Sub-Criteria "Operational"

SUB-CRITERIA	Order accuracy	Average turnover rate	Average pick time (avg. number of picks per hour)	Average turnover rate	Space utilization
Order accuracy	0,51	0,54	0,52	0,42	0,38
Return rate	0,26	0,27	0,31	0,30	0,29
Average pick time (avg. number of picks per hour)	0,10	0,09	0,10	0,18	0,21
Average turnover rate	0,07	0,05	0,03	0,06	0,08
Space utilization	0,06	0,04	0,02	0,03	0,04
SUM	1,00	1,00	1,00	1,00	1,00

Table Weights of Sub-Criteria "Operational"

SUB-CRITERIA	Weight
Order accuracy	0,48
Return rate	0,29
Average pick time (avg. number of picks per hour)	0,14
Average turnover rate	0,06
Space utilization	0,04
SUM	1,00

Table Weights of Sub-Criteria "Constructional"

SUB-CRITERIA	Weight
Resistance to natural disasters	0,53
Structural condition	0,24
Insulation	0,13
Availability of electric forklifts	0,06
Renewable energy production	0,04

Table Weights of Sub-Criteria "Social Responsibility"

SUB-CRITERIA	Weight
Environmental awareness	0,40
Waste management	0,31
LEED or ANY Certificate	0,16
Green public projects	0,09
Reduction of CO2	0,04

Table Weights of Sub-Criteria "Service"

SUB-CRITERIA	Weight
Time to response immediate requests	0,46
Providing value-added activities	0,30
EDI or Electronic order/invoice capability	0,14
Cost of service	0,07
Customer service	0,03

Table Local Priorities of Alternatives for Sub-Criteria "Training Plan for Staff"

Main-criteria -QUALITY			
Sub-Criteria -1			
Training Plan for staff	Warehouse A	Warehouse B	Warehouse C
Warehouse A	1,00	2,00	3,00
Warehouse B	0,50	1,00	2,00
Warehouse C	0,33	0,50	1,00
Sum	1,83	3,50	6,00

Table Normalized Matrix Local Priorities of Alternatives for Sub-Criteria “Training Plan for Staff”

Training Plan for staff	Warehouse A	Warehouse B	Warehouse C
Warehouse A	0,55	0,57	0,50
Warehouse B	0,27	0,29	0,33
Warehouse C	0,18	0,14	0,17
Sum	1,00	1,00	1,00

Table Local Priorities of Alternatives Weights “Training Plan for Staff”

Training Plan for staff	Weights
Warehouse A	0,54
Warehouse B	0,30
Warehouse C	0,16
Sum	1,00

Table Local Priorities of Alternatives “Problem Solving”

Problem Solving	Warehouse A	Warehouse B	Warehouse C
Warehouse A	1,00	0,50	0,20
Warehouse B	2,00	1,00	0,33
Warehouse C	5,00	3,00	1,00
Sum	8,00	4,50	1,53

Table Normalized Matrix Local Priorities of Alternatives for Sub-Criteria “Problem Solving”

Problem Solving	Warehouse A	Warehouse B	Warehouse C
Warehouse A	0,13	0,11	0,13
Warehouse B	0,25	0,22	0,22
Warehouse C	0,63	0,67	0,65
Sum	1,00	1,00	1,00

Table Local Priorities of Alternatives Weights “Problem Solving”

Problem Solving	Weights
Warehouse A	0,12
Warehouse B	0,23
Warehouse C	0,65
Sum	1,00

Table Summary AHP Results for All Criteria

Main-criteria	Main criteria Weight	Sub-criteria	Sub-criteria Weight	EVALUATION CRITERIA	Warehouse A	WarehouseB	Warehouse C
Operational	**0,44**	Effiency Stroge Area	0,48	Effiency Stroge Area	0,65	0,23	0,12
		Space Utilization	0,29	Space Utilization	0,54	0,30	0,16
		Optimation System	0,14	Optimation System	0,62	0,24	0,14
		Average Pick Time	0,06	Average Pick Time	0,58	0,31	0,11
		Shift / turn of work	0,04	Shift / turn of work	0,68	0,20	0,12
Service	**0,19**	Time to Response	0,46	Time to Response	0,12	0,23	0,65
		Providing value-added activities	0,30	Providing value-added activities	0,12	0,20	0,68
		EDI or Electronic order/invoice capability	0,14	EDI or Electronic order/invoice capability	0,58	0,31	0,11
		Processing Standards	0,07	Processing Standards	0,67	0,23	0,10
		IT System	0,03	IT System	0,17	0,09	0,74
Market	**0,15**	Closeness to the market	0,08	Closeness to the market	0,52	0,33	0,14
		Closeness to the supplier	0,18	Closeness to the supplier	0,58	0,31	0,11
		Global marketplace	0,27	Global marketplace	0,72	0,19	0,08
		Market knowledge	0,48	Market knowledge	0,63	0,29	0,08

Table Summary AHP Results for All Criteria

Quality	**0,12**	Training Plan for staff	0,52	Training Plan for staff	0,54	0,30	0,16
		Problem Solving	0,30	Problem Solving	0,12	0,23	0,65
		Customer Follow-up	0,12	Customer Follow-up	0,16	0,30	0,54
		Quality Certificates	0,06	Quality Certificates	0,20	0,49	0,31
Constructional	**0,07**	Resistance to natural disasters	0,53	Resistance to natural disasters	0,20	0,31	0,49
		Structural condition	0,24	Structural condition	0,49	0,31	0,20
		Insulation	0,13	Insulation	0,16	0,25	0,59
		Availability of electric forklifts	0,06	Availability of electric forklifts	0,14	0,31	0,55
		Fire Protection	0,04	Fire Protection	0,54	0,16	0,30
Social Responsibility	**0,04**	Environmental awareness	0,40	Environmental awareness	0,52	0,14	0,33
		Waste management	0,31	Waste management	0,54	0,30	0,16
		ISO 14000 certificate	0,16	ISO 14000 certificate	0,16	0,25	0,59
		Green public projects	0,09	Green public projects	0,20	0,31	0,49
		Reduction of CO2	0,04	Reduction of CO2	0,62	0,24	0,14

APPENDIX 2 QUESTIONAIRE

Market Criteria

A1) Where are your highly served customers located? Where your customers are mostly located? How important for you to be close to your customers? [Give points 1 - 10 (important)]

A2) Where are your suppliers located? Where are your suppliers located? How important for you to be close to your suppliers? [Give points 1 - 10 (important)]

A3) Are you getting in the global marketplace? If yes, what is your share of the global market? (%) Do you have any services that facilitate your customer's global trade? Do you have any services that facilitate your customer's global trade?

A4) Have you provide any services such as handling importing and exporting operations, related documentation with them. Do you have a bonded warehouse? Do you help your customers/suppliers to help to handle custom issues?

Quality Criteria

B1) Do you have ISO 9001 Certificate (Quality Management System)?

B2) Do you have ISO 10002 Certificate (Customer Satisfaction Management System)?

B3) Do you use Problem Solving Systems (Quick Response Quality Control)? Do you open/use corrective and preventive action (capa) form? How do you evaluate the orders of the customer?

B4) Are there any training plan to your employees periodically? (Personal training plan)

B5) Are there any customer follow up system?

B6) Do you have quality staff? If yes, do you have quality engineer?

Operational Criteria

C1) How many cubic meters total storage area? What is the effective rate of occupancy? (Warehouse occupancy rate = Total volume of product in storage / total storage volume or = Full pallet / Total palette)What is the daily occupancy rate?

C2) Are there any misplaced orders, missing orders, wrong items? Order accuracy as percentage or number of pallets?

C3) Do you have vehicle-tracking systems? (To minimize the number of transfer)

C4) How many is shifts working? In addition, how many are workers?

C5) What is the average utilization of a pallet storage area in your warehouse (in days)? How many days a pallet storage area stays empty in a year?

C6) How long time it takes to receive/put away a pallet? On the other hand, how many pallets can handle a worker in an hour?

C7) How many pallets do you ship in a year? How many of them are returned?

Constructional Criteria

D1) Is your company resistant to natural disasters? What is the cost of damage caused by natural disaster for your company? (1 to 10)

D2) Do you perform repair work periodically? (1 to 10) What are your maintenance activities? For example, how long time do you repair roof maintenance

D3) Do they get benefit of daylight? Do they use power saver lights, such as LED? Do they use censored lights (when somebody enters that area, lights are turned on, or continuous lighting? What percentage of enlightenment is provided by the light of day? Does daylight is sufficient. In addition, did you measure?

D4) Is the warehouse building insulated? Do they have any insulation to save energy?

D5) Do they produce energy from any renewable source? If yes, what is the percentage of their consumptions is provided by their production?

D6) How many forklifts/reach truck they have? How are they run, fuel, gas or electricity? How many of them are run by electricity? How much percentage of the operations in which electric forklifts are used?

D7) For packaging materials, such as boxes, stretch wraps, etc, do they have any policy for purchasing packaging materials made from recyclable materials? If yes, what they buy? What do you with unused or excess packaging materials?

D8) The pallets used in the warehouse are made from wood, metal, plastic, what? How many times they use their pallets? When they are not good for reuse, what do they do with those pallets?

D9) Is it possible to fire the necessary measures have been taken? If yes, what kind of measures has been taken? Do you have a fire department and specially trained any fire personnel? Do warehouse personnel have any trained in general fire-safety?

Social Responsibility and Green Project

E1) What is being done to create more environmentally friendly processes and workplaces? [Give points 1 - 10 (important)]

E2) Are there any procedure for waste management? Do you recyclable yourself? What do you do for wastewater, garbage, boxes, and pallets? Do you separate your garbage?

E3) Is there a 14001 environmental management system?

E4) Have they perform any public projects that contributes to environment?

E5) Does their building any green certificate such as LEED, GBCI, etc.

E6) Do they perform any projects related with reduction CO2 in the warehouse or the transportation side? Does the measurement of the carbon footprint, studies have been carried out to reduce carbon emissions?

Service Criteria

F1) how do you change your customers? For one pallet storage and handling per day, how much do you charge in average?

F2) How long have you been working with your customers (the longest and the shortest one)? How long have you been doing this job? Why do they prefer you to work? For which operations, they actually want to work with you? How often do you receive orders from them (in a year how many transactions occur between them?)

F3) When your customer asks you to ship an item immediately, how long it takes to leave from your warehouse in average?

F4) Have you provide any services such as kitting, labelling, packaging, preparing special document etc. that provides value to your customer?

F5) How do you receive orders from your customers, paper or electronic? How do you send invoices to your customers electronic or paper? So, how do you communication with email or phone or letter?

F6) Will my orders be shipping using my current order processing standards?

F7) Do you use enterprise resource planning? Do you have order management system? Do you have electronic commerce and cataloguers?

F8) Are there any optimization system for storage or warehouse management system? Do you use an optimization module? Search by transportation and warehousing direction are there any optimization system? (Survey study could be done only three of the Warehouse companies, which are under thesis study component in terms of permission problem.)