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Facility Location Selection for Global Manufacturing

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FACILITY LOCATION SELECTION FOR GLOBAL MANUFACTURING

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ABSTRACT

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The selection of a facility location for operations is an important decision in strategic planning of manufacturing corporations. As globalization is transcending national borders, the whole world is becoming the domain of site selection problem. This, in turn, significantly changes the nature of facility location problem. The change is, particularly, paramount in the consideration of attributes impacting the selection decision. Many recent studies have considered the global dimensions of manufacturing site selections and have cited economic, social, and political factors impacting manufacturing operations. The complexity of facility location problem combined with the emerging global factors impacting site selection for manufacturing operations poses challenging research topics including the selection of critical attributes and the development of a methodology for data analysis for manufacturing facility selection.

In this thesis I have reviewed the academic as well as industrial literature on recent developments on global facility location problem and have identified the most frequently cited/used attributes for the selection suitable manufacturing sites. Furthermore, I have developed a new similarity coefficient for cluster analysis for the formation of groups of prospective sites. Finally, I have employed an average clustering

algorithm to identify these groups. In addition, I have demonstrated my methodology by a numerical example.

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CHAPTER ONE

Introduction

Locating a facility is a decision that any company should make at some point. It is a decision that is made at the organizational level and has a profound effect on different aspects of the company. Many of the operations that are performed within the company depend deeply on the location of its facilities. For example if the facility is a factory and some outsider vendor supplies the raw material for that, location of the facility is one of the most important determinant in selecting type of transportation used and it also has a big influence on the transportation cost.

Facility location is categorized as a strategic decision, because it is concerned with the whole environment in which the firm operates and it involves the entire resources and the people who form the company and the interface between the two. Like any other strategic decision, facility location has long term effects on company's operation; therefore, a lot of research needs to be carried out in order to collect enough information to make an informed decision.

There are many issues that complicate facility location decisions. First, since location of the facility affects company in different ways, there are many variables that need to be taken into account in order to make a good decision. Additionally there are many people from different departments of the company that are involved in the decision making process; the interests of those people may have conflicts. For example from transportation point of view, it is better to locate the facility closer to suppliers and the market, whereas from production standpoint, it may be more desirable to locate the

facility closer to workforce and raw materials. On the other hand, like any other decision making process, the decision maker should avoid a subjective decision. The decision must be made with having all the factors on mind and by comparing every alternative in an objective way.

The complexity of the problem has invoked researchers from around the world to develop various algorithms and software packages to assist the decision makers in choosing the best alternative for locating the facility. These algorithms compare different alternative based on the set of decision making factors that are provided by the decision maker. The core of these algorithms is the data that is fed into them by the decision makers; in order to get a reliable answer decision maker should assure that the data is accurate and is free from any types of error.

One of the most important pieces of information that is provided by the decision maker is the list of decision making factors. Unless a complete list of factors is provided, the algorithms cannot find the best solution.

Each facility location problem is unique and there is no single recipe that can be used for every facility location problem. Based on the type of industry the company is active on, type of product, customers and many other variables, the set of factors varies. Despite these differences there are some major factors that are common in most of the facility location problems. Many researchers have attempted to find those common factors and a variety of lists have been proposed as a result.

One of the branches of facility location that has gained more and more attention in last few years is international facility location, in which alternatives are located in

different countries. There is a big difference between factors that are used for this type of facility location decision and those that are used for locating a facility within a country. The reason for this difference is that there are many factors that are fixed within a country but they are different from country to country. Some of these factors may have a significant influence on the facility location decision and ignoring them would result in incorrect choice of decision.

Looking at international facility location from a broader perspective, there are two main parties involved. On one side, companies are trying to find the best alternatives to locate their facility, on the other side governments are trying to improve their investment climate to attract more companies in order to gain profit. As a result finding a set of factors that is generally used by decision makers for facility location decisions can be beneficial for both of these entities.

In an earlier era, the location of natural resources often determined where manufacturing would take place. In today's economy, knowledge, know-how, technology, creativity and capital are the most important resources for production, and they are highly mobile. Not surprisingly, national economies and firms are growing more sophisticated in their ability to react to these changes and, where possible, leverage them to their advantage.

During last few years the world has undergone many major crises that influenced manufacturing in different ways. Great Depression, the devastating earthquake and tsunami in Japan in March of 2011, the Arab Spring, the European sovereign debt crisis threatening the European Union, Vladimir Putin's return as Russia's president, Standard

and Poor's downgrading of the United States (U.S.) credit rating, and an unprecedented unemployment rate in the U.S.

Due to these crises along with many other reasons the manufacturing environment is changing constantly. Many organizations and researchers have tried to picture how the world of manufacturing is going to look like a couple years from now. They have ranked the countries based on their manufacturing advantages and based on their government's policies and other influential factors.

Ranking the countries based on their desirability for companies can be a very helpful guide for the decision makers; however it may also be misleading. Meaning that just because a country's statistical data is slightly worse than another one's it is not enough information to give that country a lower rank.

A better procedure could be categorizing the countries and assigning each country to a group. Using this procedure will prevent countries with minor differences to get different rankings. Countries that are in the same group are similar and the ones in different groups are not. Using this classification would assist the decision maker to find a group of countries that are desirable for them. After finding that group they can do further analysis to find the best country that fits their criteria.

One of the most powerful tools for categorizing entities based on their similarities and differences is clustering analysis. The method is explained in details in chapter …. Generally speaking clustering is one of the most popular tools in data mining that finds specific structures in data.

Many clustering techniques are available that can be used for categorizing the countries based on their similarities and dissimilarities. Among these algorithms hierarchical clustering was found to be the best choice, because it gives the decision maker the flexibility to define their own similarity measure and is capable of analyzing a large amount of data in a short time.

In this thesis a comprehensive list of decision making factors for international facility location is presented. A clustering technique is then proposed to classify the countries based on those factors.

CHAPTER TWO

Literature Review

2.1 Cluster Analysis literature review:

Cluster analysis groups data objects based only on information found in the data that describe the objects and their relationships. The goal is that the objects within a group be similar (or related) to one another and different from the objects in other groups. The greater the similarity (or homogeneity) within a group and the greater the difference between groups, the better or more distinct the clustering.

There are many different algorithms that perform cluster analysis. Although the outputs of all these algorithms are similar in the sense that they assign each entity to a group, there are differences in the way that they precede the analysis. The algorithm that is implemented in this thesis is a similarity coefficient based clustering. A brief background of this type of clustering is provided here.

2.1.1 Similarity coefficient based clustering

McAuley (1972) and Carrie (1973) are the first people who developed similarity coefficient based clustering. McAuley implemented one of the most well-known similarity coefficients which is called Jaccard similarity coefficient. This similarity coefficient for each pair of entities is calculated as the ratio of number of attributes that get the value of 1 for both of them to the number of attributes that are one for either of them. Carrie used the same similarity coefficient, except he calculated this value for each pair of attributes instead of entities.

Using similarity coefficient method brings about many advantages. Seifoddini (1988) and Gupta and Seifoddini in (1990) presented some of those advantages.

- It is simple and easy to use
- Similarity coefficient technique lends itself more easily to computer application
- It has more flexibility in incorporating manufacturing data into the machine cell formation process.
- The level of similarity (threshold value) by which two machines or groups of machines are allowed to form is determined intrinsically by the algorithm for each iteration for a given set of data of the problem.
- The method generates a set of alternative solutions, thus additional constraints can be adopted for the final selection of a solution. For example, the number of cells can be restricted as additional constrain due to material handling cost.

Jaccard similarity coefficient does not account for many important variables. Gupta and Seifoddini (1990) proposed a new similarity coefficient for a pair of machines that is calculated based on production data such as part type production, volume, routing sequence and unit operation time.

Gupta and Seifoddini (1990) developed a similarity coefficient for a pair of machines based on production data such as part type production, volume, routing sequence and unit operation time. Using these similarity coefficients, machines are grouped into machine cells using complete linkage clustering (CLINK) technique. Nair and Narendran (1998) proposed another similarity coefficient which is calculated based on the sequence of parts. Their similarity coefficient results in a higher quality clusters.

Nair and Narendan in another paper (1999) presented another similarity coefficient that incorporated more information in calculation. Their new similarity coefficient was calculated based on production sequence, volumes, processing times and machine capacity. They also developed a non-hierarchal algorithm with twin objectives of minimizing within-cell load variation as well as intracellular moves.

Chandrasasekharan and Rajagopalan (1986) developed a ROC algorithm along with block and slice method to create a set of intersecting machines cells and non-intersecting part families. After obtaining such set a hierarchical clustering method is implemented to obtain the final clusters. Chandrasasekharan and Rajagopalan in another paper (1987) presented an algorithm for concurrent formation of part families and machine cells. The algorithm is a non-hierarchical clustering and consists of three stages. First a clustering algorithm is run based on representative seeds. A block diagonalization algorithm follows the clustering. Finally a clustering algorithm based on ideal seeds is implemented to improve the clusters that were developed previously. Another algorithm was developed by Srinivasan and Narendran (1991). They proposed a non-hierarchical clustering algorithm that utilized an assignment problem to identify the seeds.

2.1.2 Different Methods of Similarity Coefficient-Based Clustering

Cluster analysis is the task of grouping a set of objects in such a way that objects in the same group are more similar to each other than to those in other groups. There are several different clustering methods, some of these methods are: single linkage clustering, complete linkage clustering, average linkage clustering and P-median clustering.

Single Linkage Clustering (SLINK)

Single linkage clustering or SLINK was first developed by Sneath (1973). Among other similarity coefficient-based clustering algorithm SLINK is the simplest one which has the minimal computational requirements. The algorithm first calculates the similarity coefficients for each pair of machines and then forms the similarity matrix. A threshold is defined by the decision maker to determine the minimum value of similarity coefficient by which two machines are considered similar. Next, all machines with similarity coefficient higher than the threshold are grouped together.

For measuring the similarity different similarity coefficient have been developed. The first similarity coefficient that was developed is known as Jaccard Similarity Coefficient or JSC. It is calculated based on the number of parts that visit each machine. Since attributes are all binary, there are four different possibilities for each pair of machines: 1-1, 1-0, 0-1 and 0-0. Table 1 depicts these possibilities.

Table (2.1) different possibilities for the attributes

		Object j	
		1	0
Object i	1	a	b
	0	c	d

Where a is number of parts visiting both machines, b is number of parts visiting machine i but not j, c is number of parts visiting machine j and not i, and d is number of parts not visiting either machines.

By definition, Jaccard similarity coefficient is calculated as below:

$$S_{ij} = \frac{a}{a + b + c}$$

As the definition suggests, Jaccard similarity coefficient takes a value between 0 and 1. The maximum value is obtained when both machines process the same parts, meaning that b=c=0. The minimum value is obtained when there is no part that visits both machines, or a=0.

As mentioned, single linkage clustering algorithm first calculates the similarity coefficient for every machine pair and form the similarity matrix. After creating the matrix, the algorithm groups the machines with the highest similarity coefficients together and repeats this cycle until the maximum value of similarity coefficient value for the machines that have not been assigned to a cluster is less than a predefined threshold or a predefined number of clusters are obtained.

The following shows the algorithm step by step.

1. Form the similarity matrix by computing the similarity coefficient for every pair of machines.
2. Find the machine groups that have the maximum similarity coefficient and group them together.
3. Remove the rows that correspond with the machine groups that were grouped together.
4. Add a new row to the matrix for the new machine group and calculate the similarity coefficients using the following formula:

$$S_{tv} = Max\{S_{mn}\} \quad m \in t \ \& \ n \in v$$

Where t is the new machine group and v stands for other machine groups.

5. Stop if the predetermined number of machine groups has been achieved, otherwise go back to step 2.

Complete Linkage Clustering (CLINK)

Complete linkage clustering is another type of similarity coefficient based clustering. Similar to SLINK, this algorithm starts with calculating the similarity coefficients between pairs of machine groups. For computing the similarity coefficients between the machine groups CLINK uses the minimum similarity level. The following formula is used to compute similarity coefficient:

$$S_{tv} = Min\{S_{mn}\} \quad m \in t \ \& \ n \in v$$

Advantage of CLINK is that it prevents two clusters merge together only because of high level of similarity between two members while the rest of members are dissimilar.

Average Linkage Clustering (ALC)

Sokal (1968) presented a new algorithm for cluster analysis. Looking at CLINK and SLINK, they both consider the extreme cases for calculating similarity coefficient between two clusters. CLINK computes the similarity coefficient between two machine groups as the maximum level of similarities between the members of two groups. SLINK on the other hand uses the minimum level of similarity to compute similarity between two machine groups. Sokal's algorithm known as Average Linkage Clustering (ALC)

incorporates the entire machine groups' members in calculating the similarity coefficients. Similarity between machine groups is calculated as below:

$$S_{tv} = \frac{\sum_{m \epsilon t} \sum_{n \epsilon v} S_{ij}}{N_t * N_v}$$

This formula takes the average of pairwise similarity coefficient between all the machines in two groups.

The algorithm's steps are as below:

1. Form the similarity matrix by calculating the similarity coefficients for each machine pair.
2. Group the machine groups with the highest similarity coefficient.
3. Remove the rows that correspond with the machine groups that were grouped together.
4. Add a new row to the matrix for the new machine group and calculate the similarity coefficients using the following formula:

$$S_{tv} = \frac{\sum_{m \epsilon t} \sum_{n \epsilon v} S_{ij}}{N_t * N_v}$$

   Where t is the new machine group and v stands for other machine groups.

5. Stop if the predetermined number of machine groups has been achieved, otherwise go back to step 2.

2.2 Facility location literature review:

Making location decisions for the production of products is a key aspect of strategic and logistical decision making for manufacturing firms. The optimum locations may offer competitive advantage and may contribute to the success of an enterprise (McCarthy 2003). Additionally a decision to build a new plant or expand present facilities involves a long term commitment of both monetary and human resources (Epping 1982).

Many think that a location problem needs to be considered only once every several years and that once new plant is built there is no need to consider relocating until the economic life of the plant is nearing its end. Many companies have stayed in an area for 30 or 40 years without considering alternate locations. However, a good location today may not necessarily be the best one next year (Epping 1982). As a result firms need to consider relocating their facilities in a regular basis in order to maintain their competitiveness and to be able to benefit from advantages that a better location can potentially bring about for them.

The importance of facility location decision from one hand and the fact that any company regardless of their size and industry needs to make such decision at some point of their operation on the other hand makes location decision an attractive field for researchers and practitioners around the world. As a result many theories have been developed to assist firms to make a better decision.

Thunen was the first one who designed a general method for evaluating location decisions from an economic point of view (Thunen, 1875). In his work Thunen utilized the "least-cost" approach to location.

Launhardt in his paper on 1885 analyzed the location decision process by looking at the difference between the cost and demand factors at alternative locations. (Laundhardt, 1885). He also highlighted the importance of transportation costs in such decisions.

Weber's theory that was published in 1909 can be considered as an important milestone in the study of the Industrial Location Decision. He proposed three important factors that are most important in facility location decisions: transportation cost, labor cost and agglomeration forces (Weber 1929). His theory was used by many researchers in location studies (Tellier and Vert Fenille, 1995)

Harold Hotelling's work can be considered as another milestone in the history of Industrial Location Decision. He looked into the competition among companies and tried to make a connection between this competition and location decisions. (Harold Hotelling 1929) He stated that there is a tendency in firms to locate their facility close to the center of the market.

Hotelling's work became the basis of many future studies. Many researches attempted to improve his model by adding more aspects to it. Some others disputed his theory and proposed new models for the location decision behavior of companies. (Lerner and Singar 1937, Balvers and Szerb 1996, Katz 1995, Smithies 1941, Chamberlain 1946, Ohlin 1935, 1952)

Another determining works in the literature is August Losch's theory that was proposed in 1939. He considered locating a facility in a free economy and suggested that the optimal selection is obtained using cost and demand curves analysis. (August Losch 1939)

Another study based on cost and demand is Hoover's theory that was published in his papers in 1937 and 1948 (Hoover, 1937, 1948) He stated that freight rates make the transportation cost to act in a nonlinear way. Greenhut pursued this path and tried to develop a theory that combines location theory with practice. (Greenhut 1956) His theory was further improved by Button (Button 1996). In the same year that Greenhut's paper was published Isard developed a new theory that combines the preceding theories on industrial location decision and tries to put location analysis in a production economy framework.

One of the branches of industrial location decision that has gained more attention in the last few decades is international facility location. A brief review of the literature in this field is provided in the next section.

2.2.1 International facility location – decision making factors

Consumers all over the world want to buy the best products at the lowest prices, regardless of where they are produced. This recent trend has resulted in a rapid increase of global markets which are causing new competitive pressures on companies to engage in global production and service operations. Today, there are more opportunities for locating facilities overseas than there were a decade or so ago, when no foreign company would be allowed to manufacture in China, the former Soviet Union, or Eastern Europe.

In today's global economy, most of the big companies are engaged in international operations, having facilities in international locations. Consequently, these companies face a wide spectrum of political, social, economic, and cultural differences which do not exist in the domestic environment (Canel and Khumawala 1996).

A very wide range of factors may potentially influence firms in deciding to locate production facilities across national boundaries (McCarthy 2003). The literature implies that as the firm's decision makers develop better identification, analysis and assessment of these critical factors, the location decision making process will improve and result in effective long term performance for the organization (Miller, 1967; Walker, 1975; and Saxenian, 1985)

Only a limited amount of research has been reported on factors influencing international location decisions for contemporary manufacturing operations (McCarthy 2003). The new trend toward globalization along with the lack of an effective decision support system for international facility location decision has motivated many researchers to work on this field during the last few decades. The results of their works have been published in different research papers and industrial reports that attempt to draw a road map for the companies who seek to build a location abroad.

Bass, McGragor and Walters (1977) propose the following factors as the most determining factors in deriving managements to invest in a foreign country: accessibility, basic services available, environment, site costs, industrialization, labor and staff availability, host taxes and incentives, area reputation, the nature of the host government

and its policies. They use a survey of 118 plants operated by U.S. firms in Latin America, Europe and Asia.

In another survey conducted by Horst (1972) from 1191 manufacturing corporations with foreign subsidiaries the characteristics of firms investing in Canada are compared with those not doing so. Vernon (1971) surveyed 187 U.S manufacturing corporation and identifies a set of important factors for those firms.

By studying the process undertaken by multinationals to analyze political risk Rummel and Heenan (1978) propose a list of factors considered important in making international industrial location decisions: domestic instability, foreign conflict, political climate, and economic climate.

In another survey by Tong (1979) on 242 foreign-owned manufacturing firms the following factors found to be the most important factors affecting firms' location decisions:

- Transportation services
- Labor attitudes
- Space for expansions
- Nearness to markets
- Availability of a site

Tong's survey show that the least important considerations are:

- Cost and availability of capital
- Nearness to home country

- Proximity to export markets
- Nearness to operations in third countries

Epping (1982) specifies three major types of factors that seem to be major impetus for firms' having chosen specific locations in the previous studies

- Availability of transportation facilities for moving raw material and finished goods
- Availability of labor
- Personal considerations

Chernotsky (1983) surveyed 21 West German and Japanese firms to find the influential factors in their location decision making. The results of his study show that availability of desirable sites attractiveness to incoming personnel and market access were the most important considerations. Less emphasis was placed by these firms on labor, financial incentives and access to raw materials and semi-finished goods.

In another survey on 20 foreign corporations in the USA Haigh (1990) indicates the importance of states and local economic development agencies. He states that in their site selection process it typically involved three fairly distinct stages:

- the selection of a specific geographical region in the USA
- selection of two or three states within that region

- the final decision on a specific site in a particular community, usually a choice among four or more locations in any given state

Hoffman and Schniederjans (1994) propose a 2-stage model that combines the concepts of strategic management, the management science technique of goal programming, and microcomputer technology to provide managers with an effective and efficient method for evaluating global facility sites and making selection decisions.

They mention the following advantages for their model:

- Provides trade-off information revealing where subjective weighting scale values should be revised or re-evaluated to improve the site selection.
- Simultaneously considers all decision making criteria to derive an optimal selection
- Permits ordinary prioritization of decision-making criteria
- Makes it easy to change optimal performance factor and objective factor estimates and solve for a new solution with little or no effort from management.

In their study Hoffman and Schniederjans indicate some of the complex issues associated with global expansion as follows:

- The firm must deal with multiple political, economic, legal, social and cultural environments as well as various rates of change within each of them.
- Interactions between the national and foreign environments are complex because of national sovereignty issues and widely differing economic and social conditions

- Geographical separation, cultural and national differences, and variations in business practices all tend to make communication between headquarters and overseas affiliates difficult
- Analysis of present and future competition may be more difficult to undertake in a number of countries because of differences in industrial structure and business practices.
- The degree of significant economic, marketing and other information required for planning varies a great deal among countries in availability, depth, and reliability.

Their model categorizes decision making factors at two levels:

- General environment: consisting of technological, political, economic, physical and social factors
- Task environment: includes potential customers, suppliers, competitors and regulatory groups.

They further propose a list of important decision making factors in international location decision as below:

- Economic factors: include variables such as tax rates, interest rates, currency parity, currency transfers, wage level, construction costs, price controls, business cycles, inflation and overall economic condition.
- Social factors include crime rate, demographics, language, roles of women and minorities, work ethics, career expectations, average education of the potential workforce, and overall community atmosphere.

- Political factors include relationships that might prevent the firm's entry into a foreign location, or relationships that might prevent the continuation of the foreign operations, the probability of tax relief on the importation of construction materials and machinery, tax relief on the purchase of local construction material, probability of an income tax holiday, protection laws, and any other Government regulations or restrictions that could affect operations
- Technical factors include related cost factors, product and service quality, the general rate of technological change, raw materials and innovation.
- Physical factors include climate, the probability of natural disaster, seasonality, accessibility proximity to highways and airports, availability of existing facilities and equipment, and proximity to shopping, restaurants, night-life, cultural activities, sports activities, spectator sports and other outside attractions.
- Task Environment factors include projected customer base, market growth, untapped demand, the prices that existing facilities in the subject locale command, number and strength of competitors, and accessibility to supply sources.

Barkley and McNamara (1994) rank location factors for companies based on their plant size. They claim that depending on the size of the plant the importance of factors may vary.

Masood Badri, Donald Davis and Donna Davis (1995) investigate the industrial location decision behavior of firms by examination of the firms' attitudes measured on location variables. They use a questionnaire approach to gather information on the relative adequacy of these factors.

The results of their study show that the following factors are important in international location decisions:

- Transportation related factors
    - Availability of airway facilities
    - Availability of highway facilities
    - Availability of railroad facilities
    - Availability of trucking services
    - Availability of water (port) transportation
    - Availability of pipeline facilities
    - Cost of raw material transportation
    - Cost of finished goods transportation
    - Availability of postal services
- Labor related factors
    - Availability of skilled labor
    - Wage rates
    - Availability of unskilled labor
    - Existence (or non-existence) of labor unions
    - Educational level of labor
    - Dependability of labor
    - Availability of male labor
    - Availability of female labor
    - Cost of living (housing)
    - Worker stability

- Raw materials related factors
    - Availability of raw materials (or components)
    - Closeness to materials and component
    - Availability of storage facilities
    - Location of suppliers
    - Freight cost (of raw materials and components)
- Market related factors
    - Proximity to consumer's goods markets
    - Proximity to producer's goods markets
    - Anticipation of growth of markets
    - Shipping costs to market areas
    - Availability of marketing services
    - Attainment of favorable competitive position
    - Income trends Population trends
    - Consumer characteristics
    - Location of competitors
    - Future expansion opportunities
    - Size of market Industrial site
- Industrial site related factors
    - Cost of industrial land
    - Cost of developed industrial park (or area)
    - Acreage (or space) required
    - Availability of space for future expansion

  - Insurance rates (cost of insurance)
  - Availability of lending institutions (such as banks)
  - Closeness to other industries
- Utilities related factors
  - Adequacy of water supply
  - Quality of water
  - Cost of water
  - Availability of disposable facilities of industrial waste
  - Availability of fuels
  - Cost of fuels
  - Availability of electric power
  - Cost of electric power
- Government attitude related factors
  - Zoning codes
  - Compensation laws
  - Insurance laws
  - Safety inspection laws
  - Nuisance and environment pollution laws
- Tax structure related factors
  - Tax assessment basis
  - Industrial property tax rates
  - State corporate tax rates
  - Availability of tax free operations

  - State sales tax
- Climate related factors
  - Living conditions
  - Relative humidity
  - Monthly average temperature
  - Air pollution
- Community related factors
  - Availability of universities or colleges
  - Availability of schools
  - Availability of religious facilities
  - Availability of library (information) facilities
  - Availability of recreational facilities
  - Attitude of community leaders towards business
  - Availability of medical facilities
  - Availability of malls (shopping centers)
  - Availability of hotels (motels)
  - Availability of banks and financial institutions
  - Community position of future expansion
- Political situation of foreign country related factors
  - Stability of regime
  - Protection of expropriation
  - Type of treaties and pacts
  - Type of military alliances (or with which countries)

    - Attitude towards foreign capital
- Global competition and survival related factors
    - Availability of material
    - Availability of labor
    - Market opportunities
    - Availability of foreign capital
    - Proximity to other international markets
- Government regulations related factors
    - Clarity of corporate investment laws
    - Regulations concerning joint ventures and mergers
    - Regulations on transfer of earning out of country
    - Taxation of foreign owned companies
    - Foreign ownership laws
    - Allowable percentage of employees who may be foreign
    - Prevalence bureaucratic red tape
    - Imposing price controls by government
    - Requirements for setting local corporations
- Economic related factors
    - Standard of living
    - Size of per capita income
    - Strength of currency against US dollar
    - Balance of payment status
    - Availability and size of government aids

Chamnong and Colin (1995) examine the design and implementation of a knowledge-based decision support system (KBDSS) in the facility location domain. They conduct a survey of past location studies to identify the major considerations of location analysts and to develop a hierarchy of factors for locating a manufacturing facility in the USA. They state that in the early stages of location research only a small number of easily quantified location factors were considered. Later interest shifted to include a wider range of both quantifiable and nonquantifiable location factors.

They identify the top eight factor groups that affect the decision process:

- Market
- Transportation
- Labor
- Site consideration
- Raw materials and services
- Utilities
- Government concerns
- Community environment

Canel and Khumawala (1996) present a mixed-integer programming approach for the international facilities location. In their paper they focus on the formulations for both the capacitated and uncapacitated multi-period international facilities location problems, and provide applications of both of these formulations to an actual company case.

Canel and Khumawala classify the factors to be considered for having facilities in international locations along two dimensions. The first dimension consists of reactive and

proactive factors. Reactive implies that the company is responding to an occurrence in its external environment, generally something beyond its control. Proactive implies that the company seeks advantages and benefits that are available at international locations. The second dimension illustrates factors which the company may or may not control. Companies which are doing business in other countries acknowledge that there are some factors which the host country government controls and some over which the company exerts control. These factors can be further considered as either quantitative or qualitative.

They further identify the factors which are commonly cited in the literature for making an international location decisions. The list is given below:

- Trade barriers
- International customers
- International competition
- Regulations
- Additional resources
- Low cost
- Incentives
- Market access and proximity
- Customer responsiveness
- New, expanded markets
- Excess resources
- Exploitation of firm specific advantages

- Taxes.
- Economies of scale
- Synergy.
- Power and prestige
- Protect home market through offence in competitor's home.

Kupke and Pearce (1998) identify two most important industrial location factors for owner-managers as being close to the central business district and having direct access to main roads. They use a study of 87 Australian SMEs as the basis of their study.

Carod (2002) states that a firm passes through several stages before it locates in a certain territory. These stages may be chronological or simultaneous. He identifies those stages as below:

- Deciding to enter the market. This occurs when a possible business opportunity is detected and capital or human resources are available.
- Choosing the activity and the levels of technology and organization. This decision is linked to the previous one (each activity usually implies a specific level of technology and a minimum efficient size)
- Choosing the location. At this final stage, firms assume that the areas in which they could locate offer different levels of profit. At this stage the task is to identify the sites that offer maximum profits.

Mazzarol and Choo (2003) investigate the purchase of industrial real estate by small to medium enterprises using a three stage methodology

- Examine the views of a stakeholder panel.
- Draw a sample of 450 firms ranging from microbusiness to large firms.
- Examine the importance of various factors likely to influence the attractiveness of an industrial site.

McCarthy (2003) presents a comprehensive set of factors that may influence international location decisions from analysis of existing literature. His results are analyzed from a Delphi study that uses a worldwide panel of experts to investigate factors affecting international location decisions.

McCarthy categorizes the factors in 13 major groups: costs, labor characteristics, infrastructure, proximity to suppliers, proximity to markets/customers, proximity to parent company's facilities, proximity to competition, quality of life, legal and regulatory framework, economic factors, government and political factors, social and cultural factors, characteristics of a specific location. The results of his studies shows that top 5 major factors that may strongly influence international location decisions generally are: cost, infrastructure, labor characteristics, government and political factors and economic factors. Ten key sub factors identified are: quality of labor force, existence of modes of transportation, quality and reliability of modes of transportation, availability of labor force, quality and reliability of utilities, wage rates, motivation of workers, telecommunication systems, record of government stability, industrial relation laws.

McCarthy's factors cover both qualitative and quantitative aspects of the problem and include operational, strategic, economic, political, social and cultural dimensions. His

finding implies that the major motivations for firms to manufacture across national borders in order of decreasing importance are as follows:

- Ability to gain access to low labor costs and labor skills.
- Ability to gain access to market.
- Tax incentives and other privileges from the host government.
- Ability to gain access to host raw materials and technology.
- Counterattack against competitors.

He also identifies the most difficult problem in making international location decisions:

- Many factors involved in the decision process.
- Difficult to get the right information and right people.
- Management issues.
- The relation of new location and existing manufacturing resources technology.

He suggests the following ways to overcome these issues:

- Product analysis: field research, better forecasting, accurate data, adopting a careful approach, identify risks, use clear logic and analyze all impacts as well as checking with existing manufacturing networks
- Professional advice/expertise: employ qualified consultants, professional advisors or hire local agents/local governments to investigate and pull stakeholders together at the beginning of the process.
- Tools: develop appropriate tools/models for decision making, as well as for trade-offs and risk assessment.

- Incentives: develop appropriate incentives, and relevant organizational structures.

McCarthy also reports five steps in making international location decisions as below:

- Make clear overall business strategies.
- Investigate regional and country-specific factors.
- Identify relevant factors for each location alternative.
- Evaluate the alternatives against established criteria.
- Select location and implement.

He asserts that location factors and their importance vary depending on the nature or type of business and may depend on the geographical region in which location is being considered. Each business sector has specific factors that firms take or should take into consideration when considering a location choice and the importance of each factor is not equal for every case.

Badri (2007) develops an instrument for the critical factors in international location decision. His instrument, consisting of 14 dimensions, passed through a stringent empirical validation test, and is based on extensive literature search and psychometric principles. He generates two hundred and five industrial locations factors (detailed factors), from the literature. Through a judgmental process of grouping similar factors, he concludes that all could be classified into fourteen distinct categories. He suggests that together, these categories (or critical factors) define the important aspects of industrial location. He suggests that the general critical factors of industrial location within a country are transportation, labor, raw materials, markets, industrial sites, utilities, government attitude, tax structure, climate, and community. In addition, for international

location considerations, four additional general factors are identified: political situation of foreign countries, global competition and survival, government regulations, and economic factors.

Badri also considers new factors that have emerged lately in the works of other researchers. Some of those factors include:

- Proximity to schools, colleges and universities (Audretsch and Stephen, 1996).
- Interaction between location and taste for remote access (Degryse, 1996).
- Type of linkage between vertically linked industries (Venables, 1996; Carod, 2005).
- Characteristics of population trends (Braid, 1996; Mayer, 1996; Mazzarol and Choo, 2003).
- Percent of market share or expected market share (Drezner and Drezner, 1996).
- Changes in the location of users (Hansen and Roberts, 1996).
- Amount of expected development potential in the region (Wojan and Pulver, 1995).
- Level of wages (Manders, 1995; Ma, 2006).
- Changes in transport rates (Mai and Hwang, 1994; Leitham et al., 2000; Mazzarol and Choo, 2003).
- Location of other competitors (Serra and ReVelle, 1994; Cieslik, 2005; Siebert, 2006).
- Types and availability of resources (Vaughn, 1994; Chan, 2005).
- Effect of changes in local demand (Justman, 1994; Figueiredo et al., 2002).

- Hazardous waste and pollution laws (Groothuis and Miller, 1994).

Badri_categorizes the literature on industrial locations into two groups: empirical studies, and works developing theoretical concepts. The theoretical literature on international industrial locations deals with identifying strategic issues within the context of integrated global strategies (Vernon, 1968 and Skinner, 1985). International empirical studies mainly involve surveys of foreign plant managers, community leaders and other professional personnel familiar with international issues.

Beside important factors in location decision making process the difference between domestic and foreign companies in their decision process has been the topic of many researches that have been conducted in the last few decades. Kahley (1986) indicates that availability of ports and wage rates are more important for foreign investors than they are for US companies. While it is the other way round for fuel costs.

Another finding that was proposed by Ulgado (1996) is that community environment logistic and trade concerns influence location decision of foreign companies more significantly compared to those of domestic corporations, while financial considerations in terms of taxes capital and incentives play a more important role for domestic companies. Ulgado also shows that foreign companies appeared to view their site location decision as very long term commitments and it takes them relatively longer time in making a location decision. Additionally foreign companies seemed more disposed than US firms to utilize the services of state and local economic development agencies domestic companies were more likely to rely on consultants.

CHAPTER THREE

Defining the decision making factors

As mentioned in the previous chapters many algorithms have been developed by researchers around the world to assist the decision makers in location decisions both in national and international context. These algorithms approach the problem in different ways and the location that one algorithm suggests as the best option may not be the same as what another algorithm suggests.

Despite the differences among the developed algorithms, most of them compare different alternatives based on a set of decision making factors that the decision maker provides. In order to make sure that the result is reliable the decision maker need to make a comprehensive set of factors that considers all different aspects of the problem. If an important factor is ignored in the decision making process the result may not be useful and in more severe cases it could be misleading.

Each location decision problem is unique and a single solution that can be applied in every situation does not exist. However, there are some major factors that are important and need to be taken into consideration in most of the problems. Many researchers have attempted to identify those factors. A comprehensive review of these factors is provided in the literature review section.

The model that is proposed in this thesis also utilized a set of decision making factors as input and categorizes the alternatives based on their similarities and dissimilarities. The decision making factors act as the backbone of the algorithm. As a

result this chapter is dedicated to find the factors that are more critical and are needed to make a good classification to assure the validity of the results. For this purpose the factors that are cited in the literature were reviewed and those that appeared to be common between different researchers are identified. The following lists the selected factors that were identified.

3.1 Cost

Cost is one of the most important factors that need to be considered in the location decisions. It appears almost in all of the decision making factors lists that have been developed by different researchers.

The earlier theories in location analysis put more emphasize on this factor in a way that some theories suggest that the best alternative is the one that yields the least value for cost. One of the reasons behind this is that in the past the competition among the firms was not as severe as it is now. Therefore, they paid less attention to other variables that have emerged lately in strategic decisions. As competition between firms became more sophisticated other important factors came into play and the importance of cost diminished. However, while cost is not as important as it was before, it is still one of the most important factors in location decisions, because at the end of the day the final goal of most of the companies is to make profit and if a firm fails to make more money than it spends it is doomed to be eliminated from the competition.

Cost is a general factor. There are many types of cost that have been mentioned by the researchers. Based on the activities of a company some of these factors may or may not apply for them. However since the purpose of this thesis is to provide a general

framework, it is attempted to include the most important factors, regardless the type of the firm. The following lists the most important types of cost that have been cited in the literature. A brief description of each factor is also provided for the sake of clarity.

There are different types of costs that are cited in the literature. The following lists the most important ones.

3.1.1 Labor cost

- As the name suggests, this factor refers to the cost of hiring labor in the host country. Labor refers to any type of work force that the firm needs to hire. In most countries the minimum stipend of labors is decided by the government.

3.1.2 Transportation cost

- This factor encompasses the cost for any type of transportation. Transportation is a necessity for most of the manufacturing firms and lowering the cost of transportation can save a lot of money for the company.

3.1.3 Energy cost

- There are several types of energy that need to be taken into consideration here. Energy has always been a concern for countries and based on the geographical location of a country some types of energies may be limited and therefore their cost is high. This means that firms need to pay special attention to this factor in their location decisions.

3.1.4 Management cost

- While this could be considered as a category of labor cost, because of the important role of management in organizing and running the firm, it was decided to consider a different factor for management cost. Another reason for including this factor is that, in some developing countries due to bad economic situation, labor cost may be low while because of unavailability of skilled managers, management cost is high.

3.1.5 Construction cost

- Constructing a facility may be very expensive in some countries. For example firm may have to import all the machineries and incur a high cost for transporting and installing them, while by locating in a country that has the technology to make the machines firm can save a lot of money. This factor plays an important role especially for heavy manufacturing facilities that need large and specialized machines.

3.1.6 Trend in cost

- In order to make a good location decision, in addition to current costs, the trends also need to be considered. Facility location is a long term strategic decision that has long term effects on the firm. As a result it is vital to approach it in a dynamic way. A good location today may not be a good location next year, due to big variability in different factors including cost. Looking at the trends helps the firms to make a decision that not only benefits them today, but also stays reliable for several years.

3.2 Labor characteristics

Labor is a requirement of any type of business. It can be considered as the driving force of the firm that runs the companies processes and helps it to move toward its strategic goals. The importance of this factor in company's success cannot be exaggerated. In the last few decades there seems to be a trend in companies to move toward locations that has more favorable labor force. Some companies need low cost labor force; they seek locations that have low cost unskilled labors, while other companies may need skilled labor force and therefore try to locate their facilities in a location that has more educated labor with less emphasis to the cost.

The quality and characteristics of labor force can influence the firm in many different ways. Many researchers have attempted to find the most important characteristics of labor that companies consider (or should consider) in their location decisions. The following lists the most important factors that have been cited in the literature accompanied with a short description.

3.2.1 Education and training level

- Based on the activities of the firm, some companies may need high skilled labors that are trained for performing specific tasks, while some others may need unskilled and low cost labor for doing easy tasks. As a result the education and training level of the labor is a variable that plays an important role in firms' location decision.

3.2.2 Unemployment rate

- This is a factor that can have positive or negative effects on the firm. For example high unemployment rate may be interpreted as availability of labors and therefore considered as a favorable factor. While looking at it from a different point of view it can be deciphered as bad economic situation of the location and as a result has a negative interpretation for the firm.

3.2.3 Union flexibility

- During the last few decades the importance of labor unions' roles in determining the regulations related to labor force has grown exponentially. This trend has brought it to the list of top decision making factors in location decisions. In some countries, unions may be very restrictive and impose several rules to the firms that limit them and hence affect their operations, while in other countries; unions may show more flexibility and give more control to the firms.

3.2.4 Motivation

- Motivated labor force helps the firms to move toward their goals and is a key requirement for continuous improvement and lean manufacturing. As a result locations that have more motivated labor force are more attractive for companies.

3.3 Infrastructure

Availability and quality of infrastructure is a basic need for any type of firm. In order to assure that the activities of the firm can be performed in a continuous and smooth

way without any issue; firms need to locate their facility in a place that has the required infrastructure.

There are different types of infrastructure that are critical and need to be considered for making a good location decision. Based on the activities of firm the relative importance of these factors may vary, however these factor altogether help to make a location attractive for investment.

Some of the aspects of infrastructure that has been cited in the literature are listed below. A brief description is also provided for each factor to explain why it is important and need to be considered for a location decision.

3.3.1 Availability of Transportation: land, sea, airports

- The location need to be accessible through land and/or sea. The firms need to be able to transport raw material to the facility and take finished goods out of the facility. Availability of airports is another important factor. Since most of the firms that locate their facilities abroad perform in an international market it is important for them to be connected to the market. If the required infrastructure is not emplaced, it can have an adverse effect on the lead time, responsiveness and customer satisfaction.

3.3.2 Quality and reliability of transportation

- In addition to existence of modes of transportation infrastructure, companies need to pay attention to their quality and reliability. The

bad quality of transportation infrastructures in a location can influence the operations of the firm.

3.3.3 Availability of utilities

- Existence of utilities is another inevitable requirement of any operation. Firms need to take this factor into consideration when they are making location decisions.

3.3.4 Quality and reliability of utilities

- The reliability and quality of utilities is also an important factor and should be taken into account.

3.4 Market characteristics

The final goal of any company is to provide product or service to the customers. As a result customers and market need to be one of the main considerations when deciding where to locate a facility. Being close to the market can bring the company competitive advantages in many different ways. It can decrease the lead time and as a result improve customer responsiveness. It can also enable the company to keep a closer relationship with the customers and helps them to identify the latest changes in the market and be the first one among their competitors to respond to those changes.

Different characteristics of the market that have been cited in the literature as deterministic facility location decisions are listed below. The reason behind their selection is also given to justify the list.

3.4.1 Proximity to customer

- As mentioned being close to the market improve customer satisfaction and also responsiveness of the company. It helps the firm to identify the trend and adjust its policies to take the most out of the current situation of the market and be ready to make required adjustments to benefit from future trends.

3.4.2 Market size

- Before locating the facility, company needs to identify the potential markets that it can serve. Based on the location of the facility, company may be able to serve different markets. The best location from this factor point of view is where the company can serve the largest market.

3.4.3 Purchasing power of market

- The purchasing power of the market that the firm aims to serve is another factor that firm needs to take into consideration. They need to locate their facility where they can serve the market that has the most purchasing power.

3.5 Other locations

There are some locations that influence the operations of the firm. The relative position of the firm and these location can bring about advantages and disadvantages for the firm. Some of these locations may have conflict with each other and it may be impossible to find a location that is close to all of them. There are tradeoffs among these locations and it is the responsibility of the decision maker to find a location that is the best from these tradeoffs point of view.

3.5.1 Proximity to suppliers

- Being close to suppliers can help to reduce the lead time and transportation cost. It also helps to maintain a smooth flow of materials in the supply chain. Lowering the risks in supply chain is another advantage of locating facilities close to the supplier.

3.5.2 Quality and reliability of suppliers

- As mentioned, suppliers are very vital parts of supply chain and in order to have a balanced and high quality supply chain, it is very critical to choose suppliers that have a high quality and can respond to needs of the firm in a short time and with high reliability. As a result, firms need to locate their facility in a location that is close to those types of suppliers.

3.5.3 Proximity to parent company

- Another important rule for having a high quality and reliable supply chain is to keep the facilities close to the parent company. This makes it possible for the firm to maintain a good relationship with the parent company and use their support in cases of emergency. It also helps the parent company to serve its subsidiaries in a better way. If the company owns several facilities in different countries it makes it difficult for it to keep the flow in the supply chain. Therefore, it is more beneficial for the parent company to keep its subsidiaries close to itself so that the total cost of supply chain decreases.

3.5.4 Proximity to competition

- Being close to the competition helps the company to keep updated about the last changes in the market and enables it to verify the policy of its competitors and makes appropriate actions in case they are needed. It is close to the concept of agglomeration force that was first proposed by Weber (1929).

3.5.5 Trends

- In addition to current situation it is always beneficial for the firms to look at the trends. This helps the company to make decisions that are good not only today but also remains good for a longer planning horizon. This eliminates the need for changing the location a few years after the decision is made.

3.6 Regulations

Regardless of the type of company, there are always rules and regulations that are imposed by the government or other agencies that restrict certain sorts of activities and prevent the company to make specific types of decisions. Investigating the location alternatives and knowing those types of regulation ahead of time enables the company to locate their facility in a location that there are less restrictions and therefore company has more control over its activities.

There are many types of regulations that may be imposed by the local government and can affect firm. The following lists the most important factors that are cited in the literature.

3.6.1 Compensation law

- Compensation law is a type of insurance that provides employees with wage replacement and medical benefits. Some governments impose very restrictive rules to the companies. For facilities with dangerous material or machinery it is better to locate the facility in a country that has less restrictive rules.

3.6.2 Insurance law

- Insurance law is another rule that is imposed by the government and can influence firm's operations. There is a big difference between government policies toward this law. Restrictive insurance laws can make a location unfavorable for a company with many employees and high injury rate.

3.6.3 Environmental law

- Environmental law is a set of regulations to regulate the interaction of humanity and the natural environment. These laws differ from country to country and need to be considered in facility location decisions.

3.6.4 Legal system

- The origins of most of the countries legal systems come from three basic systems: civil law, common law, and religious law. However, there are individual differences among the countries that stem from their histories. The legal system of the host country is a determining factor that can have a significant effect on the company.

3.7 Economic factors

3.7.1 Tax structure and policies

- Tax structure of the host country can have a significant effect on the operation of the firm. Some countries have a very high tax rate which makes the operation of companies very expensive, while others have special rules for foreign companies to attract foreign direct investment. Therefore, it is better for the firms to know these rules ahead of time and take those into consideration for their location decision.

3.7.2 Financial incentives

- Similar to what mentioned for tax structures, governments may have special financial incentives to attract foreign direct investment. Looking at the location decision from a broader perspective, it is a game between governments and firms. Governments want to attract foreign companies to bring cash and jobs to their country, companies on the other hand want to locate their facilities where they can gain the most benefit. As a result some governments offer financial incentives for the firms to make their country an attractive place for the companies to invest.

3.7.3 Currency strength vs. US dollar

- For several decades, US dollar has been the basis for evaluating the strength of the currency of different countries. The strength of country's currency is an indicator of its economic condition. Since companies operate in an international context, it is important for them to locate in a country with favorable economic condition to avoid problems such as devaluation of company's capital.

3.7.4 National debt

- Another indicator of a country's economic condition is its national debt.

3.7.5 Interest rate

- Interest rate is the rate at which interest is paid by borrowers for the use of money that they borrow from a lender. It is specially an important factor if the firm wants to use loans for constructing the facility or for its operations.

3.7.6 Inflation

- Inflation is a rise in the level of prices in an economy over a period of time. Countries with lower inflation rate are more appropriate for locating a facility.

3.7.7 Exchange rate

- Exchange rate between two currencies is the rate at which one currency will be exchanged for another.

3.7.8 GDP

- Gross domestic product (GDP) is the market value of all officially recognized final goods and services produced within a country in a given period of time.

3.8 Quality of life

The place that firm decides to locate it facility, becomes the home of its employees. It is important for the firm to pay attention to the quality of life in alternative

locations. If the quality of life is not good in a location it can adversely affect the motivation of the workers and as a consequence the productivity of the firm decreases.

3.8.1 Environment

- This factor corresponds to the general environmental situation of an alternative location. If the environment is favorable it can positively influence the employees and the company.

3.8.2 Attitude toward business

- If the general attitude of the population in a location alternative is against the presence of a specific facility or business, it can cause problems in operations of the firm. As an example traditional societies may be opposed to construction of factories that emit a lot of pollution into the environment. Firms need to take these kinds of issue into consideration when they make location decisions.

3.8.3 Climate

- Climate could be another factor that has an effect firms' location decisions. Countries with severe climate patterns are not attractive for locating facilities.

3.8.4 Standard of living

- Standard of living should be in an acceptable level in the location.

3.8.5 Health care

- The presence of a good quality health care system is another necessity for the operation of a firm. This is especially important for hazardous industries that deal with dangerous materials and machineries.

However, it does not mean that other firms do not need to take this factor into consideration. Health care system is needed for any company with any type of activities.

3.8.6 Education system

- A well designed education system can improve the quality of life in a location in a significant way.

3.8.7 Religion

- Religion differences can make a lot of problems for the firms if they are not considered in the location decision process.

3.9 Political factors

Politics has always been a determinant in many of strategic decisions of firms. In international facility location in specific, since firms consider locations in different countries, political issues can play a deciding role in those kinds of decision making situations. Favorable government policies toward foreign investment can attract companies to a country while adverse regulations can affect the picture of the country.

There are several political variables that should be considered in facility location decisions. The following lists the most important ones.

3.9.1 Stability: current and historical

- Stability of local government and its policies is one of the most important political factors. If the government is not stable and the country goes through political upheaval it can adversely affect the operation of the facility. As a result it is important for the firms to pay

study the history of the government as well as its current situation and use that information for their location decisions.

3.9.2 Government structure

- A democratic country with a well-designed bureaucratic structure is a much more attractive alternative than a country with a dictatorial government in which government has control over any operation of the firm. Therefore, firms need to include this factor in their decision makings.

3.9.3 Consistency of policies

- In addition to stability of the government, the consistency of its policies needs to be taken into consideration. Some governments may enact some favorable temporary regulations to attract foreign investment. But if those rules are not consistent it may deceive the firm to locate its facility in that country while later by changing those rules that location may not be the best alternative anymore. Since facility location is a long term decision, firms need to look forward for the changes and account for those changes in their location decisions.

3.9.4 Government attitude toward foreign investment

- Some governments are welcoming toward foreign investment, while others may try to support local firms by imposing restrictive rules on foreign firms. The attitude of the government toward foreign investment is another determining factor in international facility location.

3.10 Social factors

This factor usually is neglected in location decision makings. However, it can have major effects on the firm and its employees. As a result it was decided to include this factor in our list to make it more comprehensive and inclusive.

Different social factors are considered to be influential for international facility locations among which the most important ones are listed below:

3.10.1 Culture, norms and customs, openness

- The cultural differences between the home country and the host country must be considered in international location decisions. If there is a huge gap between two cultures it is difficult for the employees that come from the home country to adjust with the environment and it can cause severe problems for them.

3.10.2 Language

- Language could be a concern for the firm. it can make it easier for the employees to adjust with the new environment if they do not have to learn a new language.

3.10.3 Consumer characteristics: demography, spending habits, etc.

- The country that the firm decides to locate its facility is a potential market for the firm. As a result, the consumer characteristics, demography, spending habits and other market related factors need to be investigated in the alternatives.

CHAPTER FOUR

Model description and case study

4.1 model description

As mentioned in the previous chapters, in this thesis a clustering technique is implemented to make a classification of countries based on their attractiveness for firms to locate their facility. In this chapter the developed model is described and a hypothetical case is solved using the model to illustrate the way the algorithm works.

Clustering algorithms are widely used by the researchers around the world to make classification of objects. A comprehensive introduction of clustering techniques is provided in chapter 2. The technique that is used in this thesis can be classified as a hierarchical clustering which starts from single objects and groups them together step by step in a way that in the last iteration there is only one big cluster of objects. To obtain a number of clusters instead of one unique cluster, the algorithm needs to be stopped in the middle before all clusters are merged.

Three important components of most of clustering algorithms are:

- Objects
- Attributes
- Similarity coefficient

A brief description of each of these components for our model is provided below:

Objects: the clustering model is used to group the objects together in a fashion that, objects of the same group are similar to each other while they are different from

those that are in a different group. In our model, the objects that are grouped together are the countries.

Attributes: for comparing the objects and measuring their similarity, a set of variables are required. Attributes are the backbone of clustering techniques, in order to make a good classification this set need to be comprehensive and include all the important variables. Neglecting an important and influential attribute can result in a false classification that assigns similar objects to different clusters. The attributes in our model are the decision making factors that are described in chapter 3. Because of the importance of attributes and their deciding role, it is tried to put together a comprehensive list that accounts for every dimension of the problem.

Similarity Coefficient: As mentioned, in cluster analysis objects that are similar to each other are assigned to the same groups while those that are different are separated into different groups. The words "similar" and "different" are used in an ambiguous way and can be deciphered in different ways. In cluster analysis the similarity of two objects or clusters is encapsulated in similarity coefficients. Similarity coefficients are mathematical functions that measure the similarity of two objects based on the values of the attributes. Many different similarity coefficients are proposed by researchers around the world. A very common similarity coefficient that is widely used by researchers is Jaccard Similarity Coefficient. We also use this similarity coefficient for our model. a brief introduction of this coefficient is provided below:

Jaccard Similarity Coefficient: One of the most popular similarity coefficients that have been applied by many researchers is Jaccard Similarity Coefficient. The

simplicity and high computational speed of this similarity coefficient has made it a very useful choice for cluster analysis.

The definition of Jaccard similarity coefficient is very simple, but before going into the definition, the type of data that this similarity coefficient requires, need to be explained. JSC is designed for binary variables. Binary variables take 0 or 1 as value. All of the attributes in the model need to be binary in order to use JSC.

In computing JSC for two objects since all the attributes are binary, there are four possibilities for them: 0-0, 1-0, 0-1, 1-1, where the first number is the value of the attribute for the first object and the second number is the attribute's value for the second object. Therefore we can classify the attributes as below:

Table (4.1) Attributes classification

		Machine j	
		1	0
Machine i	1	a	b
	0	c	d

In this table, a represent the attributes that take value of 1 for both objects, b represent those that take value of 1 for the first object and 0 for the second one, c corresponds to those that take value of 0 for the first object and 1 for the second one, and d represent those that take value of 0 for both of the objects.

Using this classification JSC can be calculated as below:

$$S_{ij} = \frac{a}{a + b + c}$$

In which S_{ij} is the similarity coefficient value between object i and j. In other words it is the ratio of number of attributes that take value of 1 for both machines, to the number of attributes that take value of 1 for either of them.

JSC takes a value between 0 and 1. The higher this value, the more similar two objects are. The maximum value is yield when two objects are completely identical and the minimum value is obtained when there is no similarity between two objects.

4.2 Transferring variables into binary variables

As mentioned before, in order to use Jaccard Similarity Coefficient, all the attributes of the model need to be binary, in other words they need to take just two values: 0 or 1. However, looking at the factors that are proposed in the previous section shows that most of them are not like that and take real values. As a result they need to be transferred into binary variables, in order to be used for our model.

For converting real values into binary variable a procedure is used that is explained below through an example:

- Take attribute X as an example
- Calculate the minimum value and maximum value of this attribute among the values of this attribute for different alternatives.
- Calculate the range using the following equation:
    - $range = maximum\ value - minimum\ value$
- Divide that range into 4 equal intervals with a length that is calculated as below:

- $length = range/4$

- Create 4 new binary variables, each corresponding to one of these intervals and name them X_1 , X_2 , X_3 , X_4
- For each object find the interval that includes the value of attribute X for that object. The binary variable that corresponds to that interval takes value of 1 and the rest become 0.

Using this procedure we change all the variables into binary variables so that we can use Jacard Similarity Coefficient for cluster analysis.

4.3 Clustering technique

As mentioned before, the clustering technique that is utilized in this thesis is a hierarchical clustering algorithm that starts from single objects and by linking the most similar objects with each other at each step, gradually creates clusters of objects.

There are several different hierarchical clustering techniques available, among which we found complete linkage clustering to be the most appropriate technique for our model.

Complete linkage clustering is a similarity coefficient based clustering. This algorithm starts with calculating the similarity coefficients between pairs of object groups. For computing the similarity coefficients between the object groups CLINK uses the minimum similarity level. The following formula is used to compute similarity coefficient:

$$S_{tv} = Min\{S_{mn}\} \quad m \in t \ \& \ n \in v$$

Using this equation we first need to create a similarity matrix. Similarity matrix is a square matrix with the size of number of objects. The entity in row i and column j indicates the similarity between object i and object j.

After developing the similarity matrix the algorithm follows these steps:

6. Form the similarity matrix by calculating the similarity coefficients for each machine pair.
7. Group the objects groups with the highest similarity coefficient.
8. Remove the rows that correspond with the machine groups that were grouped together.
9. Add a new row to the matrix for the new machine group and calculate the similarity coefficients using the following formula:

$$S_{tv} = Min\{S_{mn}\} \quad m \in t \ \& \ n \in v$$

   Where t is the new machine group and v stands for other machine groups.

10. Stop if the predetermined number of machine groups has been achieved, otherwise go back to step 2.

In order to show how the model works we developed a hypothetical case study with hypothetical data and ran the model for this case. A detailed description of the case is provided in the following section.

4.4 Hypothetical Case Study

Here we assume that a company has decided to locate one of its facilities in a foreign country. In order to make a good decision a committee of specialists has been

assigned to this project to first create a list of alternative countries and then compare those alternatives using a set of decision making factors. In this section we explain the steps that need to be taken by the committee to make a good decision. Since it is a hypothetical case study, no real name and data is used.

Step 1: Creating a list of alternatives

The first step for making a facility location decision is to develop a list of feasible alternative locations. In order to create this list the committee collects general data about different countries and picks the countries that best fit the firm's needs. After investigating about the problem and collecting information about countries, the committee came up with a final list of 20 alternative countries. The countries are numbered from 1 to 20. The final list is given in table (4.2).

Table (4.2) Final list of alternatives

Final list of alternatives	
Country #1	Country #11
Country #2	Country #12
Country #3	Country #13
Country #4	Country #14
Country #5	Country #15
Country #6	Country #16
Country #7	Country #17
Country #8	Country #18
Country #9	Country #19

Country #10	Country #20

Step 2: developing the list of decision making factors

In order to compare the alternatives and making a final decision, a set of decision making factors is required. This list needs to be inclusive in a way that it addresses different aspects of the problem.

Using the list of factors that was developed in chapter 2 as a basis and by eliminating the sub factors that are less important for the firm, the committee decided to use the following list of factors for comparing the alternatives:

Table (4.3) List of decision making factors for the case study

General category	**Sub factor**
Cost	Labor cost
	Transportation cost
	Energy cost
	Management cost
	Construction cost
	Trend in cost
Labor characteristics	Education and training level
	Unemployment rate
	Motivation
Infrastructure	Availability of transportation (land and airports)

	Quality and reliability of transportation
	Availability of utilities
	Quality and reliability of utilities
Market characteristics	Proximity to customer
	Market size
	Purchasing power of market
Other locations	Proximity to suppliers
	Proximity to parent company
	Proximity to competition
Regulations	Compensation law
	Insurance laws
Economic factors	Tax structure and policies
	Currency strength vs. US dollar
	Interest rate
	Inflation
Quality of life	Standard of living
	Health care
	Education system
Political factors	Stability: current and historical
	Government structure
	Consistency of policies
	Government attitude toward foreign investment
Social factors	Culture, norms and customs, openness

Step 3: data collection

After developing the list of alternatives and deciding about the decision making factors that are used for comparison, the next step is data collection. Different tools may be used for this purpose such as survey, national and international databases, previous studies, experts' opinion and other methods of data collection.

For the data collection phase it is important to note that the data may be available for some of the presented decision making factors, while for some others, it may not be possible to gather data directly and some other measurable factors are needed to be defined for them. For example, energy cost is a factor that cannot be measured directly and some other variable need to be found to measure it such as electricity cost. In this section we do not go into the details for this type of factors.

The collected data for each general category is given in a separate table. The data is hypothetical and is generated randomly. For generating data a uniform distribution is used. For adding more spices to the data, different ranges are used for different categories. The type of data also varies from factor to factor. Some factors get real data while some other get integer values. It is decided based on the nature of the factor.

Table (4.4) Generated data for cost sub factors

Country	Labor	Transportation	Energy	Management	Construction	Trend
Country #1	32.32	67.15	269.68	61.31	41.22	3.12
Country #2	32.92	55.43	260.31	32.04	20.70	2.67
Country #3	41.43	48.58	546.29	44.37	21.28	3.24
Country #4	47.80	51.46	273.42	34.02	24.55	3.10
Country #5	39.40	68.41	639.22	56.89	24.44	1.85
Country #6	37.22	50.70	500.29	64.20	33.81	3.65
Country #7	38.36	45.24	395.50	69.44	32.63	3.45
Country #8	37.46	46.15	279.36	64.42	37.04	3.33
Country #9	38.77	65.76	505.41	51.77	48.38	4.76
Country #10	46.88	68.27	652.00	46.82	23.40	1.96
Country #11	43.22	62.26	509.41	35.18	20.71	4.21
Country #12	47.12	48.49	525.47	41.32	34.17	4.27
Country #13	38.07	61.70	325.95	56.37	33.26	3.38
Country #14	32.22	59.61	403.71	45.51	28.61	1.18
Country #15	31.99	41.16	306.91	41.88	49.06	4.37
Country #16	48.50	43.77	693.89	54.93	39.05	2.87
Country #17	34.28	44.85	662.36	45.89	26.75	1.66
Country #18	36.54	51.47	214.24	32.07	25.61	2.85
Country #19	34.06	53.66	611.77	53.41	27.19	3.04
Country #20	37.26	46.11	527.82	63.81	42.75	3.11

Table (4.5) Generated data for labor characteristics sub factors

Country	Education and training level	Unemployment rate	Motivation
Country #1	3	20.87	36.14
Country #2	1	17.13	60.33
Country #3	2	23.88	77.12
Country #4	2	5.16	33.04
Country #5	6	12.13	63.44
Country #6	2	27.44	53.03
Country #7	9	9.38	36.98
Country #8	3	19.55	46.66
Country #9	9	27.97	58.33
Country #10	7	22.68	57.00
Country #11	4	23.63	40.14
Country #12	2	9.48	60.46
Country #13	2	25.76	22.24
Country #14	8	16.77	61.66
Country #15	2	5.08	50.54
Country #16	9	7.02	46.25
Country #17	3	5.19	67.37
Country #18	5	26.24	35.65
Country #19	4	25.36	20.63
Country #20	4	14.43	75.91

Table (4.6) Generated data for infrastructure sub factors

Country	Availability of transportation	Quality and reliability of transportation	Availability of utilities	Quality and reliability of utilities
Country #1	28.55	18.47	30.86	17.26
Country #2	16.81	28.62	38.26	10.35
Country #3	28.03	15.02	97.53	27.70
Country #4	34.07	15.98	58.75	20.03
Country #5	13.19	11.28	54.13	17.92
Country #6	27.43	25.59	33.51	22.42
Country #7	15.57	15.56	47.95	27.75
Country #8	43.08	29.10	91.50	15.11
Country #9	17.97	24.30	45.65	13.53
Country #10	34.62	15.12	97.71	27.52
Country #11	35.91	19.57	41.77	26.44
Country #12	40.99	24.98	73.72	24.58
Country #13	21.19	25.30	57.19	26.06
Country #14	32.31	10.24	48.26	15.83
Country #15	37.03	20.31	29.63	21.05
Country #16	19.97	15.28	29.98	25.55
Country #17	26.65	16.70	24.66	11.96
Country #18	19.74	27.42	69.97	28.47
Country #19	47.15	24.71	43.10	19.42
Country #20	37.46	17.33	23.72	21.73

Table (4.7) Generated data for market characteristics sub factors

Country	Proximity to customer	Market size	Purchasing power of market
Country #1	269.87	236.12	146.51
Country #2	311.92	464.90	139.01
Country #3	193.33	949.17	379.88
Country #4	175.84	609.30	157.07
Country #5	212.11	165.62	325.85
Country #6	127.26	233.11	130.02
Country #7	429.63	303.93	145.06
Country #8	416.65	170.14	126.47
Country #9	100.35	1050.14	369.59
Country #10	481.83	870.46	399.96
Country #11	66.36	1026.62	140.41
Country #12	431.50	670.23	439.51
Country #13	499.68	262.76	305.01
Country #14	343.96	657.13	208.99
Country #15	378.90	800.95	376.17
Country #16	510.38	214.88	290.37
Country #17	248.11	640.97	128.27
Country #18	482.12	761.39	188.71
Country #19	164.90	828.76	499.90
Country #20	424.27	210.87	403.12

Table (4.8) Generated data for other locations sub factors

Country	Proximity to suppliers	Proximity to parent company	Proximity to competition
Country #1	746.78	795.71	739.40
Country #2	996.13	275.58	354.20
Country #3	349.39	343.03	894.58
Country #4	928.80	325.34	516.28
Country #5	751.70	414.52	554.86
Country #6	617.51	328.07	356.88
Country #7	506.21	712.70	521.89
Country #8	789.76	724.95	237.61
Country #9	601.74	703.10	433.49
Country #10	1006.50	209.86	404.63
Country #11	130.10	992.17	417.39
Country #12	1096.51	495.92	561.47
Country #13	475.91	340.31	801.11
Country #14	219.70	454.15	377.16
Country #15	925.21	714.11	559.02
Country #16	674.60	427.16	428.96
Country #17	220.59	494.98	917.84
Country #18	496.20	624.59	517.43
Country #19	813.24	785.10	868.64
Country #20	781.64	224.86	932.65

Table (4.9) Generated data for regulations sub factors

Country	Compensation law	Insurance laws
Country #1	13.96	13.45
Country #2	5.40	15.24
Country #3	9.60	26.16
Country #4	13.54	28.89
Country #5	13.78	19.53
Country #6	8.94	24.90
Country #7	7.41	22.62
Country #8	9.84	18.98
Country #9	5.66	24.82
Country #10	11.07	11.23
Country #11	13.58	13.56
Country #12	6.31	21.26
Country #13	12.73	17.31
Country #14	8.01	16.51
Country #15	5.59	25.40
Country #16	6.70	11.87
Country #17	6.90	28.94
Country #18	12.28	22.94
Country #19	13.13	12.20
Country #20	5.39	29.07

Table (4.10) Generated data for economic factors sub factors

Country	Currency strength vs. US dollar	Interest rate	Inflation
Country #1	19.01	16.03	19.85
Country #2	17.07	9.35	17.04
Country #3	18.02	8.84	4.83
Country #4	16.09	11.10	2.97
Country #5	12.12	3.26	18.97
Country #6	17.00	1.24	9.74
Country #7	5.46	20.74	19.50
Country #8	10.71	7.20	7.28
Country #9	20.83	9.87	14.93
Country #10	4.51	15.88	12.37
Country #11	8.23	10.61	1.49
Country #12	15.32	19.86	20.46
Country #13	3.18	2.61	9.09
Country #14	1.17	19.94	11.45
Country #15	2.62	15.03	11.67
Country #16	5.83	18.30	14.40
Country #17	6.28	18.62	2.46
Country #18	2.93	17.66	5.58
Country #19	12.47	16.09	3.82
Country #20	6.88	12.31	20.62

Table (4.11) Generated data for quality of life sub factors

Country	Standard of living	Health care	Education system
Country #1	18	14	10
Country #2	7	18	2
Country #3	8	26	9
Country #4	5	24	15
Country #5	10	8	11
Country #6	16	8	8
Country #7	13	28	9
Country #8	14	19	16
Country #9	2	23	11
Country #10	6	5	4
Country #11	2	21	8
Country #12	4	19	5
Country #13	17	21	10
Country #14	4	4	9
Country #15	10	24	9
Country #16	4	18	14
Country #17	18	6	19
Country #18	1	11	1
Country #19	12	5	14
Country #20	15	9	6

Table (4.12) Generated data for political factors sub factors

Country	Stability: current and historical	Government structure	Consistency of policies	Government attitude toward foreign investment
Country #1	19	3	5	4
Country #2	22	2	2	2
Country #3	39	4	6	17
Country #4	33	3	2	12
Country #5	26	4	3	11
Country #6	29	2	9	13
Country #7	34	1	4	5
Country #8	26	3	8	11
Country #9	27	1	6	13
Country #10	31	4	4	4
Country #11	35	1	2	3
Country #12	36	4	10	5
Country #13	31	1	9	19
Country #14	15	1	8	11
Country #15	14	4	6	3
Country #16	26	2	8	11
Country #17	11	3	3	5
Country #18	32	4	6	9
Country #19	12	3	10	14
Country #20	30	4	10	17

Table (4.13) Generated data for social factors sub factors

Country	Culture, norms and customs, openness
Country #1	19
Country #2	22
Country #3	39
Country #4	33
Country #5	26
Country #6	29
Country #7	34
Country #8	26
Country #9	27
Country #10	31
Country #11	35
Country #12	36
Country #13	31
Country #14	15
Country #15	14
Country #16	26
Country #17	11
Country #18	32
Country #19	12
Country #20	30

Step 3: converting data to binary

As mentioned in the previous sections, in order to use the JSC all the variables need to be binary. As a result, variables those are not binary, need to be converted to binary. The conversion steps are explained in the previous section. In this step all the variables are converted to binary variables using the explained algorithm. Since the conversion process is similar for all the variables and it is tedious to explain the process for the entire list of decision making factors, here the conversion of labor cost factor is explained as an example that can easily be extended to any other factor.

The maximum value for labor cost is 48.5 that is for country #16 and the minimum value is 31.99 that is for country #15. For converting this variable to binary, first the range is calculated as below:

$$range = maximum - minimum = 48.5 - 31.99 = 16.51$$

Next this range is divided into four equal intervals as below:

- Interval 1: [31.99 , 36.1175)
- Interval 2: [36.1175 , 40.245)
- Interval 3: [40.245 , 44.3725)
- Interval 4: [44.3725 , 48.5]

After defining the intervals, 4 new binary variables are defined that correspond to each interval. The values of these variables indicate whether or not the labor cost value falls into the interval that the variable represents. If it falls in the interval the variable

becomes 1, otherwise it is 0. Here we call the variables X_1, X_2, X_3 and X_4 and they are defined as below:

- $X_1 = \begin{cases} 1 \; if \; the \; value \; of \; labor \; cost \; falls \; inside \; [31.99 \, , 36.1175) \; interval \\ 0 \quad otherwise \end{cases}$
- $X_2 = \begin{cases} 1 \; if \; the \; value \; of \; labor \; cost \; falls \; inside \; [36.1175 \, , 40.245) \; interval \\ 0 \quad otherwise \end{cases}$
- $X_3 = \begin{cases} 1 \; if \; the \; value \; of \; labor \; cost \; falls \; inside \; [40.245 \, , 44.3725) \; interval \\ 0 \quad otherwise \end{cases}$
- $X_4 = \begin{cases} 1 \; if \; the \; value \; of \; labor \; cost \; falls \; inside \; [44.3725 \, , 48.5] \; interval \\ 0 \quad otherwise \end{cases}$

After creating these variables, the conversion procedure is carried on as explained. The results of conversion are given in table 15

Table (4.14) Conversion results for labor cost.

Country	Labor cost	X_1	X_2	X_3	X_4
Country #1	32.32	1	0	0	0
Country #2	32.92	1	0	0	0
Country #3	41.43	0	0	1	0
Country #4	47.80	0	0	0	1
Country #5	39.40	0	1	0	0
Country #6	37.22	0	1	0	0
Country #7	38.36	0	1	0	0
Country #8	37.46	0	1	0	0
Country #9	38.77	0	1	0	0
Country #10	46.88	0	0	0	1

Country #11	43.22	0	0	1	0
Country #12	47.12	0	0	0	1
Country #13	38.07	0	1	0	0
Country #14	32.22	1	0	0	0
Country #15	31.99	1	0	0	0
Country #16	48.50	0	0	0	1
Country #17	34.28	1	0	0	0
Country #18	36.54	0	1	0	0
Country #19	34.06	1	0	0	0
Country #20	37.26	0	1	0	0

Step 4: running the clustering model

After converting all the variables into binary, the data can be used to run the clustering model. As mentioned a complete linkage clustering technique is used for this purpose. Countries are grouped in 5 clusters. The output of the model is illustrated in table 16.

Table (4.15) Cluster assignment

Country	**Cluster**
Country #1	5
Country #2	3
Country #3	2
Country #4	2

Country #5	5
Country #6	5
Country #7	4
Country #8	5
Country #9	4
Country #10	3
Country #11	2
Country #12	4
Country #13	5
Country #14	3
Country #15	4
Country #16	4
Country #17	1
Country #18	4
Country #19	1
Country #20	5

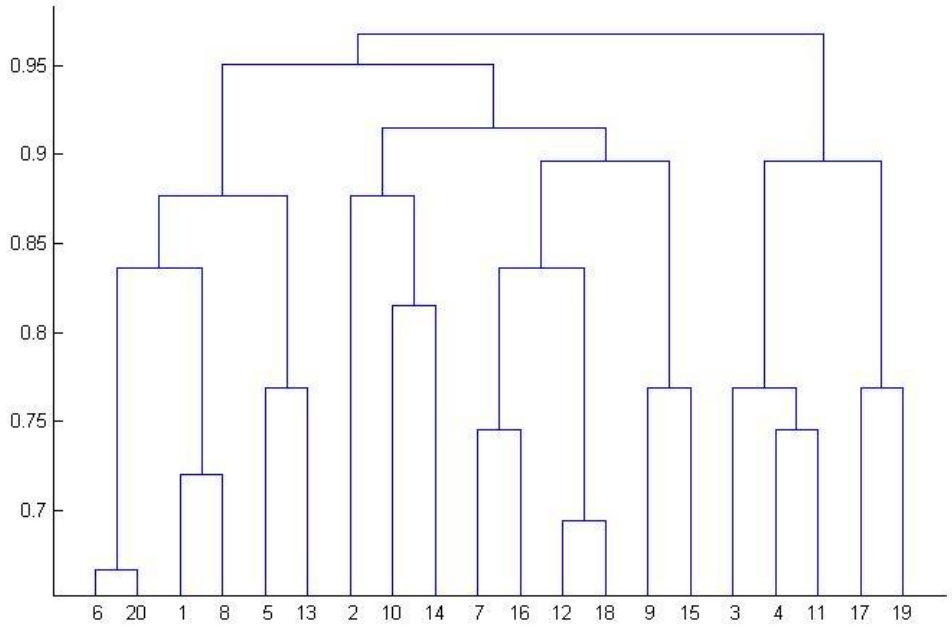

Figure (4.1) Dendrogram for the model

Step 5: interpreting the results

After running the model and getting the output, the committee needs to interpret the results for the manager so that they can make the final decision. As it is shown in the results, the alternatives are grouped into 5 clusters. The countries on each cluster are similar to each other and they are different from those that are in a different cluster.

The clusters that were generated by the model are as below:

- Cluster 1
    - Country #17
    - Country #19
- Cluster 2
    - Country #3

    - Country #4
    - Country #11
- Cluster 3
    - Country #2
    - Country #10
    - Country #14
- Cluster 4
    - Country #7
    - Country #9
    - Country #12
    - Country #15
    - Country #16
    - Country #18
- Cluster 5
    - Country #1
    - Country #5
    - Country #6
    - Country #8
    - Country #13
    - Country #20

This classification does not suggest any information about which category is better than the other. It is only to show the managers, what alternatives are similar based on the decision making factors that were fed into the model.

In order to make the final decision, the clusters need to be studied to see what makes the countries on each cluster similar to each other and what are the strengths and weaknesses of them and based on that, find the best cluster.

CHAPTER FIVE

Conclusions and Scope of Future Researches

In this thesis the international facility location problem is addresses using a clustering technique. The developed model creates a classification of alternative countries based on a set of decision making factors that is extracted from previous researches. A hypothetical case study is used in chapter four to illustrate the model's output and the way it works.

Unlike most of the available algorithms that suggest a single solution to the problem or rank the alternatives based on their attractiveness for the firms, our model create a classification of the countries in a way that countries that are similar together are in the same group. The advantage of this method is that it gives the final decision maker more flexibility by suggesting a set of options that he can choose from instead of giving one single solution. Another advantage is that it is less sensitive to the mistakes or errors in the data. For example, if the algorithm suggests a single solution, errors in the data can prevent a country to be chosen, while in our algorithm since the output is a set of alternatives, the risk of ignoring a good alternative is lower.

As mentioned in the previous chapters, the data that is used for the analysis is generated randomly and no real data has been utilized. For the future research, a real set of data can be gathered using national and international databases and other resources to run the model for a real case and make a classification of countries.

The output of the real case study can be used as the basis of a variety of analysis including:

- Identifying the most important decision making factors.
- Finding the trends in the global market
- Anticipating the future changes in the market

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