STRATEGIC LOCATION SELECTION FOR PRODUCTION FACILITIES: AN INFORMATION SYSTEM APPROACH

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ABSTRACT

This paper attempts to solve a critical problem firms all over the world face, regarding the excessive time needed to decide on the location of their facilities. A solution has been proposed to tackle this problem which aims to drastically reduce the time and resources needed to select the location. Using Optimization Techniques and Various Location Strategies, a methodology has been proposed as a software solution, which inputs various critical location factors into calculations and provides a list of locations with their comprehensive analysis, achieving the aim of reducing the man-hours spent to reach a decision. The data required is automatically mined for the user from the web from indexes of reliable agencies and Economic Development Groups.

Keywords*: *Planning, Location factors, MCDA methods, Optimization techniques.

I. INTRODUCTION

According to UNCTAD Report 2014, $1.45 trillion worth of investment at a growth rate of 9% was seen in 2013 which is projected to reach to $1.6 trillion by 2015. This heavy investment clearly states that companies are becoming global and creating manufacturing locations and offices all over the world. Every day, the companies are trying to become the world leader in their respective sectors and without being a truly multinational company, the task seems impossible. As companies try to gain a competitive edge and serve more and more international markets, they are producing goods and setting up manufacturing plants all over the world. International manufacturing is one of the major parts of a firm's competitive strategy today and beyond. Global expansion will offer the potential to take advantage of economies of scale and entry to new markets (Badri, 1999).

Companies that decide to produce and source globally must consider a variety of factors, which may not arise in location decisions in a single country. These decisions have a long term impact and are difficult to change. The objective is to maximize the benefit of location to the firm. Location strategy and finding the appropriate location isn't an easy task for which many companies even employ consultants. The whole process from setting up requirements to the groundbreaking is very time consuming. On average it takes companies 6 months to 2-3 years on deciding a location depending on the size of the firm.

In this paper, we aim to tackle the problem using Management Information Systems, Data Mining from Web, Optimization Techniques for Location Strategy and Economic Models generally used by firms. Combining all these in a software package provides us a brilliant way to reduce the time taken by a firm in deciding the optimum location for the facility. We aim to bring down the short list of the candidate locations from tens to 5-6 of the most appropriate and suitable ones for the company depending upon their needs and requirements. The executives and managers now barely need to spend a day on the software to get the shortlisted location after which they can perform the detailed analysis suitable for them on the locations, use more data to simulate conditions and make an informed decision with speed and accuracy.

II. EXISTING WORK

Various studies have been conducted to determine the various factors on which location selection is done, the analysis of choices previously made by various organisations and the general perception among executives while choosing the location. The decision of the companies on moving or expanding or starting at a new place is followed by analysis of locations, field visits, and consultations with authorities.

Some of the most important work has been done in

1. The study by Bart MacCarthy and Walailak Atthirawong named as Critical Factors in International Decisions: A Delphi Study.
2. A comprehensive work of collecting and analysing various optimization techniques have been done by Svitlana Checherenkova titled Pre-Study of the Important Factors for the Factory Start-Up Abroad.

Area Development's Annual Site Selection Consultants Survey states that "The majority of Consultants Survey respondents (78 percent) use site magazines like Area Development for information when helping their clients make location and expansion decisions. Three quarters of the consultants also utilize economic data aggregators, while two thirds also depend on financial publications. More than half of the responding consultants claim to maintain their own site selection database. Nearly all of them (93 percent) have searched the Internet for site and facility planning information."[6]

Area Development's Annual Survey of Corporate Executives states that "More than 80 percent of the Corporate Survey respondents say they utilize site magazines like Area Development for information upon which to base their location decisions. About half also use general business and financial publications as a site selection resource. While 62 percent of the respondents search the Internet for site and facility planning information, 83 percent claim social media, e.g., Twitter, LinkedIn, etc., is not utilized in this capacity. Nearly 60 percent of those responding to our 28th annual Corporate Survey say they do not use outside consultants when making a location decision."[7]

All of this goes on to show that there has been no significant work been done over time in improving this aspect of a business which obviously consumes a whole lot of time. Also as of now, no one has attempted to reduce the excessive amount of time and money wasted over the process of finding the most appropriate location using computers and software which could help us in reducing the time required by at least 50%.

III. PROBLEM STATEMENT

The problem statement can be dictated as the amount of time, and therefore, other resources, needed from start to the end of taking a decision to open a new factory/office till the ground breaking and start of the execution.
It starts with the decision taken by the executives to open up a new factory followed by setting up the requirements and parameters for the location. Furthermore, it leads to analysing and finding data of tens of locations or maybe even more. It generally involves finding the land/buildings, skilled labour availability, cooperativeness of authorities, tax laws, raw material availability, water and electricity availability, infrastructure availability, closeness to market etc. to name a few. This leads to various meetings regarding budgets, financial requirements, concerning the area, its laws and necessary paperwork. Then after shortlisting few locations over a period of months to years, the decision is taken by executives which if lucky might pass through and all of this then culminates in meetings with authorities, filling up paperwork and countless other tasks necessary for ground breaking or starting the work on the location.

All these tasks take time, from 6 months to a year for mid-size companies to 2-3 years for large companies. During this time there is no progress and a lot of precious time and money is wasted over the whole process.

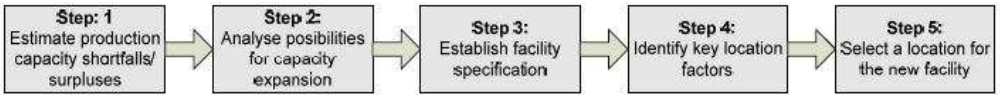


Figure 1: Steps in Manufacturing Location Decisions

IV. PROPOSED SOLUTION OVERVIEW

What we are proposing as a solution is to use the readily available analysis from various reputable agencies all over the world and apply them in the location strategy techniques to reduce the number of our options to a great extent, thereby reducing our time and resources spent. In the following paragraphs we will go step by step over our solution defining the concepts and explaining through examples. We have proposed a software which takes input from the user over few questions which would be choice based, and will help in defining their requirements and will give an idea of what kind of a company is looking for the location.

The solution we have provided can also be used for determining possible locations of offices with some minor changes in the program.

To understand the solution we need to briefly touch upon the factors important for a company in general when deciding a location for a factory. The final decision of site selection for a new facility is greatly influenced by the location factors that have been selected and evaluated, as well as by their influence on corporate objectives and operations.

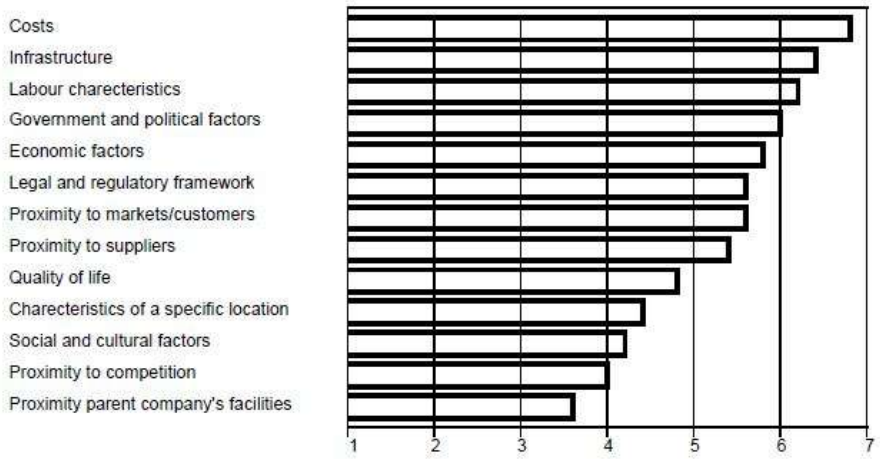


Table 1: Key Factors Affecting International Location Decisions (MacCarthy et al, 2003)

The first stage of site selection is to define a general area of search. Size of this area maybe as large as an entire economic region, such as Western Europe or North India, or it may be as small as a few square kilometres or a single metropolitan area. This is the stage where amount of detail isn't that paramount and there are plenty of alternatives.

Major factors for selection of general search area
Location in relation to markets
Location in relation to material sources
Transportation cost
Availability and cost of utilities

Table 2: Major Factors for the Selection of Economic Area/Macro-Region (Hack, 1999)

After the site, we proceed to identify the micro-region (community) within the chosen search area. Various companies have their own selection factors with varied importance, but a general list of the factors is represented in the table 3. At this stage, the detailing is quite high and average number of alternatives.

Community location factors
Local labor supply
Local labor costs
Labor management relations
Labor training programs
Transportation facilities and services
Cost and reliability of electric power
State and local taxes
Telecommunication services
Adequacy of streets and highways
Police protection
Fire protection
Recreation, parks, and civic facilities
Natural gas cost and service
Cost and reliability of water service
Adequacy of sewer system
Waste disposal
Health and medical services and facilities

Table 3: Major Factors for the Selection of Community (Hack, 1999)

The final stage is of deciding the most appropriate locations. The amount of detailing towards the factors is most important here, with a very few alternatives available. The executives need to visit the sites and analyse all the factors deeply before committing to a specific location.

Factors of site investigation
Size and shape of site
Topographic considerations
Availability and cost of utilities
Water supply
Sewer facilities
Drainage and flooding
Soil conditions
Cost of development
Location in community
Transportation facilities
Fire and police protection
Taxes and insuarance
Zoning and other legal aspects
Suitability of existing building
Land costs and options

Table 4: Major Factors for the Location of Site (Hack, 1999)

V. PROPOSED SOLUTION

1. Through a user-friendly interface, the software takes input from the user, asking questions like in field which does the company work, the estimated company size, how global they truly are, the investment they are looking to make, etc. Basically, we define the type of company for the software so that by using the historical data of similar organizations, we can provide them with the most accurate data using the experiences of similar organizations.

2. The software asks the users pre-defined questions based on the type of the company to gather the requirements of the company and to evaluate what factors are important for the company, for the selection of location, and by how much.

An example of some of these questions would be:

i. Rate the following factors in order of their importance.

a. Infrastructure.

b. Financing.

c. Taxes.

d. Labour Laws.

e. Skill of the workforce.

f. Economy of the country.

g. Trade across borders.

h. Ease of Doing Business.

i. Dealing with the authorities.

Dynamically, based on the input of these questions the software will improvise on its own and end up with a clear list of factors with the weights, corresponding to their importance to the companies, and on a scale of 0 to 1 (1 being the most important).

After obtaining the factors in order of importance, we use the **factor rating method** defined below. We collect the ranking of various countries from indexes created by thorough analysis of the agencies which list them by rank all over the internet to use. By using data mining and other techniques we obtain these data, and create a data warehouse, which needs to be updated in regular intervals. These agencies have almost all kinds of data available related to a country as well as their regions/states with most accurate information. Some of the agencies we use are:

a. Doing Business Project by World Bank Group. [8] *(Methodology for rankings. [12])*
b. World Bank Data. [9]
c. CIA Factbook.
d. OECD.[11]
e. Respective Official Country Statistics.

Correspondingly, we form the collection of countries based on their rankings for each factor. Multiplying the two gives us the weight of that factor for that country. When similarly done for all countries, we add up the numbers and find the top 5 countries which will be most appropriate for the company, location wise. Also, using filters, we can filter out specific countries/regions where the company doesn't want to enter, hence providing the most relevant options to the users.

V.I Factor rating method

There are two types of factors which influence the decision of location of a new unit- namely, tangible (that is, quantitative) and intangible (that is, qualitative) factors.

In the factor rating method, we first determine all the factors that are important to us when we decide as to where we'd like to set up the new unit. We develop a rating scale for each factor, and score all locations based on the scale. We find the corresponding factor weight of a particular country by multiplying the factor weight with the corresponding rating of the country. The total score of a country is the sum of total scores of all factors for that country. Based on the maximum total score, the client will be recommended the few best locations according to their need.

Advantages:

- Ease and simplicity of computation and decision making.

Disadvantages:

- Very basic and subjective, can solve only those problems that are direct and simple.
- We cannot accurately measure the relations between factors, if there are too many factors involved. This is handled in our model by taking the importance of factors as input from the company.

Mathematical equation:

$W_x = I_x * RI_x$ (1)

Here,

W: Weighted Score

I: Importance of the factor (Range: 0-1)

RI: Rank Importance (Higher Ranked Countries on the Index have lower RI.)

$T_c = \sum W_x$ (2)

Highest T_c corresponds to the most appropriate country where C represents the country.

Critical Success Factor	Weight (Importance)	Ranks(4=highest)				Weighted scores			
		India	China	USA	Taiwan	India	China	USA	Taiwan
Ease Of Business Index	.7	1	2	4	3	.7x1=.7	.7x2=1.4	.7x4=2.8	.7x3=2.1
Getting Electricity	.5	2	1	3	4	.5x2=1	.5x1=.5	.5x3=1.5	.5x4=2
Getting Credit	.4	2	1	3	1	.4x2=.8	.4x1=.4	.4x3=1.2	.4x1=.4
Paying Taxes	.3	1	2	3	4	.3x1=.3	.3x2=.6	.3x3=.9	.3x4=1.2
Trading Across Borders	.2	1	2	3	4	.2x1=.2	.2x2=.4	.2x3=.6	.2x4=.8
Dealing with Construction Permits	.3	2	1	3	4	.3x2=.6	.3x1=.3	.3x3=.9	.3x4=1.2
Total	N.A.	N.A.	N.A.	N.A.	N.A.	3.6	3.6	7.9	7.7

The data for Country Ranks has been used from [3]. Here, we see that USA is the most appropriate country based on the importance of factors for the company.

3. After deciding on a short list of countries, we shall ask for the target market and the major suppliers of raw materials for the production facility. Considering the data of target market and suppliers, we will implement the **improvised Centre of Gravity Method** which will provide the results in a geographical manner for the user to see.

   The factor rating method will give us a short list of the top options. After that, the following steps will take place.

   a. We obtain their coordinates on the world map.

   b. We mark them on the map along with the target markets and the major suppliers.

   c. If the target markets or suppliers are international locations near ports will be preferred i.e. given a higher weight.

   d. Applying Centre of Gravity Method, we find top 3 locations on the map which should be further analysed at the site level by the user.

VII. CENTRE OF GRAVITY METHOD

The centre of gravity method works on the principle of minimizing the transportation costs from suppliers or to markets by finding a location from where the sum of transportation costs is minimized and the proximity is maintained. We draw a grid over a map of the area with horizontal and vertical coordinates of the shortlisted locations, the target markets and the suppliers. We use q_i as an importance factor/weight whose range is between 0-1 and which is multiplied by the coordinates of the targets/suppliers where 1 is least important. This creates an illusion of our locations being closer to the more important places. We then calculate the coordinates of the "Centre of Gravity", (X,Y) which are given by

$$X = {}_{i=1 \text{ to } n} \sum(x_i * q_i) / \text{ no of locations}(n) \quad (3)$$

$$Y = {}_{i=1 \text{ to } n} \sum(y_i * q_i) / \text{ no of locations}(n) \quad (4)$$

This is further marked on the map and top shortlisted locations close to this coordinate are presented to the user.

Advantages:

- Minimizes transportation costs in order to identify the general area of unit.
- A simple method which does not require much computation.

Disadvantages:

- Is not very accurate. Rough guide for analysis, not a precise tool. This is handled in our model, by using importance factor/weight to the locations.

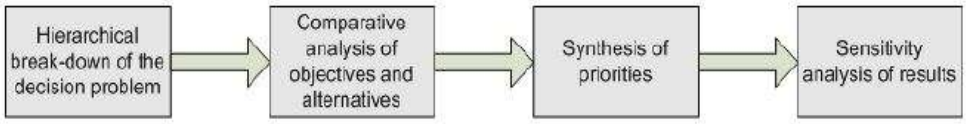
4. These steps culminate with the list of most appropriate locations which should be analysed by the company in most detail. All of this would take a day at most and will reduce the data collecting and lead time from months to a day. The analysis done by software for all locations will be provided in the form of reports for users' consideration.

5. The users can then further choose their decided locations or can choose locations for performing Analytic Hierarchy Process (AHP) and sensitivity analysis using functionality similar to Expert Choice explained below.

VIII. EXPERT CHOICE

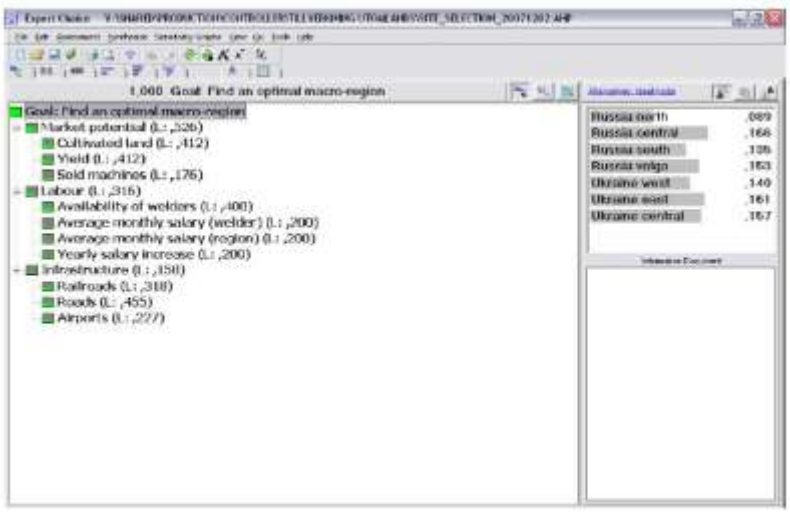
Expert Choice is a software for analysing multi-objective problems and is based on the analytic hierarchy process (AHP) developed by Saaty. According to Fernandez (1996), "Expert Choice Pro helps a decision maker examine and resolve problems involving multiple evaluation criteria. The software uses the AHP methodology to model a decision problem and evaluate the relative desirability of alternatives".

Expert Choice has a clear interface which allows aids in solving the AHP on a computer. With the software it is possible to generate a graphical representation of the hierarchy in easy and comprehensible way. In addition to providing the overall priorities for the decision alternatives, Expert Choice is capable of performing sensitivity analyses, whereby the decision maker can begin to learn how the overall priorities for the decision alternatives are affected by changes in the preference input data.

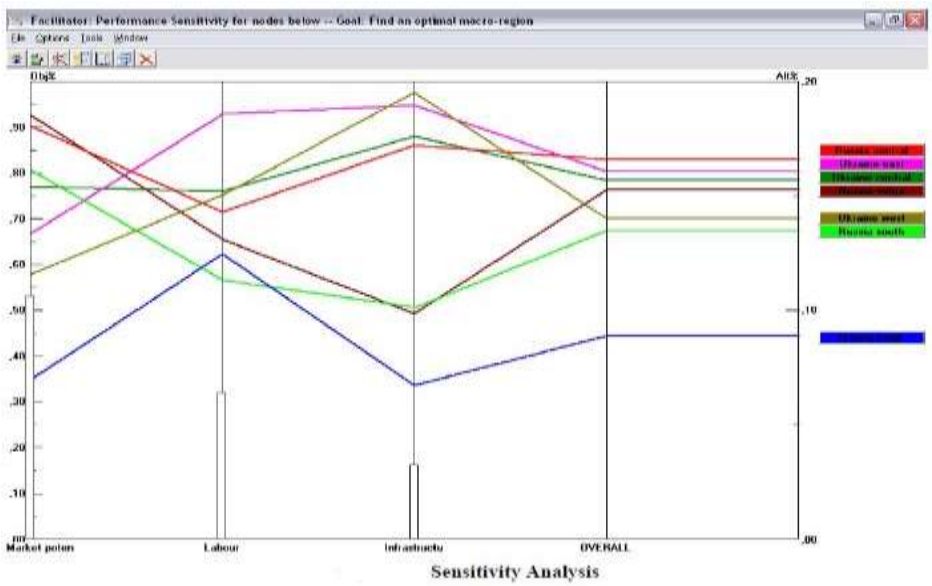


Major AHP Steps

Few examples through screenshots courtesy of (Svitlana Checherenkova titled Pre-Study of the Important Factors for the Factory Start-Up Abroad):



Decision Hierarchy in Expert Choice



Sensitivity Analysis

IX. FUTURE SCOPE

There are quite many ways in which we can further shortlist the options to 1 or 2 choices, using Predictive Analysis and other optimization techniques like Location Break Even Analysis, Transportation Linear Programming Problems, Fuzzy Logic and Economic Models like Payback Period, Rate of Return Method. Giving weightage to the results of these according to their reliability we can find out the most appropriate location.

Using advanced data mining techniques we can collect data from news sources and other articles commenting on infrastructure at those locations or attitude of authorities towards business, skill level of the nearby region workforce etc. We can give smaller weightage to these articles and news sources so as they don't affect our result by much yet provide us with a more accurate result. Finding/Collecting data about specific cities through internet or personally, we can create a database which can be used by the users.

Further, whenever users use this software their choices, data and results can be stored in an appropriately manner such as not violating their privacy or confidentiality, and use that data to improve our location deciding tool. Reaching to the specific site level using GIS (Geographical Information Systems), GPS and collected data should be the next logical step in this area.

More so, other analytical tools can be provided which can help in analysing the costs that would be incurred by the company when specific parameters are concerned and how manipulating with them changes the situation for the company. Similarly, with some minor changes, the software can also help in finding the appropriate locations for offices in which listings for offices spaces available online can be incorporated too.

X. CONCLUSION

The purpose of this paper was to drastically reduce the time and resources spent by companies all over in deciding the location of the projects. Using various techniques starting from Factor Rating method, we provide the best list of choices to the user depending on their requirements and importance towards various factors.
Furthermore, since centre of gravity takes only transportation issues into consideration, we used AHP to analyse other important factors for the factory location. AHP allowed us to analyse both qualitative and quantitative factors. The analysis of the suitable macro-region for the factory location shows that there is no definite answer in terms of the best option. Thus, the end decision has to be made by the company officials by deeply analysing various factors and how important they are to the company. It will vary from company to company depending on their size, market, their sector etc.

The most important achievement in this method is the usage of easily available indexes from reputable agencies which can be parsed by the software on its own on a regular basis and an accurate database created. The software could be pointed towards only the indexes which are most reliable to maintain the accuracy of results. This greatly reduces the time spent in finding, collecting and collating the data to compare between various locations by the manpower which could be better utilised towards other work.
Hence, we can conclude that such methodology implemented as software would form a brilliant Management Information System which would be able to accurately predict the requirements of the user and suggest accordingly the locations that should be seriously considered based on various previously proven techniques and models used by the best companies all over the world.

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