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Manufacturing Site Selection In A Global Environment: A New Approach Based On Cluster Analysis

Ghorashi, Roya **
Department of Industrial and Manufacturing Engineering
University of Wisconsin, Milwaukee
Milwaukee, WI, USA
Ghorashi@uwm.edu

Mardikoraem, Mahsa **
Department of Industrial and Manufacturing Engineering
University of Wisconsin, Milwaukee
Milwaukee, WI, USA
Mardiko2@uwm.edu

Seifoddini, Hamid K.
Department of Industrial and Manufacturing Engineering
University of Wisconsin, Milwaukee
Milwaukee, WI, USA
Seifoddi@uwm.edu

** These authors equally contributed in the paper.

***Abstract*— In this paper, factors related to the problem of manufacturing facility location selection are reviewed and a new approach to manufacturing site selection in a global context is presented. In this approach cluster analysis is employed to classify countries according to attributes impacting the suitability of a location for manufacturing operations. Furthermore, attributes are quantified using relevant economic and business metrics.**

***Key words*— Manufacturing Sites; Clustering Algorithm; Global Facility Location Factors**

I. Introduction

The decision making regarding the selection of manufacturing facility locations has been always a challenging problem for manufacturing corporations and a strategic one. At the dawn of the 21st century, however, we are witnessing one of the most profound transformations of manufacturing operations due to globalization. This transformation adds another layer of complexity to the problem of manufacturing site selection. Historically economic factors such as wages, infrastructure, education, workforce development, proximity to market, etc. have been considered for site selection. Today, however, due to the global dimension of the problem not only these traditional factors are looked at differently, but also many new factors such as political stability, social harmony, trade regulations, nature of governments, environmental consideration, etc. are crucial to the decision making about manufacturing site selection. The identification of all relevant factors in manufacturing site selection and incorporation of them into the analysis of site selection problem pose a challenge to scholars in this field.

Thanks to the endeavour of a large number of authors in the area of manufacturing facility location selection, there is a substantial body of scholarly work on relevant factors in manufacturing site selection. The solutions to the problem of incorporating these factors into the manufacturing site selection process in an effective and efficient manner, however, are less satisfactory at the present time. The subjective nature of many of the existing solutions and the huge burden of data collection through surveys make these solutions less desirable. The consideration of a wide range of factors that impact the selection of a location for manufacturing operations, the quantification of these factors, and incorporation of them into the decision making process call for a flexible, quantitative, and comprehensive approach to the problem of global manufacturing site selection.

Cluster analysis has been widely used in different field of studies for identifying groups of objects according to their common attributes. Many authors have applied cluster analysis based on similarity coefficient measures to improve the design and operation of manufacturing systems [1]; [2]; [3]; [4].

In this paper we present an approach to the global manufacturing site selection problem based on cluster analysis. We, specifically, employ complete linkage clustering and Euclidean distance coefficient based on manufacturing site selection attributes to classify countries according to their suitability for manufacturing operations. To quantify the manufacturing site selection attributes we choose the existing economic /business indices which closely reflect the relevance of each attributes to the decision on site selection. The availability of sources such as World Bank, United Nations, World Economic Forum, and so on greatly alleviates the burden of data collection through surveying and other methods. The approach to the manufacturing site selection problem presented here provides a flexible, quantitative, and custom made framework for decision making for global manufacturing site selection.

II. LITERATURE REVIEW

We have organized the literature on manufacturing site selection into two parts. The first part includes studies on factors impacting decision making about the global manufacturing facility location selection problem. In the second part, studies on solutions to the problem are reviewed.

A. Global facility location factors

In today's global economy, a wide range of factors may potentially influence corporate decisions to locate production facilities across international boundaries [5]. Reference [6] proposed some factors including market accessibility, availability of basic services, environmental considerations, site location costs, industrialization, labour and staff availability, host location taxes and incentives, area reputation, the nature of the host government , and the government policies in deriving managements to invest in a foreign country. That study use a survey of 118 plants operated by U.S. firms in Latin America, Europe and Asia. Reference [7] proposed a list of important factors in decision making about the selection of an international industrial location including political risks, domestic instability, foreign conflict, political climate, and economic climate.

Reference [8] surveyed 242 foreign-owned manufacturing firms and identified the followings as the most important factors affecting firms' location decisions: transportation services, labor attitudes, space for expansions, proximity to markets, and availability of a site.

Reference [9] indicated that firms have chosen specific locations based on three major types of factors: availability of transportation facilities for moving raw materials and finished goods, availability of labor, and personal considerations.

Reference [10] surveyed 21 German and Japanese firms to find the influential factors in their decision making on manufacturing site selection. The results of the study show that availability of sites, desirability of sites for incoming personnel, and market access were the most important considerations. These firms placed less emphasis on labor, financial incentives and access to raw materials and semi-finished goods.

Reference [11] ranked the location factors for companies based on the size of the plant. It claims that depending on the size of the plant the importance of factors may vary.

Reference [12] selected 77 factors based on literature review and used questionnaire approach to explore the impact of factors on the manufacturing site selection. It proposed three models of industrial location analysis complementary to traditional approaches of industrial location analysis.

Reference [13] examined the design and implementation of a knowledge based decision support system (KBDSS) in the facility location domain in order to develop the list of factors for manufacturing site selection. The study identified a list of factors which are important for manufacturing facilities in the USA. The list consists of market, transportation, labor, site consideration, raw materials, basic services, utilities, environmental regulations, and community's environmental concerns for locating a manufacturing facility. Another study by [14] indicated how both foreign and domestic firms in US are influenced by some basic factors. It divided factors into two groups, independent and dependant. Some of these factors are labor (skilled workers, union membership), energy (fuel cost, climate), trade volume, state development efforts, employment rate, market (personal income).

Reference [15] surveyed 319 US and foreign manufacturers in the USA. According to the survey some of the factors are state financial assistance, local financial assistance, state tax breaks, local tax breaks, business assistance, employee training, infrastructure development, free trade/enterprise zones, site improvements, site selection assistance, and land grants. This paper also demonstrates that American firms are greatly influenced by financial incentives, while foreign firms are relatively more attracted to non-financial incentives. Based on this study, factors related to communities environmental concerns, logistic factors, and trade concerns are more important for foreign companies while domestic corporations are more influenced by factors such as taxes financial incentives, capital gain laws and so on.

Reference [16] divided factors into two groups: reactive and proactive. It defined some quantitative as well qualitative factors and incorporated them into a 0-1 mixed integer programming problem.

Reference [17] in the literature review introduced the most common and influential factors on facility location decision as Labor and other production inputs; political stability; host government attitudes toward foreign investment; host government tax and trade policies; proximity to major markets; access to transportation; and existence of other competitors. They formulated the problem of global facility location using 0-1 mixed integer programming. It concluded that it is prudent for manufacturers to consider their facility location decisions in conjunction with marketing and manufacturing strategies.

Reference [5] employed Delphi study and analysed the existing literature to identify the most significant attributes in manufacturing site selection. It cited costs, infrastructure, labor characteristics, government and political factors, and economic factors as the most influential ones for manufacturing global facility location.

In more recent publications environmental impacts and sustainability factors are more paramount. Reference [18] has considered the impact of sustainability on global facility location selection decisions. That study based on the current literature demonstrates the significance of sustainability attributes in the selection of a global manufacturing site for contemporary corporations.

B. Existing Approaches to manufacturing site selection problem

The identification of the most relevant attributes is the first step in finding a solution to the manufacturing facility location selection problem. The second step involves the development of a methodology for effective use of these attributes in the decision making process in order to find a practical and useful solution to the problem. Prior to the introduction of our methodology, a brief survey of the literature on existing solutions to the problem is presented here.

Reference [19] proposed a 2-stage computer based model using goal programming (GP) software. In the first stage a suitable country is determined. Countries' Optimal Performance Factors (OPFs) are selected and weighted for each country, then trade-off information about each is entered in GP model to determine which country provides the best circumstance for global expansion. In the second stage the best available facility site in that country is selected. In a case study for the selection of a production facility for a US brewery, twenty potential European countries are evaluated based on thirteen criteria to determine which site should be chosen.

Reference [20] used fuzzy TOPSIS approach to determine the best solid waste transhipment site. They also employed fuzzy AHP for determining weighting factors. They applied TOPSIS approach on ISTAC Company in Istanbul to find the best location for solid waste among five candidate sites by using three defined objectives and fuzzy linguistic variables.

Reference [21] combined Geographical Information System (GIS) analysis and Fuzzy AHP for hospital site selection problems to develop a well distributed network of hospitals. Travel time, distance from arterial routes, population density, land cost, and air pollution are factors used in the decision making matrix.

Reference [22] employed a systematic method to measure the impact of state environmental regulations on manufacturing plant location. He considered six environmental regulatory measures as well as eleven independent variables and incorporated them in a conditional logic model of plant location choice to show that the differences in environmental regulation do not considerably affect decision making on the location of manufacturing plants.

Reference [23] studied the purchase of industrial real estates by small to medium enterprises using a three stage methodology. In the first stage, discussion guide is prepared based on literature review. In the second stage telephone survey is done based on the sample of 450 firms. In the final stage an expert panel is formed to evaluate the result from survey and its implications.

Reference [24] applied a combination of decision tree and multi-attribute utility theory in three phases to select a country for the purpose of manufacturing facility location. In the first phase it determined location factors as well as uncertainties and relationship among them. In the second phase it used decision tree to reach cumulative risk profile to feed MAUT software to weight the factors and evaluate alternative countries. Finally, it used a hypothetical auto supply company for evaluating potential plant location sites in five countries.

Reference [25] developed 14 dimensions based on literature search and psychometric principles to generate two hundred and five critical industrial locations factors. This methodology is a useful tool which can be employed by foreign investors to evaluate these critical factors for industrial location selection decision making.

Reference [26] reviewed the United Nations Development Program country classification system, World Bank country classification system and IMF country classification system which are based on countries' development level. As an alternative to these systems it proposed a new method of developing the classification system. Reference [27] applied combination of fuzzy AHP and TOPSIS using nineteen factors affecting facility location selection based on strategic objectives in producing rattan material walking support/serving trolley project. it normalized the data for each factor and then applied FAHP to weight them. Then it employed TOPSIS method to rank countries and find the best location.

More recently cluster analysis has been proposed as an approach to the problem of manufacturing facility location selection. Reference [28] as a master's thesis applied average linkage clustering method to classify facility sites based on several site selection factors. It demonstrated the model by a numerical example using generated data. Also

Reference [29] has used clustering approach to the problem of manufacturing site selection for the United States. These studies, although limited in scope, indicate that cluster analysis can be used as an effective tool to help manufacturing corporations in the decision making regarding the selection of a suitable site for their manufacturing facilities.

In the following section a new approach to the problem of manufacturing facility location selection based on cluster analysis is presented. In this approach some of the most important attributes impacting manufacturing site selection decisions which have been frequently cited in the literature are chosen for the analysis. The selection of attributes and the way they are weighted can be used to customize the model to specific industries or particular needs. To deal with the qualitative nature of these attributes we chose economic, business, social, political, and environmental metrics which best represent these attributes. Also we use numerical data from well-known global sources to quantify the attributes. Furthermore the data from the existing sources including World Bank, United Nations, World Economic Forum, and other agencies are used for the comparison of countries for their suitability for manufacturing operations. Finally, clustering algorithms are employed to classify countries according to the attributes impacting manufacturing site selection decisions. This approach provides a flexible, quantitative, and customized framework to help in decision making regarding manufacturing site selection.

III. METHODOLOGY

Finding the best generic solution to the problem of manufacturing facility location selection may not be practical due to the complexity of the problem and the dynamic nature of political, social, environmental as well as manufacturing systems. This is true because the best solution is different for each industry and even in the same industries, the best solution may vary according to the firms' vision and competitive strategies. Thus, the selection of the best solution for the manufacturing site selection problems is not a realistic goal, unless special circumstances of the company, industry, and products are determined first. For this reason we employ clustering approach to the problem. The formulation of the problem as a clustering problem provides several advantages as follows.

1) Cluster analysis is suitable for data mining on a large volume of data and this is very important in the decision making regarding manufacturing site selection.

2) The flexibility of having a frame work based on a number of alternative sites which can be further evaluated using more specific considerations for an individual corporation is another advantage of the proposed model.

3) The utilization of widely used international metrics for quantification of economic, business, social, political, and environmental factors greatly facilitate the evaluation process and significantly improve the effectiveness of the solution to the site selection problem. Use of indices such as gross national products-GDP, human development index-HDI, global competitiveness index-GPI in conjunction with worldwide data bases of World Bank, United Nations and other agencies are crucial to real world applications of manufacturing site selection solutions.

4) The ability to expand or limit the number of potential sites, based on the selection of a threshold value of the similarity level or Euclidean distance in the clustering algorithm, is another flexibility inherit in the proposed model.

5) The proper choice of site selection factors and fine tuning of their importance coefficients allow the analyst to customize the solution to specific situations.

For these reasons, the proposed methodology offers a flexible, quantitative, and customized framework for the formulation of, data analysis for, and decision making about the problem of manufacturing site selection.

To identify groups of countries with common characteristics for manufacturing operations the following steps are followed.

1) Countries and manufacturing site selection attributes are organized in an object-attribute matrix.

2) Manufacturing site selection attributes are quantified using the widely popular economic, business, social, political and environmental indices.

3) Euclidean distance value is used to calculate a measure of similarity/dissimilarity among countries based on their manufacturing site selection factors.

4) A clustering algorithm will be employed to identify groups of countries based on their common characteristics.

Among the two types hierarchical clustering algorithms (agglomerative and divisive), the agglomerative clustering algorithms are more promising for the data analysis for our proposed method. Agglomerative methods include single linkage, average linkage and complete linkage clustering which evaluate all pair-wise distances between groups to generate clusters and sub clusters [27]. To avoid the chaining problem of single linkage clustering and extra calculation burden of average linkage clustering, we chose complete linkage clustering [30] in conjunction with Euclidean distance coefficient to carry out cluster analysis. To illustrate the clusters and sub-clusters graphically and demonstrate the exercise of choices based on the threshold value of the Euclidean distances we use dendograms [31].

In this study one hundred countries are considered for analysis. To avoid arbitrary selection of countries, a combination of market size, GDP per capita, quality of life factors etc. has been used to choose the top 100 countries. To classify these countries according to their manufacturing site selection factors, thirty-four global factors which are frequently cited in the literature for their importance in manufacturing site selection decisions are chosen. These factors, also, can be quantified with relative ease using major economic, business, social, political, and environmental metrics. Numerical values for these metrics are obtained from main worldwide data sources including: World Bank data base. (“http://data.worldbank.org/”,“www3.weforum.org”, “http://data.uis.unesco.org/”,“http://www.ssfindex.com/”,“http://www.tradingeconomics.com/”,“http://www.bls.gov/fls/”,“http://www.worldeconomics.com/”,“http://knoema.com/atlas/”,“http://www.compareallcountries.com”,“http://www.oecdilibrary.org”,“http://europa.eu/about-eu/facts figures/economy/index”).

The raw data are then normalized to reflect a common scale. Factors are, also, weighted to represent the real world applications. Consequently, countries are clustered based on real data, normalized values, and weighted factors by employing complete linkage clustering in conjunction with Euclidean distance coefficient .A more detailed description of steps in the clustering of countries according to manufacturing location factors is summarized in the following sections.

A. *Decision-making factors*

According to previous studies on manufacturing site selection problems in literature, there are a large number of economic, social, environmental, political factors which significantly influence the decision about manufacturing site selection. Sixty three such factors are illustrated in Table I. Furthermore we narrow down the number of factors to thirty four based on the followings.

1) Factors which have been widely discussed and frequently cited in the literature.

2) The most distinct factors which best represent the most important characteristics crucial to effectiveness and efficiency of manufacturing operations.

3) Factors which can be quantified with relative ease by using widely popular economic, business, social, political, and environmental metrics in conjunction with used with accessible data sources such as World Bank, United Nations, World Economic Forum. The results of the final selection are presented in Table II.

B. *Data Collection and Analysis*

The World Bank database is the main source for numerical values of metrics employed to quantify site selection factors. Some other international surveys and databases are also used to complement the main data as become necessary. To have a common scale for a wide range of data used in the analysis, feature scaling method is used as shown in “(1)” below.

$$X' = (X - X_{min})/(X_{max} - X_{min}) \qquad (1)$$

It is obvious that not all factors are of the same importance in facility location decisions. For this reason, weighting factors are used to account for the degree of importance of each manufacturing location factor.

C. *Clustering Methods*

In this paper complete linkage clustering in conjunction with Euclidean distance coefficient is employed to identify groups of countries with similar potentials for manufacturing site selection [4]. Matlab software is used to carry out the calculations and to obtain clustering results.

“Equation (2)” shows Euclidean Distance:

$$\|a - b\|_2 = \sqrt{\textstyle\sum_i (ai - bi)^2} \qquad (2)$$

Maximum or complete linkage between two sets of observations A and B is shown in “(3)”.

$$\text{Max}\,\{d(a,b) : a \in A,\, b \in B\} \qquad (3)$$

The countries are categorized based on the attributes that impacts manufacturing operations. Using the complete linkage clustering method assure that all countries in each group are at least as similar as the similarity reflected in the threshold value used for the selection of clusters [1]. Also each category shows which factors are playing pivotal role in the inclusion of countries into a particular cluster. This help the decision makers to better incorporate their preferences in the selection process.

IV. ANALYSIS OF RESULTS

The dendogram "*Fig. I*" illustrates how all 100 countries come together at different threshold values of Euclidean coefficients to form clusters of countries with similar characteristic for manufacturing operations. The selection of the threshold value enables the decision makers to fine tune the solutions to their preferences. In order to generate a classification results which can be more easily analysed we impose a limit of 10 on the number of clusters to be formed. This leads to the dendrogram "*Fig. 2*" which illustrates 10 distinct groups. This dendrogram also illustrates that how one can merge these clusters to fewer groups by lowering the threshold value of the level of similarity among joining members. For example, clusters 2 and 9 are the closest groups in terms of common manufacturing site selection factors. This is useful for decision makers who want to explore and expand their alternatives for further analysis.

The results of classification of countries from the dendogram in "*Fig 1*" are presented in Table III. Furthermore, we have determined the relative contribution of each factor to the inclusion of a country in a particular cluster. The results for four different groups of countries are summarized in Table IV.

Table4 shows the percentage of each factor for group 4, 8, 9 and 10 among all ten groups. So manufacturers by referring to this table can find out the best suitable group of countries in terms of their needs. For example, group 8 (China and India) includes countries with large labor forces and low wage rates. Group 4, 9, and 10 represent Argentina, United States, and Venezuela, respectively. Manufacturers can easily justify the United States because of the high market capitalization and GDP factors compare to other countries. Argentina has the highest tax rate between all countries. Venezuela has the highest inflation, the least property right, the lowest regulatory quality, and one of the worst records for rule of law.

TABLE I. MAJOR GLOBAL FACTORS FOR SITE SELECTION PROBLEM

Economic Factors	Quality of life	Infrastructure	Labor characteristics	Business and industrial Factors	Market characteristics (Location)	Environmental Factor
Cost of business start-up procedures	Health Expenditure per capita ($)	Transport infrastructure	Labor Force	Foreign direct investment	Lead-time to import	Sustainability
GDP	Internet users	On-the-job training	Unemployment	start-up procedures	Market capitalization	space for expansion
GDP Per Capita	Safety	Research and Development	Wage rate	Time required to start a business	Market Size	Climate condition
Inflation	Quality of education	Services	Labor attitude	Business Sophistication	Number of trademark applications	
Lending Interest rate	Happiness	Robustness	Labor Knowledge	host incentive	Area reputation	
Tax rate	Insurance law	Reliability	Union flexibility	industrilisation	Accessibility	
property rights	Availablity of utilities	Availability of fuels	Motivation	Access to raw material		
Accountability	Quality and reliability of utilities			Quality and reliability of suppliers		
Site cost	Attitude toward business			Proximity to parent company		
Energy Cost						
Transportation cost						
Currency strength vs. US dollar						

TABLE II. SELECTED GLOBAL FACTORS FOR CLUSTERING THE COUNTRIES

Economic Factors	Quality of life	Infrastructure	Labor characteristics	Business Factors	Market characteristics (Location)	Environmental Factor	Political factors
Cost of business start-up procedures	Health Expenditure per capita ($)	Transport infrastructure	Labor Force	Foreign direct investment	Lead-time to import	Sustainability	Political Stability and Absence of Violence/Terrorism
GDP	Internet users	On-the-job training	Unemployment	start-up procedures	Market capitalization		Government Effectiveness
GDP Per Capita	Safety	Research and Development	Wage rate	Time required to start a business	Market Size		Regulatory Quality
Inflation	Quality of education	Services		Business Sophistication	Number of trademark applications		Rule of Law
Lending Interest rate							Control of Corruption
Tax rate							Voice and Accountability
property rights							
Accountability							

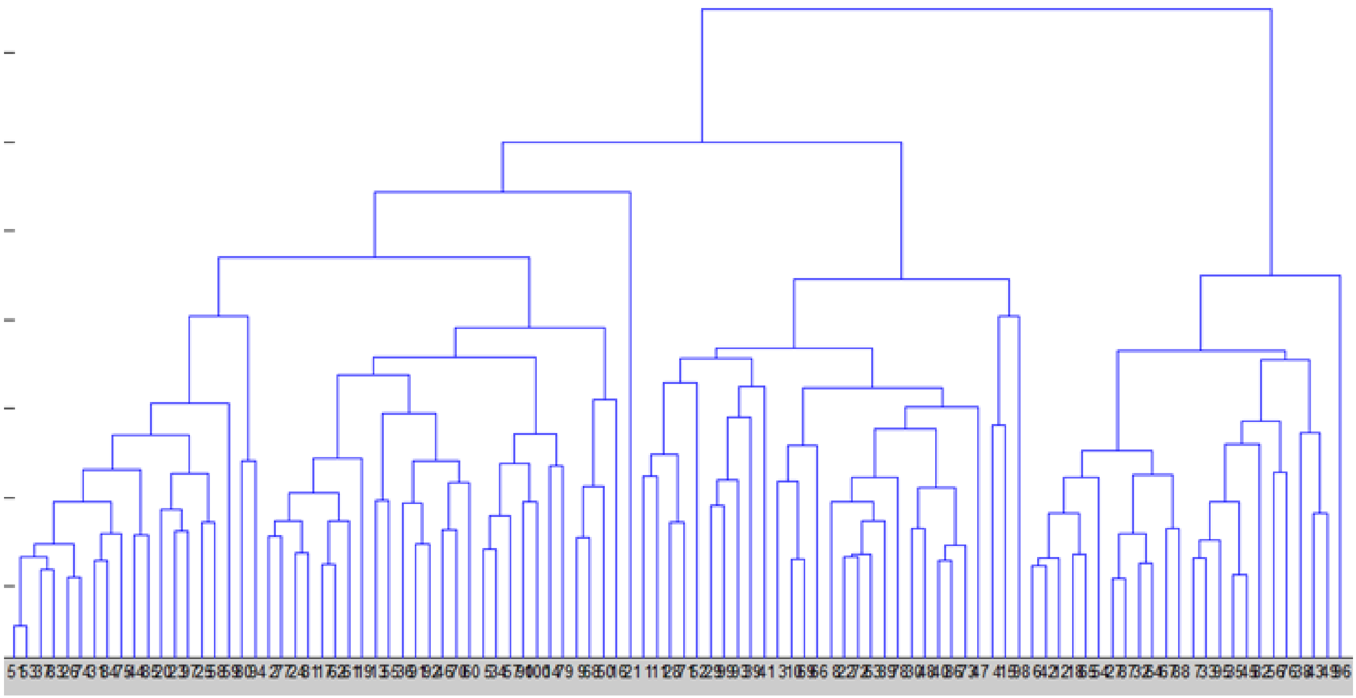

Fig. 1. *Dendrogram based on complete linkage clustering method with Euclidean distance coefficient*

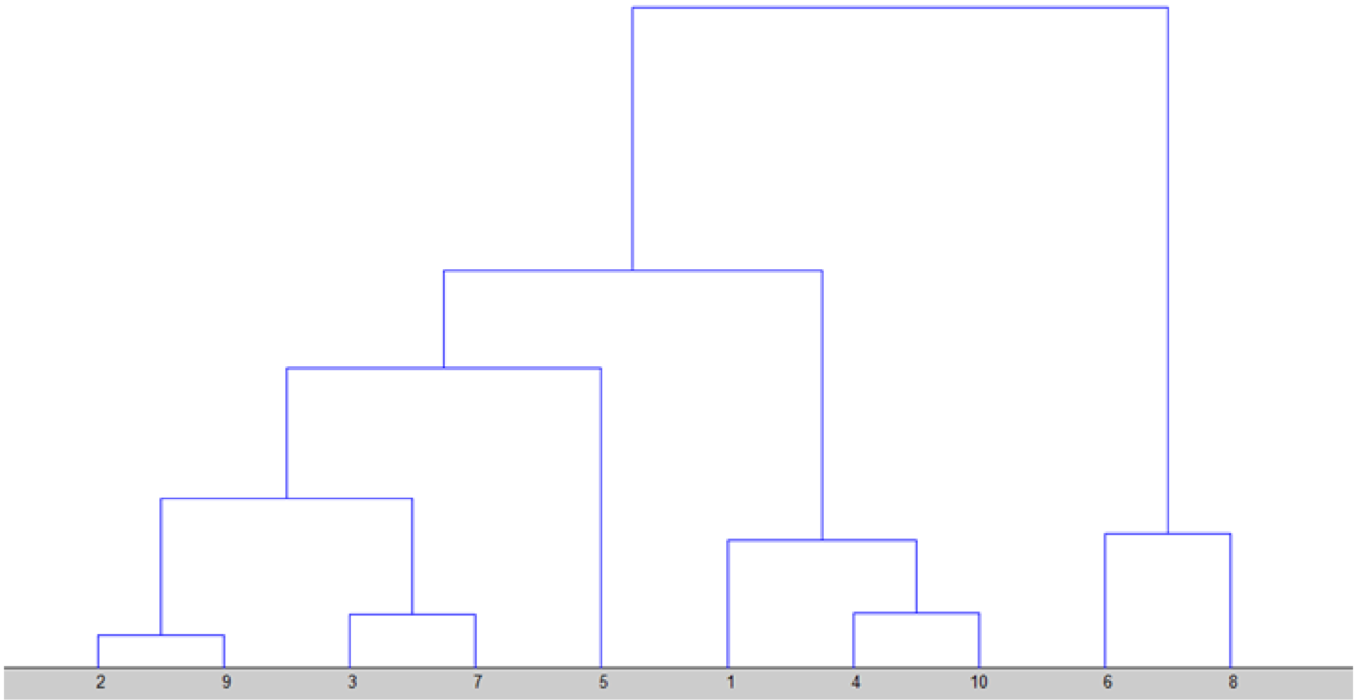

Fig. II. *Dendrogram based on Hieratical clustering is Complete Linkage with Euclidean coefficient in ten groups*

TABLE III. RESULTS OF CLUSTERS (COUNTRIES HAVE CLUSTERED IN TEN GROUPS)

GroupNo.	CountryName	GroupNo.	CountryName	GroupNo.	CountryName	GroupNo.	CountryName
1	Afghanistan	2	Samoa	3	Vietnam	6	Latvia
1	Balarus	2	Uruguay	4	Argentina	6	Lithuania
1	Botswana	3	Algeria	5	Brazil	6	Luxembourg
1	Ecuador	3	Azerbaijan	5	Costa Rica	6	Malta
1	Lebanon	3	Bangladesh	5	Czech Republic	6	Netherland
1	Maldives	3	Cape Verde	5	France	6	New Zealand
1	Trinidad and Tobago	3	Colombia	5	Greece	6	Norway
1	Zambia	3	Egypt	5	Hungary	6	Qatar
2	Albania	3	El Salvador	5	Italy	6	Singapore
2	Armenia	3	Indonesia	5	Mauritius	6	Slovenia
2	Bahrain	3	Iran, Islamic Rep.	5	Portugal	6	Sweden
2	Bosnia and Herzegovina	3	Kenya	5	Slovak Republic	6	Switzerland
2	Brunei Darussalam	3	Mexico	5	Spain	6	United Kingdom
2	Bulgaria	3	Morocco	5	Tunisia	7	Chile
2	Croatia	3	Nigeria	6	Australia	7	Israel
2	Cyprus	3	Pakistan	6	Austria	7	Korea, Rep.
2	Georgia	3	Paraguay	6	Belgium	7	Malaysia
2	Jordan	3	Peru	6	Canada	7	Poland
2	Kazakhstan	3	Philippines	6	Denmark	7	Saudi Arabia
2	Kuwait	3	Romania	6	Estonia	7	Turkey
2	Macedonia, FYR	3	Russian Federation	6	Finland	7	United Arab Emirates
2	Moldova	3	Serbia	6	Germany	8	China
2	Montenegro	3	Sri Lanka	6	Iceland	8	India
2	Oman	3	Thailand	6	Ireland	9	United State
2	Panama	3	Ukraine	6	Japan	10	Venezuela

TABLE IV. COMPARISON OF THE IMPACTS OF FACTORS FOR FOUR GROUPS

Group Number	Market Size	property rights	Health Expenditure per capita	Accountability	Transport infrastructure	Quality of education	On-the-job training	Business sophistication	Cost of business start-up procedures	Foreign direct investment	GDP	GDP Per Capita
4	0.11216976	0.03497576	0.05316474	0.04619493	0.04439927	0.08426021	0.08057337	0.0572934	0.09650843	0.032250659	0.023497664	0.0711263
8	0.17199364	0.11504803	0.00928597	0.08719905	0.14271216	0.10215892	0.0996524	0.10897481	0.1109513	0.343067905	0.213720573	0.01755095
9	0.18321061	0.15432354	0.4650129	0.20240628	0.20559478	0.14861603	0.19261103	0.22348105	0.11988418	0.426773162	0.645998731	0.26499406
10	0.09721379	0	0.02372515	0.00546259	0	0.05125564	0.01892535	0	0.03856998	0.026614859	0.016827009	0.06938145

Group Number	Inflation	Internet users	Labor Force	Lead-time to import	Lending Interest rate	Market capitalization	Research and Development	Services	start-up procedures	Time required to start a business	Tax rate	Number of trademark applications
4	0.06304106	0.10494812	0.02077259	0.09117204	0.05738083	0.00149683	0.06173609	0.11748987	0.03565462	0.104234938	0	0
8	0.10762469	0.04771252	0.70258546	0.10457969	0.10779325	0.10884307	0.13263998	0.0733018	0.06596105	0.099942911	0.088184299	0.50519337
9	0.1244798	0.15217477	0.17524057	0.10726122	0.13521414	0.81924241	0.26517738	0.16659242	0.1307336	0.121227861	0.111196655	0.28482807
10	0	0.0952307	0.01525452	0.09832279	0.06439124	0.00110453	0	0.04079814	0	0	0.085389517	0.07112747

Group Number	Unemployment	Wage rate	Safety	Sustainability	Voice and Accountability	Political Stability and Absence of Violence/Terrorism	Government Effectiveness	Regulatory Quality	Rule of Law	Control of Corruption		
4	0.10528328	0.13452966	0	0.0529862	0.1079377	0.1059901	0.06785638	0.0378483	0.05739466	0.06452608		
8	0.11966019	0.00336324	0.14494596	0.15267595	0.06501795	0.06899546	0.07861514	0.07253022	0.08202323	0.064671113		
9	0.10130197	0.16968096	0.11545479	0.13064883	0.15188929	0.12788933	0.17461934	0.16794692	0.18032999	0.180727742		
10	0.10262907	0.09417077	0.08282626	0.12111132	0.04563108	0.06059265	0.01743554	0	0	0.010087844		

In addition to primary factors which have been studied in this research, there are categories of secondary factors that can be added to the analysis. For instance the proximity of suppliers and market to the facility location, or the price of raw material required for the industry in each country is a secondary factor. Taking advantage of the flexibility of clustering, the decision makers can first find the appropriate pool of countries and then, they can add the secondary factors for these countries for further customization of the solution to their specific requirements. The procedure for finding the best country or countries to locate facilities can be described in the flowchart "*Fig 3*".

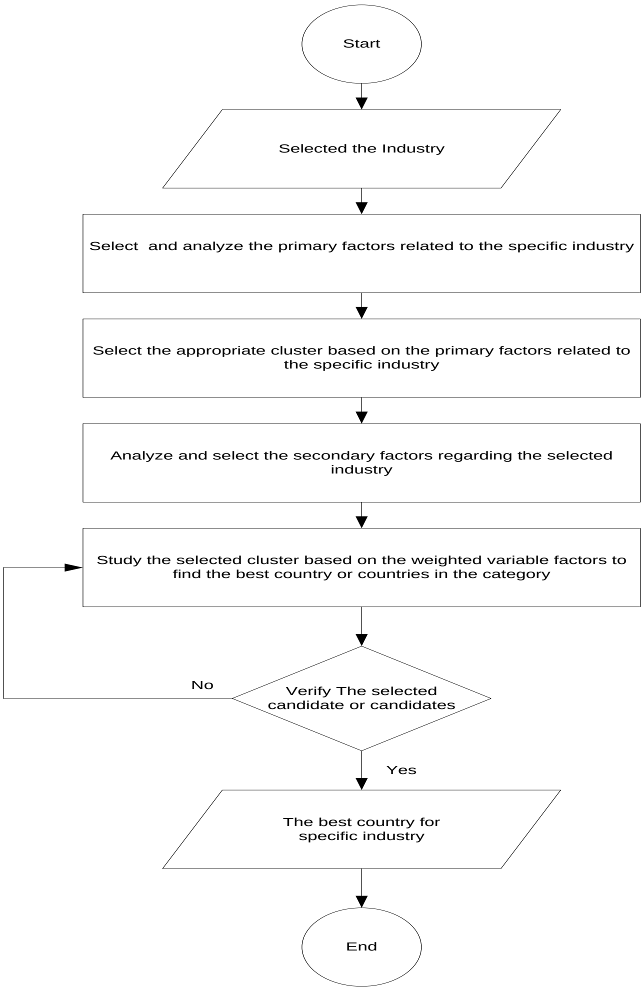

Fig. III. *Flowchart to find the best country or countries to locate facilities*

V. CONCLUSION

This paper presents a flexible and quantitative approach to manufacturing facility location problem. The manufacturing site selection factors are quantified using existing real world data. In this approach cluster analysis is employed to identify suitable manufacturing locations based on a wide range of economic, social, political, and environmental factors. The clusters of countries demonstrate the group of countries with similar potentials for manufacturing facility locations. This approach provides a framework which facilitates the decision making regarding manufacturing facility location selection.

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