

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/282397159>

Plant location selection of a manufacturing industry using analytic hierarchy process approach

Article in *International Journal of Services and Operations Management* · January 2015

DOI: 10.1504/IJSOM.2015.071531

CITATIONS

10

READS

4,257

2 authors:



Suman Gothwal

Ajay Kumar Garg Engineering College

8 PUBLICATIONS 43 CITATIONS

[SEE PROFILE](#)



Rajeev Saha

J.C. Bose University of Science and Technology, YMCA, Faridabad

18 PUBLICATIONS 54 CITATIONS

[SEE PROFILE](#)

Plant location selection of a manufacturing industry using analytic hierarchy process approach

Suman Gothwal* and Rajeev Saha

Department of Mechanical Engineering,
YMCA University of Science and Technology
Faridabad 121006, India
Email: suman_gothwal84@yahoo.com
Email: rajeevsaha@gmail.com
*Corresponding author

Abstract: Selection of plant location is a multi-person and multi-criteria decision problem. Location selection is a strategic decision that cannot be changed overnight. Even if the location decision is changed at all, a considerable loss is bound to be incurred. Without sound location planning in the beginning, the new facility may pose continuous operating disadvantages for the future operations. In this paper, analytic hierarchy process (AHP) approach is used to arrive at consensus decision. The AHP model is formulated and applied to a real case study to examine its feasibility in selecting the plant location for a manufacturing industry. Different factors were identified affecting the plant location on the five locations (Delhi, Manesar, Chandigarh, Mumbai and Baddi) suggested by a particular manufacturing industry and then AHP technique was implemented to select the best location out of these five locations. After analysis, Baddi is found to be the best location to setup their new plant. AHP is a powerful and flexible tool for tackling the complex decision problem into a simple concept of hierarchy, which incorporates both financial and non-financial factors influencing the decision alternatives in a systematic way.

Keywords: analytic hierarchy process; AHP; criteria for plant location; manufacturing industry.

Reference to this paper should be made as follows: Gothwal, S. and Saha, R. (2015) 'Plant location selection of a manufacturing industry using analytic hierarchy process approach', *Int. J. Services and Operations Management*, Vol. 22, No. 2, pp.235–255.

Biographical notes: Suman Gothwal had worked as an Assistant Professor in the Department of Mechanical Engineering, Faculty of Engineering and Technology (FET), Manav Rachna International University (MRIU), Faridabad, India. She passed her BE Mechanical from Netaji Subhas Institute of Technology (NSIT), Delhi in Manufacturing Process and Automation Engineering (MPAE), MTech in Manufacturing Process and Automation from YMCA University of Science and Technology, Faridabad and pursuing PhD research from the same university (YMCA). Her areas of interest are manufacturing technology and automation.

Rajeev Saha is working as an Assistant Professor in Mechanical Engineering Department in YMCA University of Science and Technology, Faridabad, India for last five years. He received his Bachelor's in Engineering, Master's in Technology and PhD in the field of Quality. He has about ten years of industrial experience in various capacities.

1 Introduction

In modern business environment, every entrepreneur is faced with the problem of deciding the best site for location of his plant or factory because of its complex nature. The objective of any entrepreneur is to locate the business organisation at such a place where it is convenient to run the operations and the total costs are minimised (Sharma, 2004). Babu and Krishna (2013) discussed the plant as well as facility location problem to run the operations efficiently. However, a location selection decision depends on a variety of factors so it is considered as a multiple criteria decision-making (MCDM) problem by nature (Yang and Lee, 1997). It is a problem associated with the planning phase of a factory or even a service sector. Based on the goals the projected production needs of the firm strongly influence the actual location search, i.e., entry into new markets, maintenance of market share, product diversification, and new production processes (Dicken and Lloyd, 1990). The sites where an acceptable level of sales is essentially guaranteed will be preferred by the firms (Richardson, 1979; Weber, 1972). Thunen utilised the 'least-cost' approach for location selection and developed the general framework for the economic analysis of location theory (Thunen, 1875; Isard, 1956). Launhardt used the cost variation and demand factors at alternative locations to explain the differences in the location of industry (Launhardt, 1885; Miller, 1977). He demonstrated the importance of transportation costs. Weber (1909) developed a comprehensive theory for the location of manufacturing activities (Weber, 1929; Isard, 1956). He considered three factors: transportation costs, labour costs, and agglomeration forces. For better understanding the decision-making process, the Weberian theory is used in many location studies (Tellier and Vertefeuille, 1995). Roudsari and Wong (2014) considered two factors: proximity to customer locations and number of competitors near the new location in their research work to explain the differences in location of plant. Anand et al. (2012) used analytic network process to explain location decision-making process using 40 factors. It is a very vital decision which has long-term implications. No plant can be located at a place, which fulfils all the criteria of perfect location. The efforts should be to avail maximum benefits (Sharma, 2004). Some factors compromised to take advantage of the other factors. For example, if the raw material is quite bulky and it is difficult to transport, then the plant may be located nearer to raw material source. The need of the selection of plant location then generally arises in following conditions:

- 1 when the business is newly started
- 2 the existing business unit has outgrown its original facilities and expansion is not possible; hence a new location has to be found
- 3 the volume of business or the extent of market necessitates the establishment of branches
- 4 a lease expires and the landlord does not renew the lease
- 5 other social, economic, legal or political factors; for instance, inadequate labour supply, shifting of the market, etc.
- 6 introduction of the new product or the services also require the establishment of new location

- 7 change in technology may necessitate the closer of the existing facility and establishment of new one which may not be located at the earlier site.

A bad location is a severe handicap for any enterprise and it finally bankrupts it. Once a mistake is made in locating a plant it becomes extremely difficult and costly to correct it, especially where large plants are concerned, therefore, it is very essential that utmost care should be taken in the initial stages of the location selection process. Poor location leads to higher cost, difficult marketing, difficult transportation, dissatisfaction among employees and substandard quality.

There are various factors which affect the plant location, including both qualitative and quantitative factors like political, economic, environmental and facility criteria. Thus, there is a need for developing a systematic plant location selection process of identifying and prioritising relevant criteria and evaluating the trade-offs between all these criteria. The approach should also reduce the time in selection and develop consensus decision-making. Narasimhan (1983), Nydick and Hill (1992), and Partovi et al. (1989) suggested the use of the analytic hierarchy process (AHP) because of its inherent capability to handle the qualitative and quantitative factors. Prasanna Venkatesan and Kumanan (2012), Jahromi et al. (2012), and Sunil Kumar and Subash Babu (2011) also used the AHP in their research work for the decision-making process in various fields. AHP is easy to understand and can improve the decision-making process. It decomposes the complex decision-making problem into a simple hierarchy consists of different levels, showing the problem systematically in terms of criteria and sub-criteria. This hierarchy is called AHP model. Using this model, the pairwise comparison of the criteria and sub-criteria is done and their priority weights are found. Based on this information several plant locations can be compared effectively and the best location is selected.

The purpose of this paper is to identify and analyse these criteria and sub-criteria for the selection of a plant location, a total of 33 criteria have been identified through literature and questionnaire-based survey and opinions of experts both from industry and academia. In order to find out the criteria and sub-criteria, a survey of 40 industries was conducted. The purpose of this survey was only to find the criteria and sub-criteria used to formulate the AHP model.

2 Identifying the criteria and sub-criteria

Better access to finance and to land and greater availability of infrastructure attract firms to a city. However, firms are also attracted by agglomeration economies from clustering of firms in their own industry. This means that new firms will choose to locate production in areas that are already established centres in their line of business. Several factors are considered in the selection of plant location. These factors have been grouped and discussed by numerous authors and researchers in a variety of ways. Many authors (Roudsari and Wong, 2014; Anand et al., 2012; Greenhut, 1959; Greenhut and Colberg, 1962; Dean, 1972; Nicholas, 1974; Spooner, 1974; Foster, 1977; Brown, 1979; Moriarty, 1980) emphasise the importance of critical demand factors (location of competitors, proximity to consumer markets, etc.), and cost factors (land, labour, materials, transportation, etc.) in their prescriptions for industrial location planning. The literature shows that these critical factors can be identified and analysed by the firm's decision makers in a better way therefore, the location decision-making process will improve and

result in long-term performance for the organisation (Miller and Star, 1967; Weber, 1972; Walker, 1975; Saxenian, 1985).

Five locations (Delhi, Manesar, Chandigarh, Mumbai and Baddi) were selected by a particular manufacturing industry to setup their new plant. Some reasons for selecting these locations are: Delhi's large consumer market and its abundance of skilled labour has attracted foreign investments to Delhi. Delhi has a workforce of approximately 33%, the unemployment rate in Delhi is one of the lowest in the country-about 5%. The presences of a considerable consumer market along with a large pool of skilled labour have helped Delhi in its industrialisation. Manesar is a fast growing industrial town and is listed amid top prospective investment locations in India. Manesar is an integrated and independent industrial town having all the basic infrastructure to facilitate industrialisation of the area. Today, it is swamped by people from all across the globe, indulging in almost every profession one can think of in the modern India. Mumbai has a large unskilled and semi-skilled labour population. Moreover, with limited space available in the central city, Mumbai's boundaries are constantly extending into newer areas. Mumbai is one of world's top 10 centres of commerce in terms of global financial flow. As Mumbai is the state capital, government employees make up a large percentage of the city's workforce. The major factor responsible for the growth of industry in Chandigarh is availability of infrastructure at one place. Its better living conditions have added impetus to its growth. In the small scale, there are more than 1,300 units in Mohali (town of Chandigarh) employing over 25,000 workers. These units manufacture a wide range of products which include railway components, auto parts, tractor parts, sanitary fittings, furniture items. PVC pipes, chemicals, corrugated boxes, rubber and silicon material, precision parts, industrial gases, engineering items, etc. Baddi is an industrial town. The major attractions for investors included 100% outright excise duty exemption for a period of ten years from the date of commencement of commercial production (the past budget stipulated it to industries starting on or before 31 March 2010), 100% income tax exemption for an initial period of five years and thereafter 30% for companies for a further period of five years, capital investment subsidy of 15% on plant and machinery subject to a ceiling of Rs 30 lakhs, applicable also to existing units. The area has adequate power, a rarity in India, peaceful industrial climate and is close to the rich hinterland of Delhi, Chandigarh and Amritsar.

Based on the literature review and discussion with the experts both from industry and academia, 33 different criteria affecting these locations were identified to form the survey questionnaire. All these criteria grouped into four major categories of political, economic, environmental and facilities success criteria. A survey of 40 members selected randomly from different functional areas of the manufacturing industry was conducted. The number of participants of each city are shown in Table 1. The purpose of the survey was to identify the political, economic, and environmental and facility factors as the criteria and sub-criteria. After determining the criteria and sub-criteria, AHP was implemented because of its inherent capability to handle the qualitative and quantitative criteria's. Many authors (Carnero, 2014; Mahapatara et al., 2013; Mehrmanesh et al., 2013; Jahromi et al., 2012; Shakib and Fazli, 2012; Prasanna Venkatesan and Kumanan, 2012; Desai et al., 2012; Sunil Kumar and Subash Babu, 2011) utilised AHP technique in their research work for the decision-making process because it decomposes the decision problem into a hierarchy of more easily comprehended sub-problems in a systematic way each of which can be analysed independently in a systematic way. The result of this survey is shown in Figure 1, where the mean value of each factor is determined by

multiplying the percentages of members with the values of 1, 2, 3, 4 and 5 which are associated with ‘least important’, ‘important’, ‘important and necessary’, ‘highly important’, ‘most important’ respectively and adding the resulting product. The criteria are then arranged in descending order of their mean value. The cut off is then calculated by using the formula:

$$\text{Cut off value} = \{(\text{maximum mean} - \text{minimum mean}) / 4\} + \text{minimum mean}$$

Cut off value comes out to be 3.13, it identify those factors as the relevant factors whose mean value is greater than or equal to 3.13 and these factors are shown in Figure 2. The cut off value reduces the number of criteria to a few because the presence of too many criteria makes the pairwise comparison complex and time consuming process. All criteria and sub-criteria with respect to political, economic, environment and facility are shown with their references in Table 2.

Table 1 Number of participants of each city

<i>Name of the place</i>	<i>Number of industries</i>
New Delhi	6
Ghaziabad	2
Noida	3
Faridabad	2
Gurgoan	2
Manesar	5
Mumbai	5
Pune	3
Punjab	2
Chennai	1
Coimbatore	1
Ahamabad	3
Lucknow	1
Rayagada (Orissa)	1
Hydrabad	1
Karnal	1
Panchkula	1

Table 2 Different criteria and sub-criteria with their references

<i>Factors affecting the plant location</i>	<i>References/source</i>
Political factors:	
Government attitude	Young (1994), McMillan (1965), Rees (1983), Badri (2007)
Tax structure	Moriarty (1980), Young (1994), Greenhut (1956)
Government regulations	Hudson (1983), Ward (1982), Rees (1983)

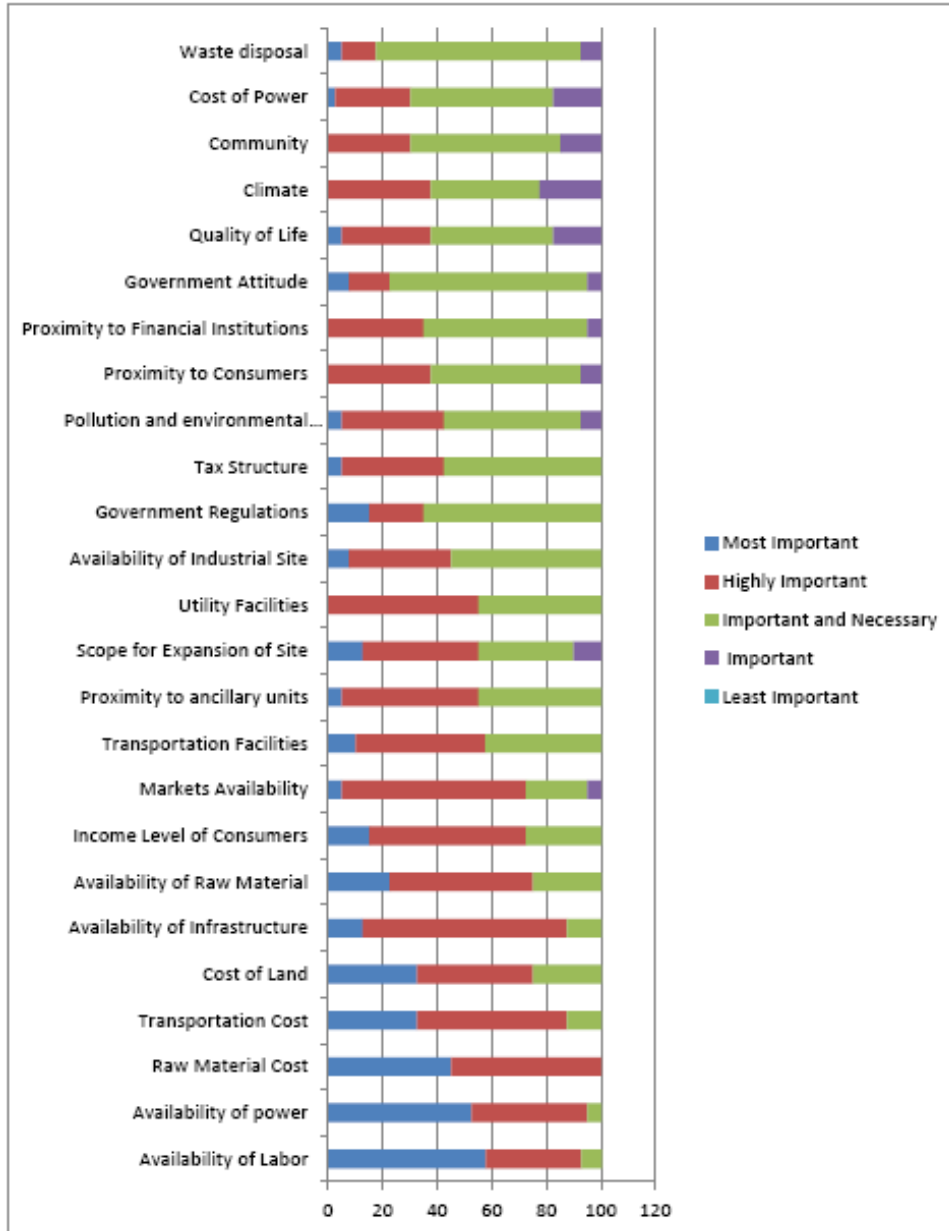
Table 2 Different criteria and sub-criteria with their references

<i>Factors affecting the plant location</i>	<i>References/source</i>
Economic factors:	
Transportation cost	Moriarty (1980), McMillan (1965), Beckmann (1968)
Raw material cost	Schmenner (1982), Moriarty (1980), Pietlock (1992)
Cost of land	Hoover (1948), Greenhut (1956)
Cost of power	Heckman (1978), Moriarty (1980), Gold (1991)
Cost of labour	McMillan (1965), Schmenner (1982)
Income level of consumers	Carnoy (1972), Dicken and Lloyd (1978)
Environmental factors:	
Pollution and environmental constraints	Schmenner (1982), Coughlin et al. (1990)
Waste disposal	Heckman (1978), Moriarty (1980)
Climate	Spooner (1974), Moriarty (1980)
Facilities:	
Availability of labour	Carnoy (1972), Rees (1972, 1983)
Transportation facilities	McMillan (1965), Beckmann (1968)
Availability of professionals	Sharma (2004)
Availability of power	Greenhut (1956), McMillan (1965), Moriarty (1980)
Availability of infrastructure	Sharma (2004)
Availability of raw material	Greenhut (1956, 1981), McMillan (1965)
Availability of markets	Dorward (1979), Moriarty (1980), Schmenner (1982)
Size of existing market	McMillan (1965), Carnoy (1972)
Site selection	Sharma (2004)
Availability of industrial site	Greenhut (1956), Smith (1966, 1981)
Industrial relations	Sharma (2004)
Proximity to financial institutions	Sharma (2004)
Proximity to ancillary units	Schmenner (1982), Coughlin et al. (1990)
Proximity to consumers	Sharma (2004)
Proximity to suppliers	Schmenner (1982), Wheeler and Mody (1992)
Community	Spooner (1974), Moriarty (1980), Rees (1983)
Utility facilities	Walters and Wheeler (1984), Gold (1991)
Scope for expansion of site	Spooner (1974), Schmenner (1982)
Quality of life	Coughlin et al. (1990, 1991), Hudson (1983, 1988)
Global competition	Pietlock (1992), Wheeler and Mody (1992)
Union problems	Greenhut (1956), Dicken and Lloyd (1978)

Figure 1 Chart showing the importance of factors on the basis of rating scale (see online version for colours)



Figure 2 Chart showing the factors which will be used to find out the best location (see online version for colours)



3 The AHP approach

Saaty (1980) developed the AHP technique, it is one of the multi-criteria decision-making approach that decomposes a complex problem into a hierarchical order (Abdi and Labib, 2003). Partovi (1994) found it, an effective and practical approach that can consider complex and unstructured decisions. This method incorporates qualitative and quantitative criteria. AHP is an ideal method for ranking alternatives when multiple criteria and sub-criteria are present in the decision-making process. Based on the decision maker's judgements, AHP offers a methodology to rank alternative courses of action concerning the importance of the criteria and the extent to which they are met by each alternative. These judgements are expressed in terms of pairwise comparisons of items on a given level of the hierarchy with respect to their impact on the next higher level. The relative importance of one item versus another are expressed by the pairwise comparisons in meeting a goal or a criterion. Each of the pairwise comparisons represents an estimate of the ratio of the weights of the two criteria being compared. Because AHP utilises a ratio scale for human judgements, the alternatives weights reflect the relative importance of the criteria in achieving the goal of the hierarchy (Maggie and Tummala, 2001). Some benefits of AHP method:

- 1 The strength of the AHP method lies in its ability to structure a complex, multi-person, multi-attribute, and multi-period problem hierarchically (Saaty, 1980).
- 2 It is simple to use and understand (Chan, 2003).
- 3 It necessitates the construction of a hierarchy of attributes, sub attributes, alternatives and so on, which facilitates communication of the problem and recommend solutions (Yusuff and Poh Yee, 2001).
- 4 It provides a unique means of quantify judgemental consistency (Chan, 2003).
- 5 It does not greatly intuition, experience, and theoretical knowledge of the domain expert as expert system (Yusuff and Poh Yee, 2001).
- 6 It does not require preferential independent of its complement (i.e., the preference order of consequences, for any pair of attributes does not depend on the levels at which all other attributes are hold) as multi-attribute utility model (Chan, 2003).

The research in this paper has focused on formulating an AHP-based model to select a location for a manufacturing plant. The theory of AHP is based on the three principles (Raj et al., 2008):

- decomposition of the decision problem
- comparative judgement of the various elements
- synthesis of priorities.

3.1 *Establishment of a structural hierarchy for the plant location selection problem*

According to Saaty (2000), there is no set of procedures for generating the levels to be included in the hierarchy. The degree of detail and complexity of the problem being analysed determines the number of the levels in a hierarchy (Zahedi, 1986). AHP allows the decision problem to be structured into a hierarchy with the objective or goal of the decision placed at the top level of the hierarchy, then criteria and sub-criteria at the intermediate levels and the decision alternatives at the last level of the hierarchy.

To develop the hierarchy, the goal is placed at the top level of hierarchy. The four strategic factors namely, political, economic, environmental factors and facilities used to achieve this goal, which forms the second level of hierarchy. The third level of the hierarchy consists of different factors defining the four strategic factors of the second level. There are three factors related to political factors, five factors related to economic factors, three factors related to environmental factors and 14 factors related to facilities. The strategic consideration factors and factors (criteria) used in these two levels can be assessed using the pairwise comparisons of elements in each level with respect to every parent element located one level above. The fourth level of the hierarchy consists of the rating scale. Here a five point rating scale of outstanding (O), good (G), average (A), fair (F), poor (P) is used and the priority weights of these five scales can be determined using the pairwise comparisons. These rating scales are used to determine the local and global priority weights. The lowest level of the hierarchy consists of the decision alternatives, i.e., different proposed locations to be evaluated to find out the best location. The AHP model is shown in Figure 3.

3.2 *Measurement and data collection*

In this phase of measurement and data collection, the pairwise comparisons of the strategic consideration factors and criteria (factors) used in the AHP hierarchy is done. Here, the pairwise comparison of all elements in each level of the hierarchy is done. The pairwise comparison judgement matrix for the five point rating scale is shown below in Table 3. After solving the pairwise comparison judgement matrix for each rating scale factor, the priority weights of outstanding, good, average, fair and poor w.r.t alternatives were determined as shown in Table 4.

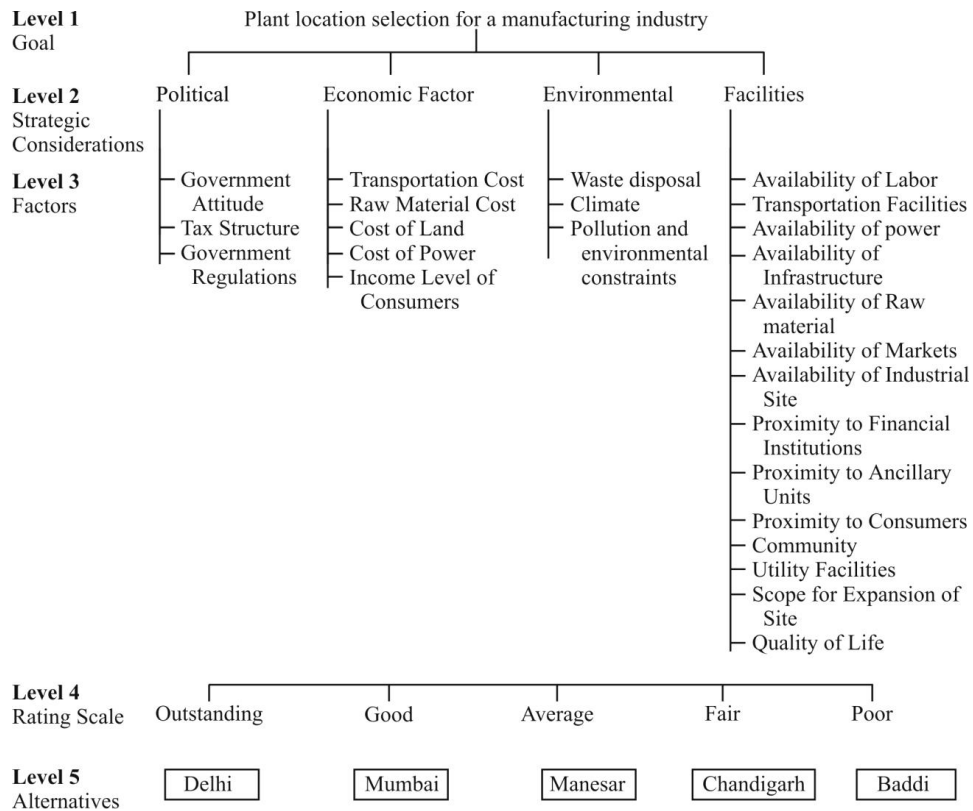
Table 3 Pairwise comparison judgement matrix for five point rating scale

	<i>O</i>	<i>G</i>	<i>A</i>	<i>F</i>	<i>P</i>
<i>O</i>	1	3	5	7	9
<i>G</i>	1/3	1	3	5	7
<i>A</i>	1/5	1/3	1	3	5
<i>F</i>	1/7	1/5	1/3	1	3
<i>P</i>	1/9	1/7	1/5	1/3	1

Table 4 Priority weights of rating scale

Outstanding (O)	0.513
Good (G)	0.261
Average (A)	0.129
Fair (F)	0.063
Poor (P)	0.034

Figure 3 AHP model



3.3 *Pairwise comparison of each factor to determine their local/priority weights*

After structuring the hierarchy, a pairwise comparison is done to evaluate the relative importance of the elements determined at each level in the hierarchy w.r.t. the overall goal of the problem. To do the pairwise comparisons, a scale is used which indicates the importance of one element over another with respect to a higher-level element. A matrix of relative rankings is generated by these pairwise comparisons for each level of the hierarchy. The number of elements at each level determines the number of matrices as shown in Table 5.

Table 5 Pairwise comparison of each factor

Goal	Political	Economic factors	Environmental	Facilities	Priority/local weight
Political	1	1.5	2	1.2	0.339
Economic factors	0.7	1	0.9	0.8	0.201
Environmental	0.5	1.1	1	1.2	0.227
Facilities	0.8	1.3	0.8	1	0.233
<i>Political</i>	<i>Government attitude</i>	<i>Tax structure</i>	<i>Government regulations</i>		<i>Priority/local weight</i>
Government attitude	1	2.5	1.5		0.496
Tax structure	0.4	1	0.9		0.228
Government regulations	0.7	1.1	1		0.276
<i>Economic factors</i>	<i>Transportation cost</i>	<i>Raw material cost</i>	<i>Cost of land</i>	<i>Cost of power</i>	<i>Income level of consumers</i>
Transportation cost	1	0.8	0.8	0.7	1.1
Raw material cost	1.3	1	0.9	1.2	1.3
Cost of land	1.3	1.1	1	1.2	1.3
Cost of power	1.4	0.8	0.8	1	1.2
Income level of consumers	0.9	0.8	0.8	0.8	1
<i>Environmental</i>	<i>Pollution and environmental constraints</i>	<i>Waste disposal</i>	<i>Climate</i>		<i>Priority/local weight</i>
Pollution and environmental constraints	1	1.5	2		0.465
Waste disposal	0.7	1	0.9		0.265
Climate	0.5	1.1	1		0.270

Table 5 Pairwise comparison of each factor (continued)

Facilities	Availability of labour	Availability of raw material	Availability of markets	Availability of power	Availability of infrastructure	Proximity to financial institutions	Proximity to ancillary units	Community	Utility facilities	Transportation facilities	Availability of industrial site	Proximity to consumers	Scope for expansion of site	Quality of life	Priority/local weight
Availability of labour	1	1.5	2	1.2	0.7	0.9	0.8	1.2	0.9	1.2	0.8	1.2	0.9	1.1	0.074
Availability of raw material	0.7	1	1.1	1.1	1.2	1.3	1.1	1.4	1.5	1.3	0.9	1.3	1.2	1.3	0.079
Availability of markets	0.5	0.9	1	1.2	1.4	1.3	0.9	1.2	0.8	0.8	0.7	0.9	1.1	1.2	0.067
Availability of power	0.8	0.9	0.8	1	1.2	1.2	1.1	1.3	1.4	1.2	0.8	1.3	1.4	1.2	0.075
Availability of infrastructure	1.1	0.8	0.8	0.8	1	2	1.2	2.2	2.5	2.1	0.8	1.8	1.5	1.6	0.097
Proximity to financial institutions	1.3	0.9	1.1	0.9	0.5	1	0.7	1.2	1.4	1.5	0.9	0.9	0.8	1.3	0.069
Proximity to ancillary units	0.8	0.7	0.8	0.8	0.8	1.4	1	1.5	2.5	1.8	0.8	1.5	0.9	1.9	0.083
Community	1.1	0.7	1.3	0.7	0.5	0.8	0.7	1	0.8	0.7	0.8	0.7	0.7	1.1	0.055
Utility facilities	0.8	0.8	1.3	0.8	0.4	0.7	0.4	1.3	1	1.2	0.9	1.3	1.2	1.5	0.065
Transportation facilities	0.8	0.8	1.3	0.8	0.5	0.7	0.6	1.4	0.8	1	0.8	1.5	1.2	1.4	0.065
Availability of industrial site	1.3	1.1	1.4	1.3	1.3	1.1	1.3	1.3	1.1	1.3	1	1.8	2	2.5	0.094
Proximity to consumers	0.8	0.8	1.1	0.8	0.6	1.1	0.7	1.4	0.8	0.7	0.6	1	0.9	1.5	0.061
Scope for expansion of site	1.1	0.8	0.9	0.7	0.7	1.3	1.1	1.4	0.8	0.8	0.5	1.1	1	1.3	0.065
Quality of life	0.9	0.8	0.8	0.8	0.6	0.8	0.5	0.9	0.7	0.7	0.4	0.7	0.8	1	0.050

3.4 Determination of global weight of each factor

For determining the global weight of each factor, the local weight of each strategic considerations (political, economic, environmental, and facilities) are multiplied with the local weights of the factors that comes under the corresponding strategic consideration as shown in Table 6.

Table 6 Global weight of each factor

<i>Strategic considerations</i>	<i>Local weights</i>	<i>Factors</i>	<i>Local weights</i>	<i>Global weights (GW)</i>
Political	0.339	Government attitude	0.496	0.168
		Tax structure	0.228	0.077
		Government regulations	0.276	0.094
Economic factors	0.201	Transportation cost	0.173	0.035
		Raw material cost	0.222	0.045
		Cost of land	0.230	0.046
		Cost of power	0.208	0.042
		Income level of consumers	0.168	0.034
Environmental	0.227	Pollution and environmental constraints	0.465	0.106
		Waste disposal	0.265	0.060
		Climate	0.270	0.061
Facilities	0.233	Availability of labour	0.074	0.017
		Availability of raw material	0.079	0.018
		Availability of markets	0.067	0.016
		Availability of power	0.075	0.018
		Availability of infrastructure	0.097	0.023
		Proximity to financial institutions	0.069	0.016
		Proximity to ancillary units	0.083	0.019
		Community	0.055	0.013
		Utility facilities	0.065	0.015
		Transportation facilities	0.065	0.015
		Availability of industrial site	0.094	0.022
		Proximity to consumers	0.061	0.014
		Scope for expansion of site	0.065	0.015
Quality of life	0.050	0.012		

Table 7 Determination of score of each factor

Factors	Delhi		Mumbai		Manesar		Chandigarh		Baddi	
	Rating	X GW	Rating	X GW	Rating	X GW	Rating	X GW	Rating	X GW
Government attitude	G	0.261	G	0.261	G	0.261	G	0.261	G	0.261
Tax structure	G	0.261	A	0.129	G	0.261	A	0.129	G	0.261
Government regulations	A	0.129	A	0.129	A	0.129	F	0.063	G	0.261
Transportation cost	A	0.129	F	0.063	A	0.129	A	0.129	F	0.063
Raw material cost	A	0.129	A	0.129	G	0.261	A	0.129	G	0.261
Cost of land	A	0.129	F	0.063	A	0.129	F	0.063	G	0.261
Cost of power	A	0.129	A	0.129	A	0.129	G	0.261	G	0.261
Income level of consumers	G	0.261	G	0.261	A	0.129	G	0.261	A	0.129
Pollution and environmental constraints	F	0.063	F	0.063	F	0.063	G	0.261	G	0.261
Waste disposal	G	0.261	A	0.129	G	0.261	F	0.063	G	0.261
Climate	F	0.063	F	0.063	F	0.063	G	0.261	G	0.261
Availability of labor	G	0.261	G	0.261	G	0.261	F	0.063	G	0.261
Availability of raw material	A	0.129	A	0.129	G	0.261	A	0.129	G	0.261
Availability of markets	G	0.261	G	0.261	A	0.129	G	0.261	G	0.261

Table 7 Determination of score of each factor (continued)

Factors	Delhi			Mumbai			Manesar			Chandigarh			Baddi		
	Rating	Score	XGW	Rating	Score	XGW	Rating	Score	XGW	Rating	Score	XGW	Rating	Score	XGW
Availability of power	O	0.513	0.009	O	0.513	0.009	G	0.261	0.005	A	0.129	0.002	G	0.261	0.005
Availability of infrastructure	G	0.261	0.006	G	0.261	0.006	A	0.129	0.003	G	0.261	0.006	F	0.063	0.001
Proximity to financial institutions	G	0.261	0.004	G	0.261	0.004	A	0.129	0.002	G	0.261	0.004	A	0.129	0.002
Proximity to ancillary units	A	0.129	0.003	A	0.129	0.003	G	0.261	0.005	A	0.129	0.003	G	0.261	0.005
Community	G	0.261	0.003	O	0.513	0.007	G	0.261	0.003	O	0.513	0.007	F	0.063	0.001
Utility facilities	A	0.129	0.002	A	0.129	0.002	G	0.261	0.004	A	0.129	0.002	A	0.129	0.002
Transportation facilities	G	0.261	0.004	G	0.261	0.004	A	0.129	0.002	G	0.261	0.004	A	0.129	0.002
Availability of industrial site	A	0.129	0.003	A	0.129	0.003	G	0.261	0.006	A	0.129	0.003	G	0.261	0.006
Proximity to consumers	G	0.261	0.004	G	0.261	0.004	A	0.129	0.002	G	0.261	0.004	A	0.129	0.002
Scope for expansion of site	F	0.063	0.001	F	0.063	0.001	G	0.261	0.004	A	0.129	0.002	G	0.261	0.004
Quality of life	G	0.261	0.003	G	0.261	0.003	A	0.129	0.002	G	0.261	0.003	A	0.129	0.002
Total			0.185			0.165			0.183			0.186			0.233
Normalising			0.19			0.17			0.19			0.20			0.24

3.5 Determination of total score achieved by each factor

After obtaining the global weights of each factor, total score achieved by each factor is calculated. To find out the total score, rating (outstanding, good, average, fair, poor) for each factor according to facilities available in a particular location is done. Priority weights of each rating as shown in Table 3, i.e., priority weights for O, G, A, F, P are 0.513, 0.261, 0.129, 0.063 and 0.034, respectively. Global weight of each location is calculated by multiplying the global priority weight of each factor with the priority weight of rating and then adding the resulting values as shown in Table 7. The location, whose total score comes out to be highest, is considered as the best location.

4 Result

This research was done for a particular manufacturing industry which wanted to setup their plant at new location to expand their business. So, they suggested five locations Delhi, Manesar, Mumbai, Chandigarh and Baddi. Different factors affecting the plant location on these locations were identified and analysed with the help of a nationwide survey which was sent to different manufacturing industries to know their opinion about various factors. The results of the survey was analysed to select the final factors which could be used for the further process. After determining the factors AHP technique was implemented to select the best location out of these five locations.

It can be seen that Baddi is the preferred location since it has the highest weight (0.24) among five locations as shown in Table 7 after normalising. Chandigarh is at the second choice (0.20), the total scores after normalising for Delhi (0.19) and Manesar (0.19) comes out to be same, so the third choice for selecting the plant location could be Delhi or Manesar and Mumbai is at the last choice (0.17) as shown in Table 8.

Table 8 Preferred choice of location on the basis of normalising

<i>Locations</i>	<i>Total score</i>	<i>After normalising</i>	<i>Preferred choice of location</i>
Delhi	0.185	0.19	IV
Mumbai	0.165	0.17	V
Manesar	0.183	0.19	III
Chandigarh	0.186	0.20	II
Baddi	0.233	0.24	I

The result shows that the model is flexible and can be applied in different types of industries. AHP is a very handy tool for managers to structure their unique problems into priority weights, which can change their own priority considerations and at the last level of the hierarchy the final priority weight of each alternative decision will result in best option. The approach reduces the process time in selecting the plant location. AHP is an effective management tool and provide tradeoffs between both qualitative and quantitative factors. This approach also helps the decision-makers to deal with inconsistent judgements systematically. AHP enables the decision makers to measure the relative judgements of two elements at one time with the help of pairwise comparison in a trustworthy manner and ensure consistency of these values.

Encouraging results are developed in this study but a lot of further research needs to be done. To corroborate the results, imitations of the empirical work are needed and further studies are needed that involve more modern-emerging items.

5 Conclusions

With the help of AHP technique, it has been seen that Baddi is the best location for the selected manufacturing industry. In the AHP technique, all possible factors (qualitative as well as quantitative) are considered which can affect an industry so it is considered as one of the best method for selecting the location for any type of industry. Here, the pairwise comparison of each factor at each level in hierarchy is done to evaluate their relative importance in selecting the particular location so it is more generalised in nature. From the research, it is concluded that the AHP technique is a powerful and flexible tool for tackling the complex decision problem because it decomposes the decision problem into a hierarchy of more easily comprehended sub-problems in a systematic way each of which can be analysed independently in a systematic way. Moreover, the process helps in facilitating the decision-making, reduces the cycle time to select the best plant location and can incorporate precise information. If all the required information and documentation from relevant sources are provided before making such evaluation then the decisions might be more accurate or precise. In AHP approach, all the factors affecting the selection of plant location are clearly defined and the problem is structured into simple hierarchy systematically. From this hierarchy, the decision maker can easily determine the advantages and disadvantages of a particular plant location by comparing them with respect to appropriate factor and helps the decision makers to reach at a consensus decision. Costly distractions that prevent teams from taking the right decision such as lack of focus, planning, participation or ownership which are the common downsides of decision-making process are minimised by AHP. It also helps to reduce bias in decision-making by incarcerating both subjective and objective evaluation measures and providing a useful mechanism for checking the consistency of the evaluation measures and alternatives suggested by the team.

References

- Abdi, M.R. and Labib, A.W. (2003) 'A design strategy for reconfigurable manufacturing systems (RMSs) using analytical hierarchical process (AHP): a case study', *International Journal of Production Research*, Vol. 41, No. 10, pp.2273–2299.
- Anand, G., Kodali, R. and Dhanekula, C.S. (2012) 'An application of analytic network process for selection of a plant location: a case study', *International Journal of Services and Operations Management*, Vol. 12, No. 1, pp.35–66.
- Babu, L.D.D. and Krishna, P.V. (2013) 'Applying operations management models for facility location problem in cloud computing environments', *International Journal of Services and Operations Management*, Vol. 15, No. 1, pp.1–27.
- Badri, M.A. (2007) 'Dimensions of industrial location factors: review and exploration', *Journal of Business and Public Affairs*, Vol. 1, No. 2, pp.1–26.
- Beckmann, M. (1968) *Location Theory*, Random House, New York.
- Brown, D. (1979) 'The location decision of a firm: an overview of theory and evidence', *Papers of the Regional Science Association*, Vol. 43, No. 1, pp.23–40.

- Carnero, M.C. (2014) 'A decision support system for maintenance benchmarking in big buildings', *European Journal of Industrial Engineering*, Vol. 8, No. 3, pp.388–420.
- Carnoy, M. (1972) *Industrialization in a Latin American Common Market*, Brookings Institute, Washington DC.
- Chan, F.T.S. (2003) 'Interactive selection model for supplier selection process: an analytical hierarchy process approach', *International Journal of Production Research*, Vol. 41, No. 15, pp.3,549–3,580.
- Coughlin, C., Joseph, V. and Vachira, A. (1990) 'State government effects on the location of foreign direct investment', *Regional Science Perspectives*, Vol. 20, No. 1, pp.194–207.
- Coughlin, C., Joseph, V. and Vachira, A. (1991) 'State characteristics and the location of foreign direct investment within the United States', *The Review of Economics and Statistics*, Vol. 73, No. 4, pp.675–683.
- Dean, R. (1972) 'Plant location decision process', *Review of Regional Studies*, Vol. 3, pp.1–14.
- Desai, S., Bidanda, B. and Lovell, M.R. (2012) 'Material and process selection in product design using decision-making technique (AHP)', *European Journal of Industrial Engineering*, Vol. 6, No. 3, pp.322–346.
- Dicken, P. and Lloyd, P. (1978) 'Inner metropolitan industrial change, enterprise structure and policy issues: case studies of Manchester and Merseyside', *Regional Studies*, Vol. 12, No. 2, pp.181–97.
- Dicken, P. and Lloyd, P.E. (1990) *Location in Space: Theoretical Perspectives in Economic Geography*, 3rd ed., Harper and Row, Publishers, New York.
- Dorward, N. (1979) 'Market area analysis and product differentiation: a case study of the West German truck industry', in Hamilton, F.E.I. and Linge, G.J.R. (Eds.): *Spatial Analysis and the Industrial Environment*, Volume 1: Industrial Systems, pp.213–260, Wiley, Chichester.
- Foster, R. (1977) 'Economic and quality of life factors in industrial location decisions', *Social Indicators Research*, Vol. 4, No. 3, pp.247–265.
- Gold, S. (1991) 'A new approach to site selection', *Distribution*, Vol. 90, pp.29–33.
- Greenhut, M. (1959) *Plant Location in Theory and Practice*, University of North Carolina Press, Chapel Hill, NC.
- Greenhut, M. (1981) 'Spatial pricing in the US, West Germany and Japan', *Economica*, Vol. 48, No. 189, pp.79–86.
- Greenhut, M. and Colberg, M. (1962) *Factors in the Location of Florida Industry*, Florida State University, Tallahassee, Florida.
- Greenhut, M.L. (1956) *Plant Location in Theory and Practice*, University of North Carolina Press, Chapel Hill.
- Heckman, J. (1978) 'An analysis of the changing location of iron and steel production in the twentieth century', *American Economic Review*, Vol. 68, No. 1, pp.123–133.
- Hoover, E. (1948) *The Location of Economic Activity*, McGraw-Hill, New York.
- Hudson, R. (1983) 'Capital accumulation and chemical production in Western Europe in the post-war period', *Environment and Planning, A*, Vol. 15, No. 1, pp.105–122.
- Hudson, R. (1988) 'Uneven development in capitalist societies: changing spatial division of labor, forms of spatial organization of production and service provision, and their impacts on localities', *Transactions*, Vol. 13, No. 4, pp.484–496, Institute of British Geographers (New Series).
- Isard, N. (1956) *Location and Space Economy*, MIT Press, Cambridge, Mass.
- Jahromi, A.R.M., Nooramin, A.S. and Safaei, A.A. (2012) 'A combined extent fuzzy AHP and simulation method for selecting stacking layout type in marine container terminals', *International Journal of Services and Operations Management*, Vol. 12, No. 3, pp.332–347.
- Launhardt, W. (1885) *Mathematische Begründung der Volkswirtschaftslehre*, Verlag von Wilhelm Engelmann, Leipzig.

- Maggie, C.Y.T. and Tummala, V.M.R. (2001) 'An application of the AHP in vendor selection of a telecommunications system', *Omega*, Vol. 29, No. 2, pp.171–182.
- Mahapatara, S.S., Sharma, S.K. and Parappagoudar, M.B. (2013) 'A novel multi-criteria decision making approach for selection of reverse manufacturing alternative', *International Journal of Services and Operations Management*, Vol. 15, No. 2, pp.176–195.
- McMillan Jr., T. (1965) 'Why manufacturers choose plant location vs. determinants of plant location', *Land Economics*, Vol. 43, No. 3, pp.239–246.
- Mehrmanesh, H., Parikhi, S. and Fazlollahtabar, H. (2013) 'Modelling the customer relationship management in a multi-layer supply chain considering product life cycle', *International Journal of Services and Operations Management*, Vol. 16, No. 4, pp.525–547.
- Miller, D. and Star, M. (1967) *The Structure of Human Decisions*, Prentice Hall, Englewood Cliffs, NJ.
- Miller, W. (1977) *Manufacturing: a Study of Industrial Location*, The Pennsylvania State University, PA.
- Moriarty, B. (1980) *Industrial Location and Community Development*, University of North Carolina Press, Chapel Hill, NC.
- Narasimhan, R. (1983) 'An analytical approach to supplier selection', *Journal of Purchasing and Material Management*, Vol. 19, No. 4, pp.27–32.
- Nicholas, J. (1974) 'Industrial location: the special case of Florida', *Review of Regional Studies*, Vol. 4, No. 2, pp.27–33.
- Nydick, R.L. and Hill, R.P. (1992) 'Using the analytic hierarchy process to structure the supplier selection procedure', *Journal of Purchasing and Material Management*, Vol. 25, No. 2, pp.1–6.
- Partovi, F.Y. (1994) 'Determining what to benchmark: an analytic hierarchy process approach', *International Journal of Operations and Production Management*, Vol. 14, No. 6, pp.25–39.
- Partovi, F.Y., Burton, J. and Banerjee, A. (1989) 'Application of analytic hierarchy process in operations management', *International Journal of Operations and Production Management*, Vol. 10, No. 3, pp.5–19.
- Pietlock, B. (1992) 'Developing foreign location factors', *Cost Engineering*, Vol. 34, No. 1, pp.7–11.
- Prasanna Venkatesan, S. and Kumanan, S. (2012) 'Supply chain risk prioritisation using a hybrid AHP and PROMETHEE approach', *International Journal of Services and Operations Management*, Vol. 13, No. 1, pp.19–41.
- Raj, T., Shankar, R., Suhaib, M., Garg, S. and Singh, Y. (2008) 'An AHP approach for the selection of advanced manufacturing system: a case study', *International Journal of Manufacturing Research*, Vol. 3, No. 4, pp.471–498.
- Rees, J. (1972) 'The industrial corporation and location decision analysis', *Area*, Vol. 4, No. 3, pp.199–204.
- Rees, J. (1983) 'Government policy and industrial location', in mInternational Journal of House (Ed.): *United States Public Policy: a Geographical View*, pp.213–262, Clarendon, Oxford.
- Richardson, H.W. (1979) *Regional Economics*, The University of Illinois Press, Chicago.
- Roudsari, A.H. and Wong, K.Y. (2014) 'A bi-objective stochastic single facility location model for a supermarket', *International Journal of Services and Operations Management*, Vol. 17, No. 3, pp.257–279.
- Saaty, T.L. (1980) *The Analytic Hierarchy Process*, McGraw-Hill, New York.
- Saaty, T.L. (2000) *Fundamentals of Decision Making and Priority Theory*, 2nd ed., RWS Publications, Pittsburgh, PA.
- Saxenian, A. (1985) 'The genesis of Silicon Valley', in Prentice Hall and Markusen, A. (Eds.): *Silicon Landscapes*, pp.20–34, Allen and Unwin, Boston.
- Schmenner, R. (1982) *Making Business Location Decisions*, Prentice Hall, Englewood Cliffs, NJ.

- Shakib, M.D. and Fazli, S. (2012) 'Separating successful and unsuccessful firms using multiple attribute decision-making methods', *International Journal of Information and Decision Sciences*, Vol. 4, No. 1, pp.19–47.
- Sharma, S. (2004) *Introduction to operation Management*, Cyber Tech Publication, New Delhi.
- Smith, D. (1966) 'A theoretical framework for geographical studies in industrial location', *Economic Geography*, Vol. 42, No. 2, pp.95–113.
- Smith, D. (1981) *Industrial Location: an Economic Geographical Analysis*, 2nd ed., Wiley, New York.
- Spooner, D. (1974) 'Some qualitative aspects of industrial movement in a problem region in the UK', *Town Planning Review*, Vol. 45, No. 1, pp.63–83.
- Sunil Kumar, K. and Subash Babu, A. (2011) 'An integrated method using AHP, DEA and GP for evaluating supply sources', *International Journal of Services and Operations Management*, Vol. 11, No. 2, pp.123–150.
- Tellier, L. and Vertefeuille, C. (1995) 'Understanding spatial inertia: center of gravity, population densities, the Weber problem, and gravity potential', *Journal of Regional Science*, Vol. 35, No. 1, pp.155–164.
- Thunen, J. (1875) *Der Isolirerte Staat in Bizehung auf Landwirtschaft und Nationalokonomie*, Schumachen-Zarchlin, Berlin.
- Walker, D. (1975) 'A behavioural approach to industrial location', in Collins, L. and Walker, D. (Eds.): *Locational Dynamics of Manufacturing Activity*, pp.135–158, Wiley, Chichester.
- Walters, B. and Wheeler, J. (1984) 'Localization economies in the American carpet industry', *Geographical Review*, Vol. 74, No. 2, pp.183–191.
- Ward, M. (1982) 'Political economy, industrial location and the European motor car industry in the post-war period', *Regional Studies*, Vol. 16, No. 6, pp.443–453.
- Weber, A. (1909) *Theory of the Location of Industry*, University of Chicago Press, Chicago.
- Weber, A. (1929) *Theory of the Location of Industries*, University of Chicago, C.J. Friedrich, Chicago.
- Weber, M.J. (1972) *Impact of Uncertainty on Location*, The M.I.T. Press, Cambridge, MA.
- Wheeler, D. and Mody, A. (1992) 'International investment location decisions: the case of U.S. firms', *Journal of International Economics*, Vol. 33, Nos. 1–2, pp.57–76.
- Yang, J. and Lee, H. (1997) 'An AHP decision model for facility location selection', *Facilities*, Vol. 15, Nos. 9/10, pp.241–254.
- Young, G. (1994) 'International competitiveness, international taxation and domestic investment', *National Institute of Economic Review*, Vol. 148, No. 1, pp.44–48.
- Yusuff, R.D. and Poh Yee, K. (2001) 'A preliminary study on the potential use of the analytical hierarchical process (AHP) to predict advanced manufacturing technology (AMT) implementation', *Robotics and Computer Integrated Manufacturing*, Vol. 17, No. 5, pp.421–427.
- Zahedi, F. (1986) 'The analytic hierarchy process: a survey of the method and its applications', *Interfaces*, Vol. 16, No. 4, pp.96–108.