Location Selection in Global Supply Chains

N. Viswanadham and S. Kameshwaran[1]
Centre for Global Logistics and Manufacturing Strategies
Indian School of Business
Hyderabad 500032 India
{N_Viswanadham, Kameshwaran_S}@isb.edu

Abstract

Supply chain decision problems are becoming more complex with the globalization of businesses spanning several international borders. One such strategic decision problem is the location selection problem, which determines an optimal location to build a new facility. This requires multicriteria evaluation of N alternate locations with respect to M location attributes. The alternate locations could be nations or regions within nations. In this paper we develop a generic framework that can aid the decision maker in identifying and grouping the M attributes into an hierarchy for location selection in global supply chains. An hierarchical structuring is proposed with four fundamental criteria: product/process value chain, economic & political integration, resources & management, and connecting technologies. These are integral to many global business activities and the generic sub-criteria for the above are identified. This aids the decision maker to identify and group the M location attributes as a multilevel hierarchical tree. This structuring facilitates the use of the analytic hierarchy process to synthesize the information about the M attributes along with the decision maker's preferences, to evaluate the locations. The framework is generic and can be used for locating business operations including industrial plants, R&D centers, call centers, special economic zones, etc. We illustrate the applicability of the framework using a stylized example of locating a Biotech R&D center in Asia.

Keywords

Location selection, global supply chain networks, hierarchical structuring, analytic hierarchy process.

1 Introduction

A global supply chain spans several countries and regions of the globe. Trade liberalization (e.g. European Union, NAFTA) and information technology have accelerated the growth of global supply chains, whereby a firm can invest and trade across national borders. It is now a competitive requirement that firms invest internationally to access markets, technology, and talent. Firms can trade across national borders either by intra-firm-trade (foreign direct investment (FDI)) or arms-length-trade (foreign outsourcing). FDI includes corporate activities such as building plants or subsidiaries in foreign countries, and buying controlling stakes or shares in foreign companies. Firms located in industrialised countries pursue vertical disintegration of their production processes by outsourcing some stages in foreign countries where economic conditions are more advantageous. For example, Intel Corporation assembles most of its microchips in wholly-owned subsidiaries in China, Costa Rica, Malaysia, and the Philippines. One of the strategic decision problems encountered by global firms is *where to locate* the business activities.

Traditionally called the *location selection* or *site selection* problem, this had been studied by economic geographers since the dawn of the industrialization era [17]. Globalization has not only

[1]Corresponding Author: Tel: +91 40 23187974, Fax: +91 40 23007099, Email: Kameshwaran_S@isb.edu

made this problem more prevalent and important, but also has added more complexities to it. At the industry level, location decisions pertain not only to traditional manufacturing plants and warehouses, but also to services sectors like R&D facilities, call centers, ITeS, BPO, etc. Secondly, at the firm level, a firm entering a greenfield investment in a foreign territory has to consider transport, IT, taxes, tariffs, subsidies, foreign trade agreements, resource availability, customs clearance times, legal systems, etc. Further, this problem needs to be solved at the national level to select a country for investment and at the subnational level to select a location within the country.

In this paper, we consider the multicriteria evaluation of alternate locations with respect to a multitude of location factors. Specifically, we are concerned with the ranking of N alternate locations based on M location attributes. The paper is not about location selection for a particular industry like automobiles, or for a specific kind of facility like a warehouse. In contrast, we develop a generic framework that can be used by the decision maker for location selection problems in global supply chains. It is obvious that every location selection problem is unique in the requirements of the investing firm and the intended business activity. However, they all share certain generic characteristics and in this paper we identify and formalize these characteristics. We propose an hierarchical structuring, called the PERC model, to homogeneously cluster the M location attributes under appropriate criteria. Following this analysis stage is the synthesis, where the weights for the attributes and the criteria are first elicited from the decision maker using the above hierarchical clusters. This is then combined with the information about the N locations for the M attributes to arrive at the final ranking. For this stage, we recommend the use of the *analytic hierarchy process* (AHP), though in principle other multicriteria decision techniques like *multiattribute utility theory* can be used. We illustrate the applicability of the framework using an hypothetical biotech firm that intends to locate its R&D activity in Asia.

The remainder of the paper is organized as follows. The problem of multiple criteria evaluation of locations is described in Section 2. Section 3 briefly reviews the literature related to location selection studied by different disciplines. The PERC model used for the analysis stage of the decision framework is explained in Section 4. The analytic hierarchy process, which is used for the synthesis, is briefly described in Section 5. Section 6 presents a stylized case study of locating a biotech R&D in Asia using the proposed framework. Final notes and conclusions are drawn in Section 7.

2 Multiple Criteria Evaluation of Locations

2.1 Motivation

The paper is motivated by the location of a single facility *i.e.* to find an optimal location from a given finite set of alternate locations. This is different from the classical *facility location problem* [10], which determines an optimal *set* of locations given the demand patterns, transportation costs, and production costs. In general, industrial location decision making is a highly complex process with multifaceted characteristics including tangible and intangible elements that are very difficult to measure and evaluate [17]. The basic steps involved to arrive at the best possible location recommendation are [27]:

1. The basic requirements of the location project are first identified, usually by using an all-

¡¡ Insert Figure 1 here ¿¿

Figure 1: Multiattribute Evaluation with Weights and Scores

purpose location questionnaire. From this, critical and desirable factors for the locations are determined. Critical factors are mandatory factors that play a crucial role in identifying potential locations and eliminating infeasible ones. For example, if a seaport is a mandatory factor then locations without seaports can be eliminated for consideration.

2. A list of N alternate locations that satisfy the mandatory critical factors are shortlisted. Matching algorithms are sometimes used to determine these locations by estimating matching scores between the locations and the desirable location factors.

3. Based on the intended investment and the nature of the investing firm, M location attributes are identified. These are the location factors over which the N locations are to be evaluated.

4. Information about the N locations for each of the M attributes is obtained using public databases, private investigations, and personal meetings with the local authorities. This includes quantitative information like economic cost analysis of non-recurring and recurring costs, prediction of future sales, return of investment, production efficiency, government incentives, etc. Also qualitative information like living conditions and political climate are also determined.

5. The N locations are ranked with respect to the M attributes. This is a multicriteria decision analysis problem.

This paper is about the last step in the above process, which is explained in more detail in the following. Let us assume that the N alternate locations, M location attributes, and the information about the locations with respect to each of the attributes are known to the decision maker (DM). Now to evaluate the locations, two numerical entities are required:

- *Weights*: $W = \{w_1, \ldots, w_j, \ldots, w_M\}$.
- *Scores*: $S_i = \{s_{i1}, \ldots, s_{ij}, \ldots, s_{iM}\}$, $i = 1, \ldots, N$.

The relative importance of the location attributes (as perceived by the DM based on the firm's objectives and constraints) are denoted using the weights W. The scores, on the other hand, rates the performance of a location for each of the attributes. The total score for a location i is then obtained by combining the weights W and the scores S_i in some mathematically acceptable way, which depends on how the weights and scores are represented and obtained. Figure 1 illustrates the multicriteria analysis using scores and weights. In the figure, the total scoring function $\{W^T\}\{S_i\}$ for location i is left unspecified and it can be any mathematically acceptable combination. The various multicriteria evaluation techniques differ by the way they *estimate* the weights and scores, and by the way the *combine* them. They can be formalized in two steps: arranging the criteria into a hierarchy (analysis) and then measuring how well the alternatives perform on each criterion (synthesis) [31].

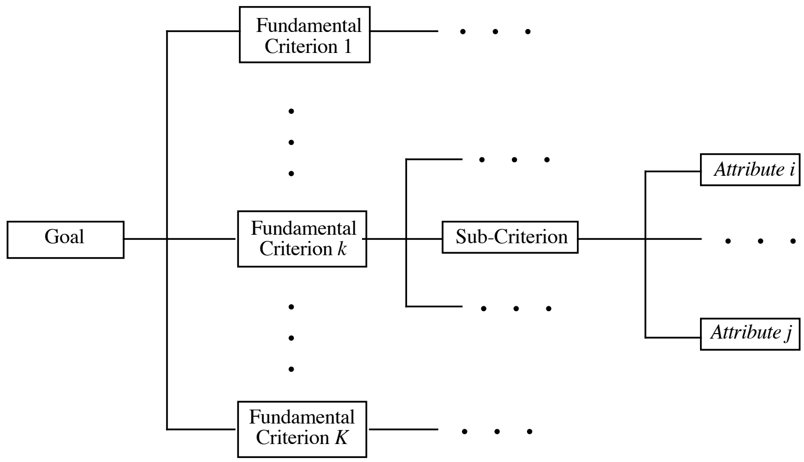

Figure 2: Hierarchical Structuring of Criteria and Attributes

2.2 Analysis

The analysis starts with the identification of *criteria* and *attributes*. We use the word *criteria* to refer to objectives or directions along which the DM seeks better performance from the alternatives. The performance is measured in terms of *attributes*. For example, the criterion economic factors can be measured using attributes such as income tax, property tax, and sales tax. There is a considerable interplay in the identification of criteria and attributes. This complex creative process is achieved through hierarchically structuring homogeneous clusters of criteria and attributes [24, 23, 33]. The resulting multilevel hierarchy is shown in Figure 2. The fundamental criteria are next to the overall goal and can be further divided into sub-criteria, sub-sub-criteria, and so on, till they cannot be further subdivided. This last level contains measurable attributes. These are measurable in the sense that numerical scores can be given to the locations for each of these attributes. The hierarchy implies a one way dependence relationship from a parent node to its child node. There are models that can incorporate other kinds of dependence like feedback, by creating a network of criteria and attribute nodes [23, 34].

2.3 Synthesis

Given the hierarchy, the next step is the application of a multicriteria decision analysis technique, which determines the weights W, scores S, and combines them to give a final ranking. The hierarchical clustering of criteria and attributes is used to elicit the weights W from the decision maker. Two commonly used multicriteria techniques [5] are the *multiattribute utility/value theory* (MAUT) [24] and the *analytic hierarchy process* (AHP) [33]. They use different techniques to elicit the weights W from the DM, which denote the relative importance among the attributes and the criteria. MAUT allows the DM to directly state W (values) or estimate it as a utility function identified through risk lotteries. AHP uses paired comparisons of hierarchical factors to derive W as ratio scale measures. Both have been used for a wide variety of applications and the choice depends on the applicability of the methodology to the problem being solved. An insightful comparison of both techniques is presented in [5]. For a comprehensive study of different multicriteria techniques the reader is referred to [31].

3 Related Literature

The location choice problem has been studied with varying assumptions and perspectives by different disciplines like economic geography, management science, and international business. In this section, we briefly review the literature from various disciplines, providing complementary sources of significant location attributes and decision insights.

3.1 Location-Production Models

These are the earliest and simplest analytical models and commonly referred to as Weber's and Moses' models. These classical and neoclassical microeconomic models analyze the production behavior of an individual stylized firm in relation to the spatial economic costs. These costs include local labour prices, land costs, transportation costs, and telecommunication costs. The objective is to locate a plant in the plane by minimizing the weighted sum of Euclidean distances from that plant to a finite number of sites corresponding to the markets where the plant purchases its inputs and sells its outputs. Some of these models also consider the production as a decision variable, which often depends on the location. Interested readers are referred to [26] for an excellent review of the range of microeconomic location-production models. In our location choice problem, we consider only the location decision; production levels are not variables in the model. These models are still popular and currently used in the early stages of location selection (step 2 in Section 2.1) to identify the N alternate locations. The common feature of the above models is the consideration of the firm or plant in isolation, without any competition from other firms.

3.2 Agglomeration Economies

The inclusion of other firms from the same or related industry in the analysis, brings out a new set of factors for the location decision. The regional science community uses the term *economies of agglomeration* to describe the benefits that firms obtain when locating near each other. It is related to the idea of economies of scale and network effects, in that the more related firms that are clustered together, the lower the production cost and the greater the market. The production costs are lower due to availability of specialized resources, such as competing suppliers, skilled labour, and infrastructure. On the demand side, the informational externalities from other firms and the reduction in consumer search costs are beneficial for total market demand. Several studies show that agglomeration economies are dominant factors in the location choice of MNCs for FDI [18, 8, 6, 4, 16].

This agglomeration phenomena, from the management science literature, is explained using *clusters* [32]. Clusters are geographic concentrations of interconnected companies and institutions in a particular field. The linked industries and institutions can consist of suppliers to universities to government agencies. Clusters promote both competition and cooperation. For a firm, location in clusters is a source of competitive advantage. The other related model is the *core periphery* model that explains why certain regions or cities attract more industries than others. *New economic* *geography* [15] uses general equilibrium models to explain the location of industrial and economic activities. All these models reinforce the idea that the presence of other firms in the same or related industries is an important location decision factor.

3.3 International Business Literature

The Dunning's eclectic OLI (ownership, location, and internalization) [11, 12] framework is the widely accepted model for the study of FDI by MNCs. The OLI framework suggests that a firm will prefer FDI to trade and become a MNC if the following three conditions are satisfied. First, the firm must possess *ownership* advantages not available to other firms in terms of superior technology, firm size, brand name, etc. Second, the foreign market should offer *location* specific advantages like market size, cheap resources, and infrastructure. Finally, there should be *internalization* advantages, which eliminates the transaction and coordination costs associated with market interaction and internalizes these activities by bringing them inside the hierarchy of the firm. The framework is also used in the analysis of location decisions [29] and mode of entry decisions [7]. Accordingly, the location decision is contingent on ownership and internalization factors. This framework is more useful for location choice at the national level, which also takes into account the mode of entry.

3.4 Multiattribute Decision Models

Except for the location-allocation models, the above are not prescriptive decision models that can aid a DM to select a location. A linear additive MAUT based location evaluation was used to locate a manufacturing facility in [22]. AHP has been used extensively for a wide variety of location problems: generic plant location [39, 41]; sure service terminal location [19]; landfill siting problem [13]; location of international consolidation terminals [28]; overseas plant location [42]; global facility location-allocation problem [3]; industrial plant location [1]; and international location decisions [2]. All the above models followed the two stage analysis-synthesis framework: developing the hierarchical structure of criteria followed by the use of a multicriteria technique (AHP/MAUT). These models are also used for measuring the investment climate and market attractiveness of different locations [35, Chapter 9], [38].

3.5 Industry Best Practices

Location consultants aid firms in the complex decision making of selecting a location for expansion or investment or relocation. They usually support the whole location selection process (all the steps outlined in Section 2.1), starting from the initial search of locations till the negotiations on investment subsidies and agreements on land and/or buildings. For a detailed exposure on the industrial location selection process with real world cases and experiences, see [27]. It should be noted that location consultants do a lot more than the evaluation of locations, which is the main theme of this paper. However, according to the author of [27], who has worked on more than 1500 location cases, this step (step 5 in Section 2.1) is the most difficult and least understood part of location studies. The author uses a multicriteria model assigning weights directly on a one to ten scale. Many of the location consultants use this simple linear additive technique. IBM Plant Location International[2] uses a hierarchy of criteria clustered as quality factors and cost factors.

[2] http://www.ibm.com/bcs/pli

The weights are directly assigned based on experience. Many popular location consultants listed by Global Direct Investment Solutions[3] use the technique of directly assigning, combining them in a linear additive fashion to get a final rank.

Buck Consultants International[4] (BCI) developed a cost-quality matrix to compare different locations. The matrix has a vertical axis showing all costs for the next 5 years and a horizontal axis showing the quality of the investment climate in a weighted form. An optimal location is the one with low costs and the high quality business environment. DealTek[5] provides web based decision support software called DEALS to search and rank locations in US. The software combines the economic and demographic data with the user inputs to rank the locations. The innovative feature of the software is that it allows the user to input possible business scenarios, under varying assumptions on the economic conditions, like *Optimistic*, *Most Likely*, and *Pessimistic*. The locations are first shortlisted using user selected criteria from a set of pre-defined criteria like labor cost, labor availability, etc). Then these locations are ranked, taking into account the business scenarios, financial projections, etc.

The above brief survey is intended to provide an overview of the location selection problem studied from different perspectives. For a more expository review, see [40] and references therein. It is worth noting how the location problem has changed with the evolution of business as a single isolated firm to be a part of a global supply chain. In the following, we describe our proposed two stage analysis-synthesis decision framework.

4 Analysis: Hierarchical Structuring Using the PERC Model

There is little work in multiple criteria decision making to advise on how hierarchies should be constructed and what makes a good hierarchical representation [5]. However, there are broad guidelines on the hierarchy development process and the properties that a hierarchical structuring should possess [24, 23]. In general, this phase is entirely under the control of the DM. There are many different ways one can cluster and form a hierarchy of criteria and it is not possible to claim or prove the superiority of one over the other. Tables 1 and 2 presents different hierarchical clustering proposed in the literature and being used in practice. The list is not exhaustive and it includes location selection problems studied from varying perspectives: locating in foreign countries [42, 2], locating manufacturing industries [41, 1, 2], locating R&D facilities [21], industry location consultants [20], and measuring market attractiveness of countries [35] and locations within a country [38]. There are two things that are evident from tables 1 and 2. Firstly, the hierarchical structure depends on the particular industry and firm, and for the same type, one can arrive at different structures. The second observation is that there are some common features in these seemingly different location problems. To complement and extend these efforts, we propose here the PERC model [36], which is an abstract higher level model that consists of the following four fundamental criteria:

- Product/Process value chain
- Economic and political integration

[3] http://www.gdi-solutions.com/profsvcs/lists/location_consultants.htm
[4] http://www.bciglobal.com
[5] http://www.dealtek.com

Table 1: Fundamental Criteria and Sub-Criteria of Various Hierarchical Structuring.

Fundamental Criteria	**Sub-criteria**
Location of Japanese firms in European Commission [42]	
1. Labour	labour force, costs, union;
2. Markets	product market, raw materials;
3. Transport	airways, railways, seaport, roadways;
4. Financial inducement	tax, country risk, loan availability;
5. Living conditions	firms from host country, educational facilities, crimes, consumer price index;
6. Environment for operations	electricity rate, water charge, sewage facilities, rules and regulations;
International location decision for manufacturing plants [2]	
1. Cost	direct costs, indirect costs;
2. Quality of products	labour, infrastructure;
3. Time to markets	markets, suppliers, macro-environment;
Industrial location decision [1]	
1. Environmental aspects	regulations, disposal, taxation;
2. Cost	operating, start-up;
3. Quality of living	climate, crime rate, traffic congestion, living expenses;
4. Local incentives	tax, union, laws, skilled labour;
5. Time reliability provided to customers	proximity to centers, suppliers, customers, waterway, rail, highway;
6. Response flexibility to customer demand	proximity to suppliers and customers, other company's complimentary facilities;
7. Integration with customers	post-sale service, co-makership, co-design;
Facility location selection [41]	
1. Market	growth potential, proximity to market, raw materials;
2. Transportation	land, water, air;
3. Labour	cost, availability of skilled and semi-skilled labour;
4. Community	housing, educational, business climate;
Locating global R&D operations [21]	
1. Demand factors	proximity to the final market, growth potential, response to local variations
2. Supply factors	local scientific talent, local technology, know-how
3. General competitive factors	competitive environment

Table 2: Fundamental Criteria and Sub-Criteria of Various Hierarchical Structuring (*contd.*).

Benchmarking of European locations by IBM PLI [20]	
1. Cost	property costs, labour costs;
2. Quality	staff availability, language skills, labour laws, international accessibility, attractivesness for international staff;
Market attractiveness of developing countries [35, Chapter 9]	
1. Political factors	turmoil, strategic relevance;
2. Economic-financial factors	risk of direct investment, GDP, inflation rate, growth rate of GDP;
Investment climate of India for manufacturing industry [38]	
1. Business environment	regulation, corruption, infrastructure, factor markets;
2. Agglomeration economies	own industry concentration, economic diversity, spatial distribution;

- Resources and management
- Connecting technologies

The above are the fundamental criteria in the hierarchical structuring. The sub-criteria under each of them are shown in Table 3. There are uncertainties in any kind of business investment. Those that could be leveraged for growth are *opportunities* and those that could affect the firm negatively are *risks*. Their certain counterparts are *benefits* and *costs*, respectively. To enhance the understanding the four fundamental criteria, the benefits, opportunities, costs, and risks associated with them are listed in Table 4. They are explained in detail in the following.

4.0.1 Product/Process Value Chain

The investment is intended for some business process like manufacturing a product or providing a service. This criterion is about the value chain dimension of the intended subsidiary. It is not about the entire global supply or value chain, but the part confined to the location. It is concerned with forward and backward linkages, supply and demand (market conditions), agglomeration economies (competing and complementing businesses) and business process innovation (adapting to local markets, creating new business opportunities). The above aspects of the location are clustered under this criterion.

The important sub-criteria considered are supply-demand and agglomeration. The traditional supply-demand factors are enhanced in global supply chains in terms of cheap supplies, local demand, and potential for market growth. However, deviations and disruptions in demand and supply can result in costly discrepancies elsewhere in the global supply chain. Similarly, the stronger agglomeration economies and cluster effects provide many benefits and opportunities and also pose major risks. The presence of related businesses in the location reduces supply costs and provides

Table 3: Fundamental Criteria and Sub-Criteria of PERC Model.

Fundamental Criteria	**Sub-criteria**
1. **P**roduct/Process value chain	suppliers, markets and demand, agglomeration economies and clusters, knowledge sharing and collaboration;
2. **E**conomic & political integration	economic policies, trade facilitations, laws & regulations, financial inducements and incentives, political factors, living conditions;
3. **R**esources and management	human resources (skilled workforce), financial resources (loans, investors), utilities and industry inputs (land, water, power, educational and training institutes), management services (legal, marketing, business consulting, financial planning);
4. **C**onnecting technologies	transport (rail, road, air, sea), information and communication technologies (Internet, wireless, landline, data);

higher demand. It also enables knowledge sharing and collaboration to make the business process efficient, but knowledge spill-over could result in IP violations. Ignorance of domain knowledge will be an added advantage of the locals with added expertise due to knowledge spill-over. The agglomeration, on the other hand, can help in business process innovations by leveraging the global expertise to meet local demands. The DM, hence has to take into account the above conflicting factors to arrive at an optimal location decision.

4.0.2 Economic and Political Integration

Economic and political factors play an important role in global supply chains. The interaction between the investing firm and the host government during the location decision has been modeled using game theory in the international business discipline [25, 9]. The host government attempts to elicit desired behavior from the investing firm using direct (through legislative and executive controls) and indirect (through incentives) stimuli. The firm is always assumed to choose amongst several alternative locations, greatly reducing the bargaining power and role of the host government [30]. However, the economic and political profile of the government plays a significant role in the location decision.

This criterion include taxes (income, sales, trade, import, export), regulatory framework (labor, environmental, legal), trade agreements, government incentives and subsidies, political stability, and living conditions. The obvious benefits of incentives, subsidies, and trade agreements also come with a great pool of risks like anti-dumping legislation, voluntary export restrictions, and breach of promises. Once the investments are made, the bargaining powers of the firms are lost and are dependent on the functioning of the government. The exposure of the firm's information while applying for incentives is another risk encountered commonly in practice [27]. The indirect influences of the government like terrorism and crime are other sources of risk.

The regulatory framework is another major sub-criterion that is government dependent. Many studies [37, 14] based on surveys have indicated that rules and regulations (labor laws, licensing,

Table 4: Benefits, Opportunities, Costs, and Risks.

	Benefits	Opportunities	Costs	Risks
P	- Local Demand	- Market growth	- Production cost	- Deviations in demand and supply
	- Own-industry concentration	- Product/process innovation to meet local requirements (or leveraging local expertise)	- Operating cost	- Local competition
	- Inter-industry concentration	- Spin-offs/ins		- Ignorance of domain knowledge
	- Special economic zones and technology parks	- Knowledge sharing and collaboration with universities and peers	- Direct and indirect costs	- Knowledge spill-over and intellectual property rights violation
E	- Incentives: taxes, utilities, exports, imports	- Improving public facilities	- Taxes: income, land, utilities, exports, imports	- Exposure of company information while applying for incentives
	- Flexible labour laws		- Delays due to regulations	- Anti-dumping
	- Transparent regulations		- Corruption	- Political instability
	- Living conditions		- Cost of living	- Bankruptcy
				- Breach of promises by government
				- Crime and terrorism
R	- Investors and loan availability	- Developing integrated services	- Cost of utilities: land, power, water	- Sub-optimal quality
	- Institutions: educational, training, research	- Customized training	- Cost of raw materials	- Unskilled labour
	- Value-added services		- Services cost	- Exposure of business process
				- Labour strikes
C	- Transport infrastructure: airports, seaports, railways, roadways	- Developing public facilities	- Freight costs	- Disruption of connectivity due to natural calamities
			- Custom clearance delays	- Security in global sourcing
	- Network connectivity		- Bandwidth cost	Network reliability and security

environmental) are seen as hindrance by firms. The bureaucratic framework results in unproductive delays and non-transparent functioning leads to corruption. Finally, the intangible attributes living conditions and public attitude also have subtle effects on location selection.

The role of this criterion in location selection is evident at the national level, when choosing countries for investment. They also play an important role at the sub-national level for countries with federal systems co-administered with several regional or state governments. Incentives, subsidies, and regulatory frameworks are generally the dominating factors while choosing a location within a country.

4.0.3 Resources and Management

The third criterion covers the resources and the management of resources. Resources include human (skilled and unskilled), natural (raw materials, land, coast line), utilities (water, electricity), and also financial (loans, banks, venture capitalists). Management of resources is an important sub-criterion that is overlooked. Many global business operations depend largely on resource management skills like global sourcing, global marketing, research and training institutions, legal services, human resource training, and financial planning. Resource management complements with the resources and sometimes even substitutes when the resources are not available.

4.0.4 Connecting Technologies

The final criteria is about how a firm connects to the external world using the transport and network infrastructure. The inbound and outbound flow of materials, manpower, information, and data are considered in this criterion. The obvious attributes include availability of sea ports, airports, railways, road ways, freight forwarding costs, lead time, network readiness, IT connectivity, mobile networks, postal and courier systems, IT enabled services, etc. The other network components due to globalization are customs clearance and quality tracking systems. International logistics flows are substantially more complex with more documentation like commercial invoices and customs paperwork. Hence, locations that employ automated trade documentation are advantageous.

The following characteristics of the PERC model are worth noting.

- The four fundamental criteria are integral to many global investments. Indeed, they can be interpreted as four forces whose interplay affect the evolution of a global supply chain. Their relative importance, however, depends on the industry and the investing firm. For example, in locating a large manufacturing plant, all four criteria have almost equal significance, whereas in locating a call center, network connectivity and resources play a dominant role. Thus its widespread applicability lies in its genericness.

- The model is complete in the sense of covering all aspects and takes an end-to-end view of a global investment.

- It is a top-down approach, starting with the fundamental criteria first and then identifying the suitable sub-criteria and the attributes. It is not based on the importance of the attributes, perceived *a priori* by the DM. It is also not classified by the tangible or intangible nature of the attributes. It can aid the practitioners in identifying and grouping the attributes for new-age business processes, which are not yet studied well in the literature.

- The number of fundamental criteria in the PERC model is optimal. As observed earlier, the main reason for an hierarchical structuring is to elicit the preferences of the DM for the attributes in terms of weights. It has been long observed in cognitive science that the comparative capability ofthe human brain is limited to five distinct entities simultaneously. Thus too many fundamental criteria is undesirable and too few would result clustering of non-homogeneous attributes.

- The PERC model assumes that information about a location for the location factors is already known. For example, it is usual in production investments to forecast and project sales for period of a five years. Similar to this are the risk evaluations. It is assumed that such calculations are already available to the DM.

- The PERC model only suggests what can be included under a criterion. Some of the attributes in Table 4 are interrelated. For example, the benefit high labor availability is a mathematical inverse of labour cost. They can also be indirectly related like high taxes and poor infrastructure. The DM should make sure that such related attributes are not included, to avoid double counting. The lack of a step-by-step cookbook procedure is an obvious outcome of its generic nature, though the Tables 3 and 4 can be used as checklists by the practitioners.

5 Synthesis: Analytic Hierarchy Process

The second phase in the multicriteria evaluation is to determine the scores for the locations for each of the attributes and weights for the attributes and criteria that reflect their relative significance. This multidimensional scale of measurements is then combined into a unidimensional scale of ranks. Out of the two commonly used methodologies, MAUT is preferred by location consultants (Section 3.5), whereas AHP is advocated more by academicians (Section 3.4). To be more precise, location consultants use *value* functions by directly assigning values to the criteria on some interval scale (say 1 to 10) and not *utility* functions, which are elicited through risk lotteries. This direct assignment of values is subject to a high degree of human subjective errors. On the other hand, use of utility functions, though mathematically infallible, is found to be difficult to understand and implement in practice for DMs. AHP is widely accepted as the best trade-off between mathematical accuracy and implementation in practice. It is also best suited to handle both tangible and intangible attributes along with objective and perception data, which is the norm in the location selection problem.

Given the problem in hierarchical structure, AHP determines the scores and weights using pairwise comparisons of sibling nodes under each parent node. Actually, it does not distinguish between scores and weights and they are called *priorities*, which are numbers in ratio scales. The priorities are obtained for each set of siblings separately. The siblings are compared pairwise with respect to their parent and a numeric value is given, which represents the *ratio* of preference between the two factors. A matrix of pairwise comparisons is constructed by reference to the semantic scale and a 1-9 numeric scale, shown in Table 5. Let A denote the matrix with scales assigned through pairwise comparisons. A is a positive, ratio matrix with $a_{ij} = 1/a_{ji}$. The priorities of the factors p is the normalized eigenvector associated with the largest eigenvalue of A. It is obtained by solving the following set of linear equations:

$$Aw = \lambda_{\max} p \tag{1}$$

Table 5: The fundamental scale used in AHP for pairwise comparison

Scale	**Definition**	**Explanation**
1	Equal importance	Two factors contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment moderately favor one factor over another
5	Essential or strong importance	Experience and judgement strongly favor one factor over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one factor over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals	If factor **F1** has one of the above numbers assigned to it when compared with factor **F2**, then **F2** has the reciprocal value when compared with **F1**	

The largest eigenvalue $\lambda_{\max}$ will be greater than or equal to the size of matrix A. If it is equal to the size of A, then the judgement made from pairwise comparison is consistent. However, such consistency is rarely a reality in the real world and AHP allows for inconsistencies. As each pairwise comparison is already a ratio, the resulting priorities are ratio scale measures as well. Once the priorities are obtained for all the nodes, the location is evaluated by multi-linear superposition. The derivation of priorities and the evaluation of alternatives are explained in detail using an example in the next section. For a more detailed account of AHP, see [33].

6 Example: Location of a Biotech R&D Facility in Asia

In this section, we illustrate the proposed methodology using a simplistic stylized location selection problem faced by a global biotech firm. The problem is to locate a R&D facility in Asia. The following is not an in depth analysis, which is beyond the scope of this work. Furthermore, the evaluation of locations in reality is ultimately made with subjective judgement (though objective and perception data are used) by the investing firm based on its objectives and characteristics [38]. Hence, with the intention of illustrating the methodology we proceed with the following example. The location selection is done at two levels: first at the national level to choose the country and then at the subnational level to choose the location within the country.

6.1 National Location Selection

The investing firm has decided upon a greenfield investment for an R&D facility in one of the following countries in Asia: China, India, and Singapore. These countries are the top three in Asia-Pacific that received highest amount of FDI in R&D for the year 2005 (India 48%, China 29%, Singapore 8%), according to the global investment location database of IBM Plant Location

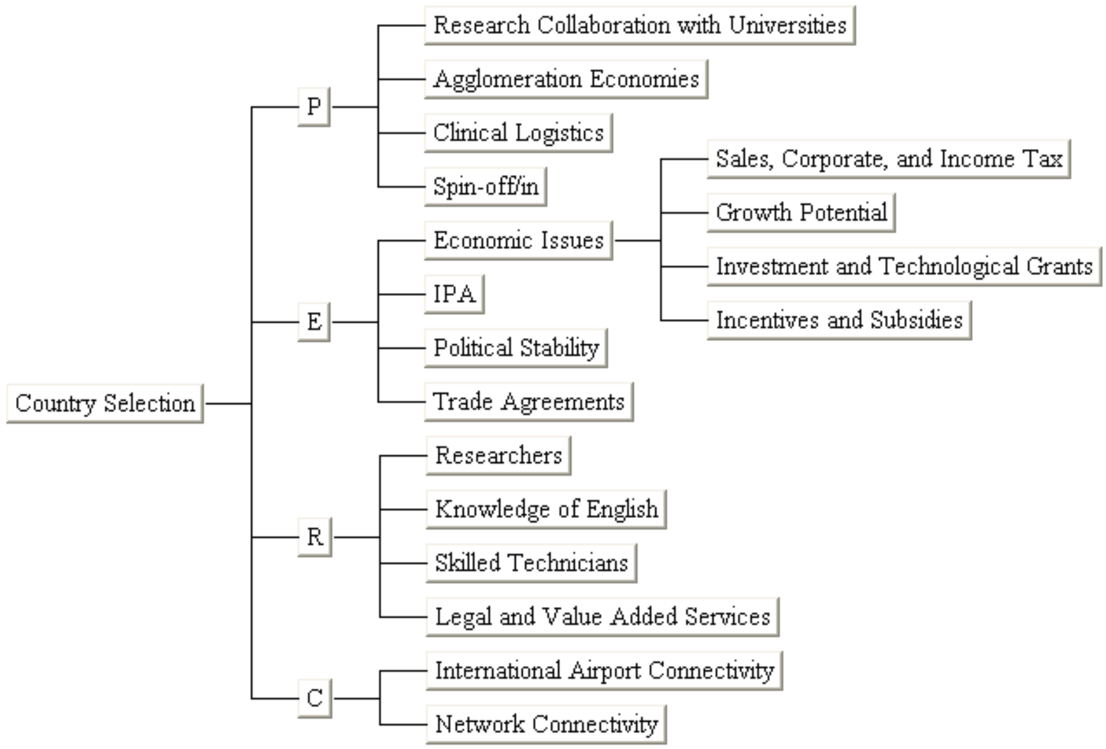

Figure 3: PERC based Hierarchical Structuring for National Location Selection

Table 6: Derivation of Scores for 'Researchers'

	China	**India**	**Singapore**	*Scores*
China	1	1/2	4	0.315
India	2	1	7	0.603
Singapore	1/4	1/7	1	0.082

International. A study conducted by OCO Consulting[6], showed that the following motives drove investments in the biotech sector: skilled workforce availability, government support, finance incentives or taxes or funding, universities or researchers, regulations or business climate, industry cluster, domestic market growth potential, technology or innovation, infrastructure and logistics, and ICT infrastructure. Figure 3 shows the hierarchical structuring developed using the PERC model based on the above motives.

In Figure 3, the attributes at the leaf nodes are measurable with respect to the alternatives. For example, the attribute *Researchers* is a measurable entity for the countries China, India, and Singapore. The scores (or priorities in AHP parlance) of these countries for attribute *Researchers* is obtained by pairwise comparison, as shown in Table 6. The countries are compared pairwise and a scale is assigned for comparison according to Table 5. The diagonal entries are obviously 1, due to the equal importance of comparing the same country with itself. India is assigned a scale

[6]http://www.ococonsulting.com

Table 7: Derivation of weights for the fundamental criteria

	P	**E**	**R**	**C**	*Weights*
P	1	1/3	1/5	3	0.122
E	3	1	1/4	3	0.222
R	5	4	1	6	0.590
C	1/3	1/3	1/6	1	0.066

Table 8: WWW Information Sources.

National Location Choice	
Invest in China	http://www.fdi.gov.cn/
Singapore Economic Development Board	http://www.edb.gov.sg/
FICCI: India in Business	http://www.indiainbusiness.nic.in/
Subnational Location Choice	
Bangalore Helix	http://www.bangalorebio.com/
TICEL, Chennai	http://www.ticelbiopark.com/
ICICI Knowledge Park, Hyderabad	http://www.iciciknowledgepark.com/
Lucknow Biotech Park	http://www.biotechcitylucknow.org/
International Biotech Park, Pune	http://www.ibpl.net/
Indian Investment Centre	http://iic.nic.in/
National Council of Applied Economic Research reports on incentive packages and e-readiness	http://www.ncaer.org/

Table 9: Scores and weights for the country selection

Research Collaboration

	Ch.	Ind.	Sing.	*Scores*
Ch.		1/3	3	0.258
Ind.			5	0.637
Sing.				0.105

Agglomeration Economies

	Ch.	Ind.	Sing.	*Scores*
Ch.		1	4	0.444
Ind.			4	0.444
Sing.				0.111

Clinical Logistics

	Ch.	Ind.	Sing.	*Scores*
Ch.		1/2	4	0.333
Ind.			5	0.570
Sing.				0.097

Spin-off/in

	Ch.	Ind.	Sing.	*Scores*
Ch.		1/2	1/5	0.122
Ind.			1/3	0.230
Sing.				0.648

Sales, Corporate, and Income Tax

	Ch.	Ind.	Sing.	*Scores*
Ch.		3	1/2	0.300
Ind.			1/6	0.100
Sing.				0.600

Growth Potential

	Ch.	Ind.	Sing.	*Scores*
Ch.		1/2	5	0.333
Ind.			7	0.592
Sing.				0.075

Investment and Technological Grants

	Ch.	Ind.	Sing.	*Scores*
Ch.		1/3	1/6	0.100
Ind.			1/2	0.300
Sing.				0.600

Incentives and Subsidies

	Ch.	Ind.	Sing.	*Scores*
Ch.		1/2	1/4	0.143
Ind.			1/2	0.286
Sing.				0.571

IPA

	Ch.	Ind.	Sing.	*Scores*
Ch.		1/2	1/5	0.106
Ind.			1/7	0.150
Sing.				0.744

Political Stability

	Ch.	Ind.	Sing.	*Scores*
Ch.		1/2	3	0.320
Ind.			4	0.558
Sing.				0.122

Trade Agreements

	Ch.	Ind.	Sing.	*Scores*
Ch.		1/2	2	0.286
Ind.			4	0.571
Sing.				0.143

Knowledge of English

	Ch.	Ind.	Sing.	*Scores*
Ch.		1/9	1/5	0.060
Ind.			4	0.709
Sing.				0.231

Table 10: Scores and weights for the country selection (*contd.*)

Skilled Technicians

	Ch.	**Ind.**	**Sing.**	*Scores*
Ch.		1/2	5	0.326
Ind.			8	0.604
Sing.				0.070

Legal and Value Added Services

	Ch.	**Ind.**	**Sing.**	*Scores*
Ch.		1/3	1/5	0.109
Ind.			1/2	0.309
Sing.				0.582

International Airport Connectivity

	Ch.	**Ind.**	**Sing.**	*Scores*
Ch.		1	2	0.400
Ind.			2	0.400
Sing.				0.200

Network Connectivity

	Ch.	**Ind.**	**Sing.**	*Scores*
Ch.		1/2	1/2	0.2
Ind.			1	0.4
Sing.				0.4

Table 11: Weights for the sub-criterion Economic Issues

	Tax	**G. P.**	**I. T. G.**	**I. & S.**	*Weights*
Tax		5	7	3	0.591
Growth			4	3	0.225
I. T. Grants				1/2	0.062
Inc. & Subs.					0.122

Table 12: Weights for the fundamental criterion Product/Process Value Chain

	R. C.	**A. E.**	**C. L.**	**Spin off/in**	*Weights*
Res. Coll.		3	4	9	0.557
Agg. Eco			3	7	0.279
Cli. Log.				3	0.119
Spin off/in					0.046

Table 13: Weights for the fundamental criterion Economic & Political Integration

	E. I.	**IPA**	**P. S.**	**T. A.**	*Weights*
Eco. Issues		1/2	7	7	0.408
IPA			5	3	0.433
Pol. Sta.				1/2	0.060
Trade Ags.					0.099

Table 14: Weights for the fundamental criterion Resources & Management

	Res.	K. Eng.	S. Tech.	Ser.	*Weights*
Researchers		5	3	8	0.591
Know. English			1/2	3	0.134
Skill. Tech.				3	0.213
Services					0.062

of 2 over China, which is an intermediate value between 1 (equal importance) and 3 (moderate importance). Accordingly, China's measure over India in terms of researchers is the reciprocal 1/2. India has a very strong importance (scale 7) over Singapore in terms of researchers. This matrix of scales with an identity diagonal and reciprocal entries allows for the determination of priorities p in 1. The normalized eigenvector p denotes the priorities (scores in this case) of the three countries for the attribute *Researchers*. It should be noted that one can further sub-divide *Researchers* into number of doctorates, post-doctorates, research publications, patents, etc to obtain more authentic and accurate measures. The measure obtained in this paper were based on subjective judgement using information about the three countries from the WWW (Table 8).

The derivation of weights for the criteria and sub-criteria are also obtained using pairwise comparison. The criteria at the same level (siblings) are compared with respect to their parent criterion. For example, the criteria *International airport connectivity* and *Network connectivity* are compared with respect to their parent criterion *Connecting technologies*. The four fundamental criteria P, E, R, and C are compared with the overall goal of selecting the country. The derivation of weights for the fundamental criteria is shown in Table 7. The weights and scores for the remaining attributes and criteria were determined in the same fashion (Tables 9-14). The final score for a location is obtained through multilinear superposition of weights and scores. First the linear combination of scores with the corresponding weights is obtained for attributes that have the same parent criterion. This becomes the score for that criterion. This is repeated for all attributes and all criteria at each level, till the goal node is reached, which gives the final consolidated score for the location. For this synthesis part, Expert Choice software that implements AHP was used. The final ranking of the countries based on our subjective judgement were: India (0.504), China (0.259), and Singapore (0.237). With India chosen as the destination for FDI, selection of a city within India is the next problem to be solved.

6.2 Subnational Location Selection

India has long enjoyed a reputation as a destination for IT and business process outsourcing. Now, the country is fast emerging as a major center for cutting-edge R&D projects for global multinationals. Given its natural resources and the skilled workforce, India has identified its potential in biotechnology nearly two decades ago. Several state governments are making conscious efforts to create a conducive environment to attract entrepreneurs to set up their units and leverage on the vast talent pool and rich biodiversities in the respective states. As a result, India will have at least 20 biotech parks in the next few years. With the availability of biotech parks with built-in facilities,

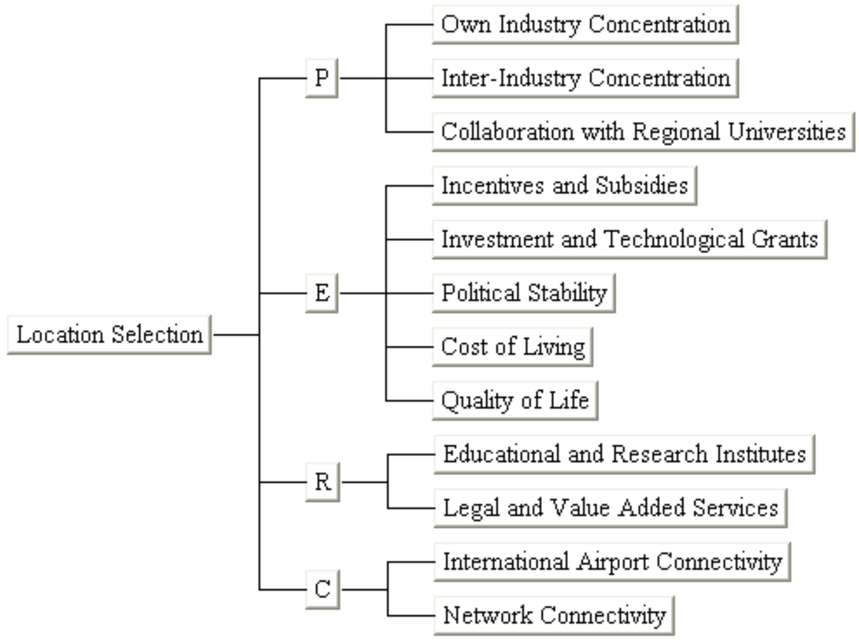

Figure 4: PERC based Hierarchical Structuring for Subnational Location Selection

it is relatively advantageous for the investing firm to locate in a biotech park. The following five cities are considered for investment: Bangalore, Chennai, Hyderabad, Lucknow, and Pune.

The hierarchical structuring for the subnational location selection is shown in Figure 4. Attributes like IPA, trade agreements, and corporate income tax were not considered as they are uniform across the country. Factors like waste handling and regulatory framework were not considered as they were taken care by the biotech parks. The information and data about the locations for the above factors were obtained from the WWW (Table 8). The weights and scores were obtained by pairwise comparison. For the sake of brevity, we have not presented the detailed derivation of weights and scores. The final ranking of cities based on our subjective evaluation were: Bangalore (0.368), Hyderabad (0.217), Lucknow (0.217), Pune (0.126), and Chennai (0.073). This simple example illustrated the practical application of the proposed framework. One can also perform a more detailed study by creating different PERC based hierarchies for each of the benefits, opportunities, costs, and risks and synthesize them to evaluate the locations.

7 Final Notes

In this paper we developed a generic decision framework for aiding the location selection process in global supply chains. The attributes that influence the location selection have evolved with the businesses operating as a single firm to a part of a global supply chain. Location analysis from different studies was complemented and extended to include the global business scenario. The methodology is generic and can be used for many new business processes like BPO and ITeS, which are not as intensively studied as location of manufacturing plants.

The proposed decision methodology for multicriteria evaluation of locations can also be used for measuring investment climate, market attractiveness, and FDI attractiveness. All the above inherently evaluate locations (countries, regions, cities) with respect to different factors, depending on the industry. The methodology can also be used by economic development agencies to evaluate locations. For example, the evaluation of the host location with its competing locations can be used by the economic development agency to identify directions along with developments needing to be carried out. Sensitivity analysis in AHP can aid in determining the level of improvement required for certain criteria in order to attract investments. Governments can also use the methodology to identify the next tier of cities that are potential investment locations. With the continuing increase of FDI in developing countries, many tier one cities are saturated and the governments should plan ahead in identifying and improving the next tier of locations.

The PERC model can also be viewed as a classification of four forces whose interplay is integral to global supply chains. It can thus be used for other strategic problems like partner selection, mode of entry (acquisition, merger, greenfield), and choice of FDI versus outsourcing. It can also be used for performance evaluation of global supply chains. Performance indices like cost and lead time can be measured by identifying the factors along the four dimensions and by modeling their interactions. Another potential research direction is risk evaluation and mitigation along the four dimensions.

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