An Analytical Approach for International Location Problem

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This paper proposes a structured model for evaluating an overseas manufacturing plant using the Analytical Hierarchy Process (AHP) approach. The model is developed using evidence from empirical studies. The paper seeks to demonstrate how the model can help in solving such decisions in real applications. A usability evaluation of the AHP-based model with two companies is investigated. It also examines the structure of the decision hierarchy, whether or not it is capable of representing international location decisions in practice and whether it covers the key factors affecting international location choices. Finally, the effectiveness of the AHP-based model is illustrated using a case company in Thailand.

1. Introduction

The rapid expansion of world-wide competition has forced many firms to move their production bases across national borders in order to gain competitive advantage, as well as providing better and faster customer service. Making decisions on location for the production of products is a key aspect of strategic and logistical decision-making for manufacturing firms as they shape the entire logistics system. However, decisions on selecting new locations on the country in which to manufacture products tend to be complex and depend upon a whole range of factors, most of which relate to the conditions and resource availability within each country under consideration and are difficult to quantify. Moreover, these factors vary according to the characteristics of location decisions such as type of business. Although location decisions have a well-developed theoretical foundation for over century, an analysis of the literature shows that the gap between theory and practice remains, particularly in the international context.

The approaches advocated in location theory are found to be limited in real applications as, in these problems, a large number of qualitative and quantitative factors are involved (e.g. Hoffman and Schniederjans, 1994; Juthrapanich and Benjamin, 1995; Badri et al., 1995; Atthirawong, 2001; Atthirawong and MacCarthy, 2001; MacCarthy and Atthirawong, 2003). Previous research on location decisions often addresses only a single objective. Factors which have been considered in those models are mostly related to costs or factors that are convertible into numerical values. However, location selection is a multiple criteria decision-making problem (MCDM) by nature, as the decisions depend on a variety of factors. Therefore, it is necessary to develop approaches that can take into consideration a wide range of factors including objective and subjective aspects for evaluating international location decisions effectively. It is also important to examine all relevant factors, balancing various objective criteria of firms in terms of benefits, time to deliver products to markets, risks associated with location, quality of labour and quality of products for each location alternative.

This paper presents a structured model for evaluating an overseas manufacturing plant using the Analytical Hierarchy Process (AHP) approach. The proposed model is based on extensive field studies i.e. a Delphi study (MacCarthy and Atthirawong, 2003 and 2001) case studies (Atthirawong and MacCarthy,2002) and a survey (Atthirawong and MacCarthy, 2001). Firstly, an overview of AHP is introduced in section 2. Secondly, the AHP-based model is proposed to evaluate international location decisions in section 3. Thirdly, the model is tested with two companies to examine the structure of the hierarchy, whether or not it is capable of representing international location decisions in reality and whether it covers the key factors affecting international location choices. After that the model is applied to a further company in order to illustrate its application and explore its effectiveness. All these companies are located in Thailand and have foreign participant. Finally, a brief conclusion is summarised.

2. An overview of AHP

The Analytical Hierarchy Process (Saaty, 2000) is a decision approach designed to aid in the solution of complex multiple criteria problems in a number of application domains. This method has been found to be an effective and practical approach that can consider complex and unstructured decisions (Partovi, 1994). The Analytical Hierarchy Process (AHP) is proposed in this research in order to handle both tangible and intangible factors and sub-factors affecting international location decisions. The selection of the methodology is based on the characteristics of the problem and the consideration of the advantages and drawbacks of other methodologies (MacCarthy and Atthirawong, 2000). The decision-maker judges the importance of each criterion in pair-wise comparisons. The outcome of AHP is a prioritised ranking or weighting of each decision alternative. The research has focused on formulating an AHP-based model to select a country in which to locate a manufacturing plant. However, the concepts of the development and the structure of the model will be similar and can be applied to site selections within a particular country.

Basically, there are three steps for considering decision problems using AHP: constructing hierarchies; comparative judgement; and synthesis of priorities, described as follows.

2.1 Establishment of a structural hierarchy

This step allows a complex decision to be structured into a hierarchy descending from an overall objective to various 'criteria', 'sub-criteria', and so on until the lowest level. The objective or the overall goal of the decision is represented at the top level of the hierarchy. The criteria and sub-criteria contributing to the decision are represented at the intermediate levels. Finally, the decision alternatives or selection choices are laid down at the bottom level of the hierarchy.

2.2 Establishment of comparative judgements

Once the hierarchy has been structured, the next step is to determine the priorities of elements at each level (*'element'* here means every member of the hierarchy). A set of comparison matrices of all elements in a level of the hierarchy with respect to an element of the immediately higher level are constructed so as to prioritise and convert individual comparative judgements into ratio scale measurements. The pair-wise comparisons are given in terms of how much element A is more important than element B. The preferences are quantified by using a nine-point scale. '1' means two activities contribute equally to the objective, whereas '9' means one activity is extremely favoured over another (see Crowe et al., 1998; Saaty, 2000; Hafeez et al., 2002 for more details). As the AHP approach is a subjective methodology (Cheng and Li, 2001), information and the priority weights of elements may be obtained from a decision-maker of the company using direct questioning or a questionnaire method.

2.3 Synthesis of priorities and the measurement of consistency

The pair-wise comparisons generate a matrix of relative rankings for each level of the hierarchy. The number of matrices depends on the number elements at each level. The order of the matrix at each level depends on the number of elements at the lower level that it links to. After all matrices are developed and all pair-wise comparisons are obtained eigenvectors or the relative weights (the degree of relative importance amongst the elements), global weights, and the maximum eigenvalue (λ_{max}) for each matrix are then calculated. The λ_{max} value is an important validating parameter in AHP. It is used as a reference index to screen information by calculating the consistency ratio, CR (Saaty, 2000) of the estimated vector in order to validate whether the pair-wise comparison matrix provides a completely consistent evaluation.

If the value of CR is equal to, or less than 0.10 (Saaty, 2000), it implies that the evaluation within the matrix is acceptable or indicates a good level of consistency in the

comparative judgements represented in that matrix. In contrast, if CR is more than the acceptable value, inconsistency of judgements within that matrix has occurred and the evaluation process should therefore be reviewed, reconsidered and improved. The comparative judgements should be reconsidered with respect to the issues raised in section 2.2. The problem may also have to be more carefully restructured i.e. grouping related elements together under a more general topic (Crowe et al., 1998). An acceptable consistency property helps to ensure decision-maker reliability in determining the priorities of a set of criteria.

3. The proposed model using AHP

In this section a conceptual approach for structuring international location decisions using the AHP is introduced. A six level hierarchy decision process displayed in Figure 1 is described below.

Level I: Initially, the objective or the overall goal of the decision is presented at the top level of hierarchy. Specifically, the overall goal of this application is to *'select the best or most suitable country to locate a manufacturing plant'.*

Level II: The second level represents performance capabilities of a firm for setting up a new manufacturing plant and the corporate strategy that a firm uses to outperform competitors, which are identified to achieve the overall goal. The performance capabilities related derive from a number of sources. They are bought forward through the interview process and from operations strategy thinking and theory. According to Slack and Lewis (2002), the performance capabilities can be classified into five aspects: cost, quality, speed, flexibility and dependability. Krajewski and Ritzman (2002) define manufacturing's objectives as cost, quality, time and flexibility. However, in this study, only three issues, which are often mentioned during case interviewing conducted for this

research (Atthirawong and MacCarthy, 2002), i.e. *'cost', 'quality of products'* and *'time to markets'* are used to constitute the second level to achieve the overall goal.

Levels III and IV: The major factors affecting international location decisions are represented at the third level of hierarchy and the fourth level of the hierarchy contains the sub-factors of the each major factor. At this stage, extensive empirical studies i.e. a Delphi study (MacCarthy and Atthirawong, 2003 and 2001) case studies (Atthirawong and MacCarthy, 2002) and a survey (Atthirawong and MacCarthy, 2001) were conducted to identify international location sub-factors from real world decision-making environment. Factors (level III) and sub-factors (level IV) affecting international location decisions were grouped together using factor analysis, cluster analysis and descriptive statistics (Atthirawong and MacCarthy, 2001). A category for other factors and sub-factors are added into both levels so as to provide flexibility in applying the framework in any circumstance. The abbreviations of sub-factors (level IV) are given in Appendix 1.

Level V: Due to a large number of sub-factors involved in international location decisions, it may be difficult to make a pair-wise comparison amongst each sub-factor at the fourth level and location alternatives at the lowest or bottom level (Tam and Tummala, 2001). For this reason, a five-point rating (Liberatore et al., 1992) is introduced into this model and lies at the fifth level of the hierarchy. This level helps to reduce the number of pair-wise judgements that are needed between sub-factors and alternative choices, which normally equals n*(n-1)/2 for each of m sub-factors, where n is the number of alternatives. For instance, if 10 location alternatives are considered, the required pair-wise comparisons equal to 10*(10-1)/2 = 45 for each of 70 sub-factors. This will result in difficulty in the comparison process. The alternative approach is to use the five-rating score of outstanding (O=1), good (G=2), average (A=3), fair (F=4) and poor (P=5) to rate each location alternative according to each sub-factor. Also, this helps to

decrease unexpected bias that might occur in the process of decision-making when there are a large number of sub-factors to be compared. Following this step, the decision need to be made on how much more preferable each of the sub-factors in the fourth level is for each location alternative in the sixth level.

Level VI: Finally, at the lowest level of the hierarchy, the location alternatives of the manufacturing plants are identified, which are decision options.

The AHP model in Figure 1 may be regarded as a feasible way for visualising any international location decision problem systematically. The decision-makers can apply this framework to structure their particular problems in selecting international location choices in many circumstances.

4. Usability testing for the AHP based-model

Not only should a model represent the real-world view, it should also be usable, feasible and useful (Platts et al., 1998; Platts, 1993). Furthermore, the model should be appropriate for application in different types of industry. In this study, usability approach was selected to measure how easily the AHP-based model could be followed in practice (Platts et al., 1998). The aims of this stage are to investigate whether the model covers all factors affecting international location choices. It also aims to measure whether the model enabled decision-makers to formulate their decisions effectively and the model achieved high level of user usability in order to suggest improvements and refinements. The form of an observational evaluation and survey evaluation, using unstructured interview technique was selected for the process of evaluation.

4.1 An overview of the usability evaluation process

The AHP-based model was proposed to two international manufacturing companies by highlighting the benefits of the model and demonstrating how to use it. It also aims to

examine the structure of the hierarchy and test whether the model is easy to use and follow. The question to be answered is whether the proposed model is suitable for international location decisions in different contexts or not. A presentation was made on how the model works and how the process helps managers to make a decision, as well as outlining the process that needs to be followed by each company at the beginning of the meeting. The benefits and disadvantages of using the model for selecting international manufacturing plant were also observed and noted during the evaluation process. Table 1 summarises characteristics of both companies involved in this process.

Table 1: Profile of companies

Company	Products	Interviewee position	Type of venture	Location of parent company
A	Snack foods	Managing Director (Singaporean)	Wholly foreign owned	Singapore
B	Canned foods	Managing Director (Taiwanese)	Joint venture	Taiwan

4.2 Results

The analysis from interviewing those two companies concerning the usability of the AHP-based model provided a considerable amount of information regarding general background of companies, factors affecting international location decisions and the effectiveness of the model in use. The feedback and opinions of the decision-maker of each company as to how the model can help the company to solve such decisions were also noted during the process of evaluation. The companies envisaged that the model is wide enough and could be applied for other industries, by adding relevant factors and sub-factors into *'other'* if some of them are missing. Both companies also commented that the model is easy to follow and helps in learning how to make international location decisions. As a result of the analysis of usability study at this stage, the AHP-based model was further applied with a third company, as described in the next section.

5. Application of the model

The objective of this stage is to illustrate how international location decisions are made using this model and to get feedback to identify the points where the model can be improved to make it more usable and flexible. The model was applied with company C which has a production base in Thailand.

5.1 An overview of company C

Company C is a large sport shoes manufacturer based in the US. All products are exported to end-users mostly in the US and Europe. More than 60% of raw materials are imported from Korea and Taiwan. The company has a high reputation for quality of products. Company C would like to evaluate the possibility of expanding its production base to Indochina (Cambodia, Laos and Vietnam) or China, where wage rates are inexpensive. This may help the company gain more benefits from the potential cost reduction from lower wage rates in the long term. Three alternatives i.e. Vietnam, China and Laos were considered as attractive countries in which the company prefers to expand its production base. Table 2 shows strategic issues, factors and sub-factors that the decision-maker considered were important in the location decision process. The following section is the summary of the results.

5.2 Results and some considerations for location factors

After all information relating to location investment was determined, all pair-wise comparisons were obtained. The relative weights of each element and the consistency ratio of each matrix were then analysed. The results showed that there were inconsistency occurred in some matrices. As a result, the decision-maker was asked to reconsider his judgements on those matrices. After the revision process, the relative weights were combined together with respect to all successive hierarchical levels in order to obtain the global weights of all 17 sub-factors. Table 3 summarises the relative weights and the global priority weights.

Table 2: Hierarchical representation of location factors of company C

Strategic issues (level II)	Factors (level III)	Sub-factors (level IV)
Cost	Direct costs	Wage rates (A1)
		Transportation costs (A2)
		Fixed costs (A3)
	Indirect costs	Tax structure and tax incentives (B1)
		Custom duties (B2)
Quality of products	Labour characteristics	Quality of labour force (D1)
		Availability of labour force (D2)
		Motivation of workers (D3)
		Attitudes towards work (D4)
	Infrastructure	Telecommunication systems (E3)
		Quality and reliability of modes of transportation (E4)
Time to markets	Proximity to markets	Proximity to demand (G2)
		Responsiveness (G3)
	Proximity to suppliers	Quality of suppliers (H1)
		Speed and responsiveness (H2)
	Macro- environment	Consistency of government (I3)
		Industrial regulations laws (I5)

The relative weights and the global weights of all relevant criteria of company C shown in Table 3 could help to explain how the company evaluated location factors. By considering the global weights in the last column of the table, it is found that availability of labour force (0.199920), quality of labour force (0.118453), wage rates (0.110775), motivation of workers (0.105458) and quality of suppliers (0.080173) were ranked in the

top five among those 17 sub-factors. The findings suggest that even though the company is searching for a country where costs of production are inexpensive, the decision is still evaluated taking into account the company's competitive priorities, which has put emphasis on quality of products.

Table 3: Composite relative weights of critical attributes of company C

Strategic issues	Relative weights	Factors	Relative weights	Sub-factors	Relative weights	Global weights
Cost	0.200	Direct costs	0.875	**A1**	0.633	**0.110775**
				A2	0.106	0.018550
				A3	0.260	0.045500
		Indirect costs	0.125	B1	0.750	0.018453
				B2	0.250	0.006250
Quality of products	0.600	Labour characteristics	0.833	**D1**	0.237	**0.118453**
				D2	0.400	**0.199920**
				D3	0.211	**0.105458**
				D4	0.152	0.075970
		Infrastructure	0.167	E3	0.750	0.075150
				E4	0.250	0.025050
Time to markets	0.200	Proximity to markets	0.229	G2	0.100	0.004580
				G3	0.900	0.041220
		Proximity to suppliers	0.601	**H1**	0.667	**0.080173**
				H2	0.333	0.040027
		Macro- environment	0.170	I3	0.200	0.006800
				I5	0.800	0.027200

As mentioned earlier (in section 3), Liberatore's five-point rating scale is employed to rate alternative countries with respect to each sub-factor in order to facilitate and reduce the time and effort in making pair-wise comparisons. The pair-wise comparison matrix of the five-point rating scale is shown Table 4. This matrix is then normalised to obtain the relative weight or eigenvector of each rating scale. The relative weights of outstanding (O), good (G), average (A), fair (F) and poor (P) are calculated using C programming, which are equal to 0.513, 0.260, 0.134, 0.068 and 0.035, respectively.

Table 4: Pair-wise comparison judgement matrix for five-point rating scale

Rating scale	O	G	A	F	P	Relative weights
Outstanding (O)	1	3	5	7	9	**0.503**
Good (G)	1/3	1	3	5	7	**0.260**
Average (A)	1/5	1/3	1	3	5	**0.134**
Fair (F)	1/7	1/5	1/3	1	3	**0.068**
Poor (P)	1/9	1/7	1/5	1/3	1	**0.035**

The decision-maker was then asked to assign the five-point rating scale (outstanding, good, average, fair or poor) of the three countries (Thailand, India and China) with respect to each sub-factor, as depicted in columns 3, 5 and 7 of Table 5. Each rating scale is then converted into its corresponding relative weight obtained from Table 4. Finally, the global weight for each country can be calculated by multiplying the relative weight of each sub-criterion with the relative weight of rating scale and then summing up those values. After renormalising the total scores, the result reveals that Vietnam is the most suitable country to locate a manufacturing plant since it has the highest weight (0.397552) among these countries. China is represented as the second choice (0.311708) and Laos is at the last choice (0.29074) provided by the approach. However, the percentage of weight between China and Laos does not show much difference.

Table 5: Overall rating of three countries identified by company C

Strategic issues, factors and sub-factors		Vietnam		China		Laos	
		Score	*GW	Score	*GW	Score	*GW
Cost							
Direct costs	A1=0.111775	0.068	0.007533	0.134	0.014844	0.260	0.028802
	A2=0.018550	0.503	0.009331	0.260	0.004823	0.134	0.002486
	A3=0.045500	0.503	0.022887	0.503	0.022887	0.503	0.022887
Indirect costs	B1=0.018750	0.503	0.009431	0.260	0.004875	0.134	0.002513
	B2=0.006250	0.503	0.003144	0.260	0.001625	0.134	0.000838
Quality of products							
Labour characteristics	D1=0.118453	0.503	0.059582	0.134	0.015873	0.260	0.030798
	D2=0.199920	0.503	0.10056	0.503	0.10056	0.134	0.026789
	D3=0.105458	0.503	0.053045	0.260	0.027419	0.503	0.053045
	D4=0.006250	0.503	0.038213	0.134	0.01018	0.260	0.019752
Infrastructure	E3=0.075150	0.260	0.019539	0.134	0.01007	0.503	0.0378
	E4=0.025050	0.260	0.006513	0.134	0.003357	0.503	0.0126
Time to markets							
Proximity to markets	G2=0.004580	0.503	0.002304	0.134	0.000614	0.068	0.000311
	G3=0.041220	0.260	0.010717	0.134	0.005523	0.503	0.020734
Proximity to suppliers	H1=0.080173	0.260	0.020845	0.503	0.040327	0.134	0.010743
	H2=0.040027	0.260	0.010407	0.503	0.020133	0.134	0.005364
Macro-environment	I3=0.006800	0.260	0.001768	0.503	0.00342	0.134	0.000911
	I5=0.027200	0.260	0.007072	0.503	0.013682	0.134	0.003645
Total scores		$\sum$	**0.382889**		**0.300211**		**0.280017**
Renormalised scores			**0.397552**		**0.311708**		**0.29074**

The decision-maker concluded that the model provided a powerful and flexible tool for tackling the complex decision process into a simple concept of hierarchy, which incorporates both important financial and non-financial factors influencing the decision alternatives in a systematic way. Moreover, it was also claimed that the process would

not take a long time and can incorporate precise information. However, it is suggested that the decisions might be more accurate or precise if all necessary supporting information and documentation from relevant sources are provided before making such evaluation.

6. Conclusion remarks

This study has proposed an AHP-based model in order to help decision-makers in evaluating international location decisions. The paper investigates how easy the proposed AHP model is to work with by conducting a usability study with two companies and then demonstrating how the model can be applied in real applications. The results show that the model has the capability to be flexible to apply in different types of industries by allowing managers to structure their unique problems into priority weights, which can reflect their own priority considerations. The final priority weight of each alternative at the lowest level of the hierarchy will lead to a recommended best option. It can be concluded that the model could facilitate the decision-making process and assist managers to identify all information sources of input data in order to make pair-wise comparisons. The approach could help in reducing time-consuming effort in the selection process. Not only can the model make trade-offs between both qualitative and quantitative factors, but it also enables decision-makers to deal with inconsistent judgements systematically. The pair-wise comparison procedure is able to capture relative judgements of two elements at one time in a trustworthy manner and ensure consistency of these values. The results also provide an understanding on a set of importance factors influencing international location decisions of a case instance. The feedback from the decision-maker in the case company confirmed the usability, feasibility and value of the approach.

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Appendix 1: Detailed list of strategic issues, factors and sub-factors

Strategic issues (level II)	Factors (level III)	Sub-factors (level IV)
Cost	Direct costs	Wage rate (A1)
		Transportation costs (A2)
		Fixed costs (A3)
		Energy costs (A4)
		Other sub-factors (A5)
	Indirect costs	Tax incentives and tax structures (B1)
		Custom duties (B2)
		Bureaucratic red tape (B3)
		Financial incentives (B4)
		Tariffs (B5)
		Other sub-factor (B6)
	Other factor	Other sub-factor (C1)
		Other sub-factor (C2)
		Other sub-factor (C3)
Quality of products	Labour characteristic	Quality of labour force (D1)
		Availability of labour force (D2)
		Motivation of workers (D3)
		Attitudes towards work(D4)
		Workforce management (D5)
		Other sub-factor (D6)
	Infrastructure	Quality and reliability of utilities (E1)
		Existence of modes of transportation (E2)
		Telecommunication systems(E3)
		Quality and reliability of modes of transportation (E4)
		Other sub-factor (E5)
	Other factor	Other sub-factor (F1)
		Other sub-factor (F2)
		Other sub-factor (F3)
Time to markets	Proximity to markets	Size of markets(G1)
		Proximity to demand (G2)
		Responsiveness (G3)
		Other sub-factors (G4)
	Proximity to	Quality of suppliers (H1)
	suppliers	Speed and responsiveness (H2)
		Other sub-factor(H3)
	Macro- environment	Legal system (I1)
		Attitude of government to inward investment (I2)
		Consistency of government (I3)
		Regulations on transfer of earnings out of country rates (I4)
		Industrial regulations laws (I5)
		Record of government stability (I6)
		Environment regulations (I7)
		Other sub-factor (I8)
	Other factor	Other sub-factor (J1)
		Other sub-factor (J2)
		Other sub-factor (J3)

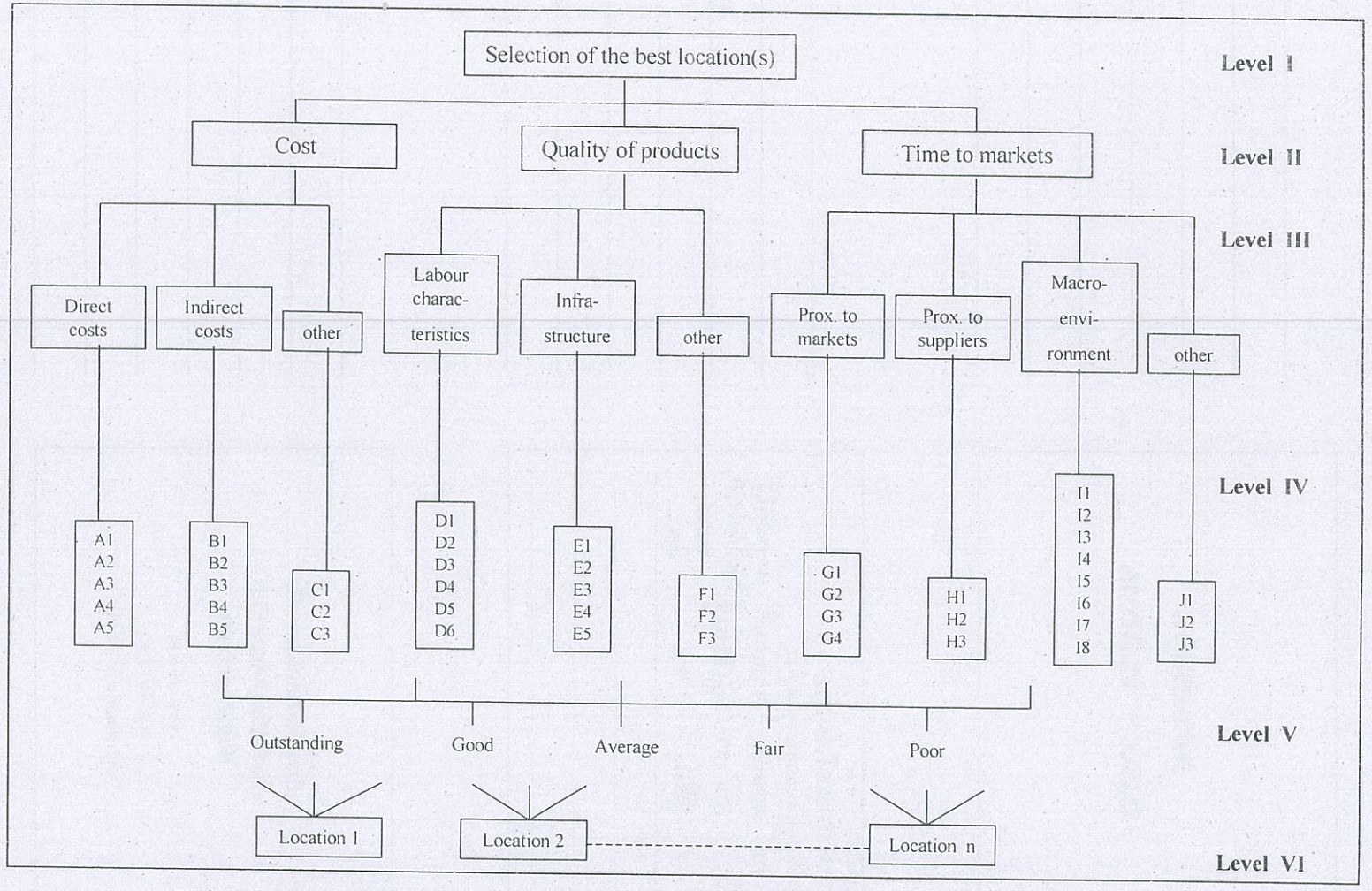

Figure 1: The AHP proposed model for international location decision-making