Application of Analytic Hierarchy Process in Decision Making in Sri Lankan Context with Special Reference to Site Selection for Dedicated Economic Centre of the Northern Province

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***Abstract* - Historically, Northern Province has been a vibrant economic hub, with an educated population and an entrepreneurial workforce. But the people have faced numerous hardships over the years. Many have left due to the conflict, and there is a sizeable group living in vulnerable condition. Conflict has severely curbed economic activity too, with production falling sharply in all crops and manufacturing output also dropping. There are no signs of recovery and the take-off in GDP of the Northern Province. Many credits this to the strong tripartite efforts by government, chambers of commerce and private businesses. The setting up of Dedicated Economic Centers (DECs) was started in 1998 in Sri Lanka, as means of implementing marketing development strategy to provide marketing facilities for producers in the rural areas. Recently, the DEC for Northern Province is a problematic aspect for suitable site selection for the construction activity. Developmental Officers, Public and Politicians are discussing this in different ways but no one did do any proper research and analysis for the suitable site selection. However, the constructions activities have started at Mathakuvaithakulam in Vavuniya District but people are opposing against for this site selection for the construction. Therefore, the researcher applied the Analytic Hierarchy Process (AHP) analysis method for the appropriate site selection for the DEC for Northern Province. The main objective of this study is to identify the suitable site for the DEC for Northern Province using AHP technique by reporting criteria to indicate important aspects with multi-criteria decision analysis method. According to ultimate synthesis results, the Maankulam was selected as a most appropriate site with the 0,235 performance score compared with other three areas. This model and priority area could be used for the decision making among a larger outline of the problems. Development officers and decision makers should be considered this type of analysis and result for the site selection and implementation of the projects.**

Key Words: **Analytic Hierarchy Process, Suitable Sites, Multi-Criteria Decision, Marketing Development, Economic centers**

I. BACKGROUND

The Analytic Hierarchy Process (AHP), developed by Saaty in the late 1970s, is one of the methods for multi-criteria decision making. The AHP disaggregates a complex decision problem into different hierarchical levels. The weight for each criterion and alternative are judged in pair wise comparisons and priorities are calculated by the Eigenvector method. AHP is a technique that has been evolved first in mathematics and then adopted in Military Science, Management decisions and many other fields. The slowly increasing application of the AHP was the motivation for the study to explore the suitable sites for the development oriented tasks.

Historically, Northern Province has been a vibrant economic hub, with an educated population and an entrepreneurial workforce. But the people have faced numerous hardships over the years. Many have left due to the conflict, and there is a sizeable group living in vulnerable condition. Conflict has severely curbed economic activity too, with production falling sharply in all crops and manufacturing output also dropping. There are no signs of recovery and the take-off in GDP of the Northern Province from Rs. 12 billion in 1995 to Rs. 30 billion. Agriculture has the capacity to grow almost exponentially in the years ahead, with a push from the public and private sectors. Today it accounts for around 20% of the Northern Province GDP, but it employs over 50% of the workforce. The setting up of Dedicated Economic Centers (DECs) was started in 1998 in Sri Lanka, as means of implementing marketing development strategy to provide marketing facilities for producers in the rural areas. The subject of establishing DECs which was carried out by the Ministry of Rural Employment Promotion was assigned to the Ministry of Trade, Marketing Development, Co-operatives and Consumer Services in 2007. Accordingly, coordination and supervision of operation of all DECs are done by this Ministry. The objectives of setting up economic centers are to

ensure obtaining reasonable prices for producers for their products and encourage business community by providing competitive marketing environment for traders. Recently, the DEC for Northern Province is a problematic aspect for suitable site selection for the construction activity. Developmental Officers, Public and Politicians are discussing this in different ways but no one did do any proper research and analysis for the suitable site selection. However, the constructions activities have started at Mathakuvaithakulam in Vavuniya District but people are opposing against for this site selection for the construction. Therefore, the researcher applied the AHP analysis method for the appropriate site selection for the DEC for Northern Province.

II. Research Problem

Economic centers are most important to ensure obtaining reasonable prices for producers for their products and encourage business community by providing competitive marketing environment for traders. The fund for this development task was allocated by the Sri Lankan Government through the budget allocation but proper site was not identified by the respective authority. DEC for Northern Province is changed as a problematic aspect without suitable site selection for the construction activity. Developmental Officers, Public and Politicians are discussing this in different ways but no one did do any proper research and analysis for the suitable site selection. However, the constructions activities have started at Mathakuvaithakulam in Vavuniya District but people are opposing against for this site selection for the construction. Therefore, the researcher tried to apply the AHP analysis method for the appropriate site selection for the DEC for Northern Province.

III. Research Objective

The main objective of this study is to identify the suitable site for the DEC for Northern Province using AHP technique. Further, following three objectives were selected to make detail study through this research.

i. To determine the requirements for establishing a Dedicated Economic Centre
ii. To define the suitable criteria and alternatives for DEC
iii. To evaluate alternatives against criteria using the AHP Technique
iv. To validate Solutions against problem statement

IV. Study Area

The Northern Province covers just over 13% (or 8,847 sq.km) of the total land area of Sri Lanka and contains five Districts, Jaffna, Kilinochchi, Mannar, Mullaittivu and Vavuniya. The Boundaries of the five Districts are illustrated in Map 1.

Map:1, Study Area – Northern Province

Source: Structure Plan of Northern Province, 2016

The Province covers the northern parts of the country which are generally flat and low. The Province has a long coastline, a number of inhabited small islands, and is rich in natural resources, particularly the forests, mineral deposits and coastal resources. It has extensive areas of protected forest and woodland as well as coastal and wetland sanctuaries, substantial mineral deposits, and a coastal belt that offers access to fisheries, ports and aquaculture whilst offering tourism potential.

IV. Methodology

A systematic literature review conducted by searching the Reports and Web of Science databases for articles with the following keywords in their titles or abstracts: “Analytic Hierarchy Process,” “Analytical Hierarchy Process,” “multi-criteria decision analysis,” “multiple criteria decision,” “stated preference,” and “pair wise comparison.” In addition, researcher developed reporting criteria to indicate important aspects and criteria for the site selection.

A. Research Design

The Deductive Approach was used to conduct this research because different situational criteria and alternatives included to explore which area most suitable for the DEC. Urban or Town sector stand of the researcher was more helpful to conduct this research. The researcher became closer to the actors’ perspective through semi structured questionnaire survey and observations based on the following Criteria and alternatives which are in Figure 2.

I. Steps of the Analytical Hierarchy Process (AHP): Since real world problems have complex nature, decision makers may fail to perceive whole aspects of the problem together. This situation may lead wrong decisions. Multi-Criteria Decision Making (MCDM) techniques provide facilities in that decision makers can tackle with structuring multi-dimensional problems.

Analytical Hierarchy Process (AHP) is one of the MCDM tool, developed by Thomas Saaty. So far, many researchers have paid attention on AHP to pleasant mathematical attributes and easy-to-understand algorithm of the method. During the decision process, AHP combines tangible and intangible variables affecting the goal together as a remarkable benefit. Therefore, many kinds of metric factors as well as perceptions, feelings, judgments etc. are organized into the same framework. AHP transforms several kinds of problems into a multilevel structure of criteria, sub-criteria, and alternatives. Briefly, the procedure of AHP is as follows (Rahimdel & Ataei, 2014):

Step 1: The hierarchical structure is found from the top level (the main goal of research) through subsequent levels being criteria, sub-criteria, and alternatives (Saaty, 2001, pp. 29-36).

Step 2: The importance weights of criteria and sub-criteria are derived from pair wise comparisons. These comparisons are also used for obtaining relative performance of alternatives in terms of each criterion. Hence, verbal judgments are converted into a numeric score by using 9-point scale and demonstrated in an n x n pair wise comparison matrix (Saaty, 2006, p. 69)

$$A=\begin{matrix} 1 & a_{12} & --- & a_{1n} \\ A_{21} & 1 & --- & a_{2n} \\ --- & --- & --- & --- \\ A_n\ 1 & a_{n2} & --- & 1 \end{matrix} \qquad (1)$$

Step 3: Just as pair wise comparison matrix is found, priority vector bringing the weights of elements is calculated. Let the importance degree of its criterion is W_i then,

$$w_i = \frac{(\prod_{j=1}^{n} a_{ij})^{1/n}}{\sum_{i=1}^{n}(\prod_{j=1}^{n} a_{ij})} \qquad i, j = 1,2,\ldots, n \qquad (2)$$

Step 4: In this stage consistency level of criteria priorities are checked whether assessment of pair wise comparison matrix makes sense and acceptable or not. Let c stands for an n-dimensional column vector which depicts the sum of the weighted scores as the priorities of criteria, then,

$$c = [c_i] = AW_{nx1}^{T}, \qquad i = 1,2,\ldots,n \qquad (3)$$

In which

$$AW = \begin{pmatrix} 1 & A_{12} & --- & A_{1n} \\ A_{21} & 1 & --- & A_2 \\ --- & --- & --- & --- \\ A_n\ 1 & A_{n2} & --- & 1 \end{pmatrix} \begin{pmatrix} W1, W2, \ldots, Wn^{T} = \end{pmatrix} \begin{pmatrix} C1 \\ C2 \\ \hline \\ Cn \end{pmatrix}$$

The vector $CV = [cv]_{nx1}$ stands for consistency scores for each group of criteria. A typical element of cv_i is defined as the follow:

$$cv_i = \frac{c_i}{w_i}, \qquad i = 1,2,\ldots, n \qquad (4)$$

In case consistency of criteria is not satisfactory, AHP has a mechanism in order to compensate for this problem. Saaty suggested using the maximal Eigen value λ_{max} to overcome inconsistency which diminishes the effectiveness of measurement. The maximum Eigen value $\lambda_{max}$is calculated as follow:

$$\lambda_{max} = \frac{\sum_{i=1}^{n} cv_i}{n}, \qquad i = 1,2,\ldots,n \qquad (5)$$

The consistency index CI, taking the maximal Eigen value into consideration, is calculated as follow:

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad (6)$$

Here, when the difference between maximal Eigen value λ_{max} and n decreases, the consistency level CI gets rise until pair wise comparison matrix is completely consistent in which the situation CI =0. In order to interpret the level of consistency, a consistency ratio (CR) is described as CR = CI RI in which the RI stands for the average random index (see Table 1). As long as CR is lower than 0,1 consistency of criteria weights are considered to be reasonable.

TABLE 1

RANDOM CONSISTENCY INDEX (See Annex)

Step 5: Priorities regarding approximate importance degrees of criteria are identified. Then, ranks of alternatives are determined to what extent each of alternatives performs in terms of every single criterion in total is calculated.

B. Methodological Framework

When conducting a research, it is important to identify the framework of the methodology for the detail study by step by step. The following Figure 1 indicates the overall method of the study.

Figure: 1, Methodological Framework (See Annex)

There can't be fixed the time and resources without proper framework of research. Therefore, the figure 1 shows clearly the methodology of this research. The objective of the study is to select the most appropriate land for the construction site of DEC among four alternatives, all of which are in Vavuniya and Mullaitivu districts of Sri Lanka. For this purpose, an AHP rating model has been proposed.

Figure 2: Criteria and Alternatives for the site selection of EDC (See Annex)

C. Strategy of Inquiry and Design

When conducting a research, it is important to identify the framework of the design for the study. Here, the research questions approached using mixed methods research approach to conduct this research and flexible research design which included semi-structured questionnaire and interviews with research participants, as well as use of quantitative data to investigate alternatives for the site selection.

In other hand, Qualitative and quantitative studies were applied with the intention of providing a description to the concept and theories of AHP technique and DEC. Qualitative study methodology offered tools for the researcher to study amalgamated phenomenon within their contexts. It provided the chance to search or explain an aspect in perspective using an array of data sources. Quantitative study method helped to analysis the primary data which were collected through the questionnaire survey, Interview and discussions.

D. Data Collection

It should be cleared which types of data, method of collection and techniques of data before entering the field. Here, types of data and process of data discuss following.

I. *Types of Data and methods of data collection:* The most common sources of data are in two types which are primary and secondary data. Primary data were collected by observation, interview, Questionnaire and discussion. Thorough the observation, visiting around the sites of around 10 km with friends and alone with covering the center and neighborhood areas which were highlighted the particular site's aspects such as social impact, Economical Aspects, Environmental Impacts and physical aspects. Interview was conducted with subject knowledge persons, Public and relevant field workers. The discussion conducted to investigate stakeholders' thoughts and feelings about the sties, its impacts and other regional growth of the areas. Further structured questionnaires were distributed and collected to get the demographic, social, economic, environmental, physical and technical impacts of the EDC which were distributed to the Officers from different Departments, People from CBD, Public or interest groups, Designers – Engineers, Architects, Planners and Special Interest Groups – suppliers, manufacturers and Environmentalists. Nearly 50 questionnaires were distributed to each site. 200 questioners totally were distributed for the data collection.

II. *Data Analysis:* Multi-criteria decision making system used for the analysis. The AHP disaggregates a complex decision problem into different hierarchical levels. The weight for each criterion and alternatives were judged using pair wise comparisons matrix and Normalized matrix, priorities were calculated by the Eigenvector method.

V. Result

The AHP applied inconsistently in developmental decision making research in the Sri Lankan Context and especially local context. Based on the fundamental scale of pair wise comparison and normalized matrix, the collected data were analyzed including social, economic, environmental, physical and technical impacts of every site. There was selected suitable site for the Dedicated Economic Centre for the Northern Province in Sri Lanka according to the AHP technique.

As it is shown in Table 2, the most important factor affecting the site selection decision is "Economic Factors" and the most important sub-criteria of which is "Availability of Land". Since consistency ratios are smaller than 0.10, they are both acceptable.

TABLE 2

Criteria Weights and Consistency Ratio (See Annex)

Table 3 indicates performance measurements of alternatives on each criterion according to AHP rating scales determined before. Preference rank has derived from the appropriate combination of these measures and criteria weights within the concept of AHP algorithm.

TABLE: 3

Performance Measurements of Alternatives (See Annex)

According to ultimate synthesis results, the most appropriate site is Maankulam with the 0,235 performance score compared with other three areas. That shows the high scores in social, economic, environment and physical/ technical aspects and overall factor analysis as well.

VI. Conclusion

The main objective of this paper is to identify the suitable location for the DEC for the Northern Province of Sri Lanka. No matter how complicated nature has the planning stage of any project, the proposed AHP rating model organizes and structures many sorts of tangible and intangible variables so that leaders can make the accurate decision for the benefits of regional development and people. Thus, usage of this model during the early stages of projects may bring significant competitive advantage to operators.

In significance of the study, it was found that criteria are ranked according to their priorities as Social Factors, Economic aspects, Environmental Position and Physical/

Technical aspects in descending and deductive manner. As the most important criterion, economical aspects assure the long quality of the development. It means what makes a residential project more "humanistic" should always come first in site selection decision. The thing promising more value in terms of primary humanistic needs is sufficient surrounding space in the project area as represented in sub-criterion.

The criterion of Maankulam is mostly derived from all factors as a result of their combination which is most suitable place for the construction of the DEC for the Northern Province based on the analysis. However, Legal Status has not included into the weighting in all criteria. It indicates that decision-makers in project team dedicate to legal boundaries of site selection in their mind. Normally, legal restrictions are not so stiff associated with regional attributions, that they affect site selection decisions in practice. The apparent limitation of the study is that only one multi criteria decision method was used along the AHP technique. It is also crucial that criteria worked in the model rather focus on DEC and customer's benefits, social, cultural, economic and environmental aspects of urbanization are included. These are important to ensure sustainable development in any branches of human life. Customers and consumers can easily do their activities with the parking facilities, pleasant environment and maintenance facilities. Therefore, the model and priority area could be used for the decision making among a larger outline of the problems. Development officers and decision makers should be considered this type of analysis and result for the site selection and implementation of the projects.

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ANNEXES

TABLE 1

RANDOM CONSISTENCY INDEX

r	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0,0	0,0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48	1,56	1,57	1,59

Source: (Saaty, 1988, p. 21)

TABLE 2
CRITERIA WEIGHTS AND CONSISTENCY RATIO

	Factors for the DEC	Normalized Weights				Idealized Weights	Consistency Ratio			
		1	2	3	4		1	2	3	4
Criteria	1. Social	0,291	0,268	0,302	0,465	0,925	0,038	0,074	0,024	0,096
	2. Economic	0,564	0,411	0,213	0,562	1,000				
	3. Environment	0,321	0,378	0,356	0,497	1,000				
	4. Physical / Technical	0,456	0,211	0,201	0,532	0,899				
Sub Criteria	1.1 Residential Land Area	0,221	0.201	0,112	0,211	0,166	0,057	0,253	0,325	0,547
	1.2 Community Places	0,234	0.122	0,101	0,152	0,313				
	1.3 Stake holders' Interests	0,113	0,153	0,201	0,185	0,369				
	2.1 Proximity to Demand Centers	0,101	0,125	0,211	0,275	0,302	0,089	0,078	0,074	0,098
	2.2 Market Value	0,256	0,153	0,112	0,189	0,356				
	2.3 Availability of infrastructure	0,152	0,152	0,132	0,175	0,268				
	2.4 Agricultural Land Area	0,231	0,111	0,112	0,241	0,325				
	3.1 Environmental Sensitive Areas	0,159	0,321	0,125	0,186	0,425	0,012	0,025	0,032	0,051
	3.2 Community Places within Noise Contours	0,321	0,421	0,212	0,155	0,652				
	4.1 Atmospheric Conditions	0.241	0,321	0,163	0,285	0,368	0,050	0,045	0,036	0,053
	4.2 Availability of Land	0,111	0,024	0,214	0,166	0,325				
	4.3 Distance / Accessibility	0,135	0,120	0,152	0,145	0,285				
	4.4 Obstacles/Disasters	0,211	0,123	0,165	0,152	0,352				

Source: Author, 2018

TABLE: 3

PERFORMANCE MEASUREMENTS OF ALTERNATIVES

Criteria and Sub Criteria	Omanthai	Thandik Kulam	Mathakuvaiththa Kulam	Maankulum
1. Social				
1.1 Residential Land Area	Available	Available	Available	Unavailable
1.2 Community Places	Very Close	Very Close	Very Close	Near
1.3 Stake holders' Interests	Medium	Low	Low	High
2. Economic				
2.1 Proximity to Demand Centers	Below Average	Below Average	Below Average	Excellent
2.2 Market Value of the Land	High	High	Medium	Medium
2.3 Availability of infrastructure	Above Average	Below Average	Below Average	Excellent
2.4 Agricultural Land Area	Less	Less	Less	High
3. Environment				
3.1 Environmental Sensitive Areas	Less	Less	Less	Available
3.2 Community Places within Noise Contours	High	High	High	Less
4. Physical / Technical				
4.1 Atmospheric Conditions	Average	Average	Average	Excellent
4.2 Availability of Land	Less	Less	Less	High
4.3 Distance /Accessibility	Restricted	Restricted	Restricted	Unrestricted
4.4 Obstacles/Disasters	Less	Less	Less	Less
Normal Score	0,186	0,126	0,123	0,235
Ideal Score	0,682	0,569	0,532	0,835
Ranking	**2**	**3**	**4**	**1**

Source: Compiled by Author during data Analysis, 2018

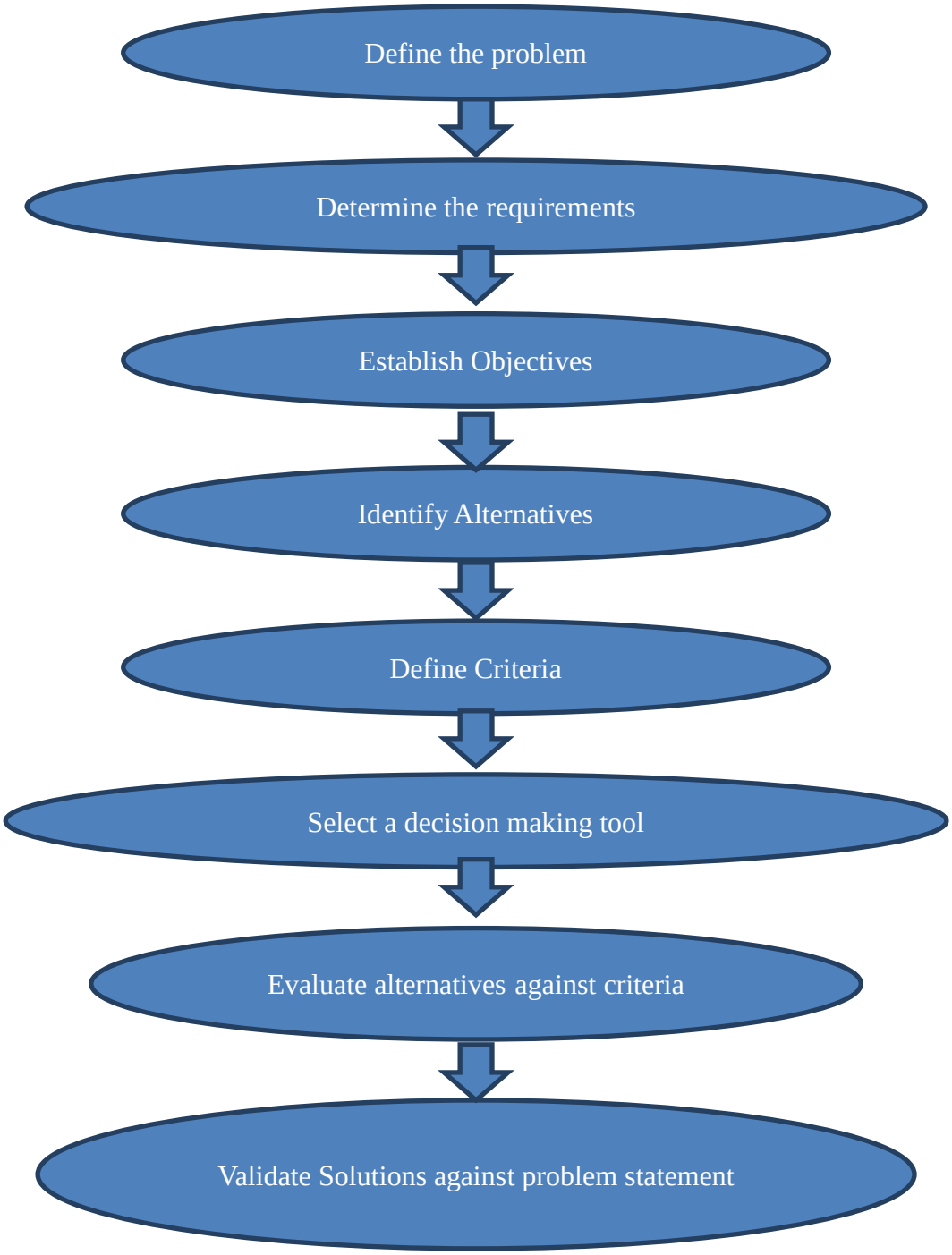

Figure: 1, Methodological Framework

Source: Compiled by author, 2017

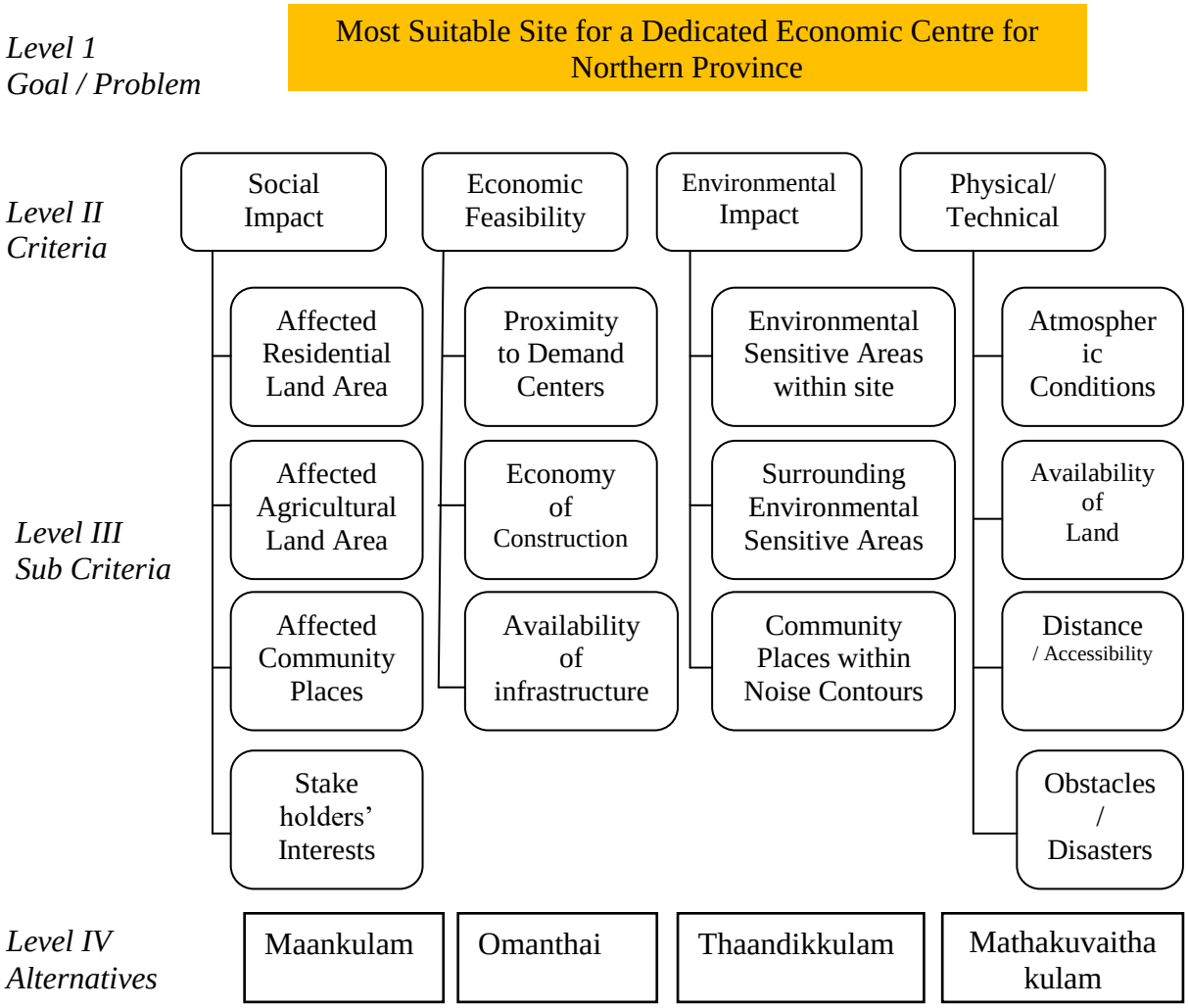

Figure 2: Criteria and Alternatives for the site selection of EDC

Source: Compiled by author, 2017