EVALUATION AND ANALYSIS OF LAND USE SUITABILITY OF RECENT DEVELOPMENT PLAN OF COX'S BAZAR AREA

FARZANA KHATUN

DEPARTMENT OF URBAN AND REGIONAL PLANNING (DURP)
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET), DHAKA

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THESIS ACCEPTANCE FORM

The thesis titled **"EVALUATION AND ANALYSIS OF LAND USE SUITABILITY OF RECENT DEVELOPMENT PLAN OF COX'S BAZAR AREA"** submitted by **Farzana Khatun,** Roll No: **1009152013 P,** Session: **OCTOBER, 2009** has been accepted as satisfactory in partial fulfillment of the requirement of the degree of Master of Urban and Regional Planning (MURP) on 29th June, 2014.

Board of Examiners

1. --- Dr. Mohammad Shakil Akther Supervisor Professor, Department of URP, BUET, Dhaka-1000.	Chairman
2. --- Dr. Mohammad Shakil Akther Head, Department of URP, BUET, Dhaka-1000.	Member (Ex-Officio)
3. --- Dr. Ishrat Islam Professor, Department of URP, BUET, Dhaka-1000.	Member
4. --- Ms. Rezwana Rafiq Assistant Professor, Department of URP, BUET, Dhaka-1000.	Member
5. --- Dr. Akter Mahmud Professor, Department of URP, Jahangirnagar University, Savar, Dhaka.	Member (External)

CANDIDATE DECLARATION

I hereby declared that this thesis has been prepared in partial fulfillment of the requirements for the degree of Master of Urban and Regional Planning at the Bangladesh University of Engineering and Technology, Dhaka and has not been submitted anywhere else for any other degree.

Signature of the Candidate

Farzana Khatun
Student No: 1009152013 (P)
DURP, BUET, Dhaka.

Dedicated to

My Mother, My Husband, My Sister and my family members

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Abstract

Bangladesh has been experiencing rapid growth and development since last few decades. This development has been mostly unplanned and spontaneous, resulting in acute pressure on the resources. The most affected of all, arguably, is the land resource which is acutely over-utilized and constantly being polluted to support the huge population of Bangladesh. The reasons for declining of the land resource can be attributed to unplanned and illegal development of land, poor land administration and management system, absence of proper land use planning etc. It is now of utmost importance to ensure the most effective and optimum use of land resources. For that purpose there is no alternative to systematic land use planning. To achieve that goal "Land use suitability analysis" is a pivotal instrument. Land use suitability analysis is a process through which the most suitable use for a parcel of land is determined depending on several criteria. Important international guidelines like "FAO framework" of 1976 describes land use suitability as a must before any kind of development. Various types of land use suitability analysis are conducted in different countries. Unfortunately this type of exercises has not been practiced in Bangladesh, even though there have been a number of attempts to create various development plans nationwide. None of these plans have attempted to justify the suitability of proposed land uses. This may result in proposing unsuitable land uses which in longer term would adversely affect the sustainability of the plans. So, to ensure the most effective and efficient use of a given tract of land, land use suitability analysis is a must in every development plan.

This study aims at analyzing the land use suitability of a one of the Ecologically Critical areas, Cox's bazar, which is also the most famous tourist spot in the country. For environmentally critical area it is of utmost important to protect the resource without hampering the development potential. Recently the development

plan of Cox's Bazar District has been prepared. But like other development plans, Cox's Bazar development plan was also prepared without any land use suitability analysis. This study successfully attempted to analyze the land use suitability in the Cox's bazar *Paurashava* (municipality) and surrounding area and then compare the proposed land uses in the development plan to the results from suitability analysis.

For analyzing the land use suitability Fuzzy AHP method was applied incorporating GIS software in the process. This study focused on the finding out suitable places for residential and commercial development. At the first step, suitable criteria for analyzing residential and commercial land use suitability were determined through expert opinion and elaborate literature study. Three types of criteria were considered for both residential and commercial land use suitability: physical factors, development factors and environmental factors. For residential land use suitability analysis physical factors were: slope and elevation; development factors were: Proximity to existing residential area, Proximity to existing commercial area, Proximity to existing nearest paved road, Proximity to open space and recreational area; and environmental factors were: Distance from existing water body, Distance from existing forest and vegetation and Distance from Sea-beach area. Similarly physical criteria for commercial land use suitability were slope and elevation; development factors were: Proximity to existing residential area, Proximity to existing commercial area, Proximity to existing nearest paved road; and environmental factors were: Distance from existing forest and vegetation, Distance from Sea-beach area. The weights of these criteria were determined through Fuzzy AHP method and Chang's extent analysis. Considering those criteria suitability analysis was conducted through a model in GIS software. Once a suitability map was generated, this was compared to the proposed land uses in the "Cox's Bazar development plan" to identify matched and mismatched land uses.

From the analysis it was found out that 97.68 sq km area was suitable for residential development and 92.5 sq km was suitable for commercial

development. Around 10.25 sq. km cannot be utilized for development and hence restricted zone. Separate suitability maps were generated showing the suitable land parcels for each land use type. From the comparison of the proposed land uses in the development plan to the suitability map, it was seen that a considerable amount of development was proposed in the plan on unsuitable and restricted zone, which may hamper the sustainability of the plans in future. From the analysis it was evident that about 94% of the total proposed residential land use was in the highly and moderately suitable lands which only cover 39% of the total suitable land area. However, most strikingly, 5.08% of the total proposed residential area is proposed to be built in the restricted zone as defined by the suitability analysis. The land use proposed in the moderately suitable and restricted zone could have easily been shifted to the highly suitable area, had there been a suitability analysis done. In the long run this would have helped in achieving the goal of sustainable development. Similarly, 85.89% of the total proposed commercial land falls in the highly and moderately suitable land and 14.11% of the total proposed commercial land use falls in the low suitable and restricted zone, which can easily be shifted to the high and moderate suitable zone.

The outcome of this study will help decision makers and practitioners from different fields to understand the importance of land use planning and suitability analysis. It can be very useful tool for strategic policy preparation, development control and guidance, zoning etc. and very helpful for central, local authorities, private organizations involved in development planning and implementation.

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List of Abbreviations

AHP: Analytic Hierarchy Process

BBS: Bangladesh Bureau of statistics

DoE: Directorate of Environment

ECA: Ecologically Critical Areas

FAHP: Fuzzy Analytic Hierarchy Process

FAO: Food and Agriculture Organization

GIS: Geographic Information System

MCDM: Multi Criteria Decision Making

UDD: Urban Development Directorate

Chapter 1: Introduction

1.1 Background and statement of the problem:

Land is arguably the scarcest resource in Bangladesh which is acutely over-utilized and constantly being polluted to support its huge population. Moreover, unplanned and illegal development of land, poor land administration and management system etc. are making this crucial resource more vulnerable for future use. Ensuring the most effective and optimum use of land resources has become the most important planning issue in our country. There have been a number of attempts to create various development plans nationwide, but none of these plans have attempted to justify the suitability of proposed land uses. This may result in proposing unsuitable land uses which in longer term would adversely affect the sustainability of the plans. So, to ensure the most effective and efficient use of a given tract of land, land use suitability analysis is a must in every development plan.

Land use suitability analysis is the process of finding out the mostsuitable use for a given tract of land with respect to some criteria like physical attributes of the land, social perception of people in that particular land area, existing natural resources and environmental factors of the area and its surrounding, economical factors related with the land etc.(Hopkins, 1977).

"FAO framework" of 1976, describes that land suitability analysis is a must before any kind of development (FAO 1976). In many decision making and planning processes of different countries, land suitability analysis has become a vital part (For example, various states of the USA, Yemen) (Al-Mashreki, et. al. 2011, Parker et. al. 2011, Garfield County, 2011). But it is a matter of concern and regrets that almost none of the development plans in Bangladesh has a systematic policy or rule for land suitability analysis.

Recently the development plan of Cox's Bazar District has been prepared. Cox's Bazar area, is one of the most well-known places for tourism in Bangladesh. Around two million people visit Cox's Bazar area in the peak season from November to March(Ahmed, 2010).It is famous for her unbroken sea beach which is the longest in the world. It is also richin bio-diversity as15933 birds of 52 species have been spotted in Cox's Bazar (the Daily Star, 2009). In 1999, asperEnvironmentalConservation Act 1995, Cox's Bazar to Teknaf Peninsula and Saint Martin's Island was declared as Ecologically Critical Areas (ECA). ECA are those ecosystems which are adversely affected by human activities and in a critical state in terms of loss of biodiversity. These Environmentally Critical Areas (ECAs) can be put forward as a critical issue in the process of uncontrolled land development in Bangladesh.

Land use suitability analysis is an integral component of land use planning. For environmentally critical area it is of utmost important to protect the resource without hampering the development potential. For example in between 2004 to 2011 Cox's bazar lost 25% of its coral reef due to increase tourism activity (Sheltech, 2011). For economic growth of the region, it is necessary to have increased number of tourists but at the same time it is necessary to have the coral reef. These can only be done through a proper land use planning and a landuse plan cannot be called 'proper' unless it considers all issues regarding the use of a particular parcel of land. This can be done through 'land suitability analyses'.

However land suitability analysis is a complicated process. It is very contentious to decide the most appropriate use for a certain parcel of land, as there are many alternatives to choose from, which in turn incorporate different conflicting beliefs, interests, views, goals of different stakeholders. This makes the whole process essentially a Multi-Dimensional Decision Making problem which can be handled and evaluated through Multi Criteria Decision Making (MCDM) technique. This is a method which helps to combine the preferences and opinions of different stakeholders in a matrix to develop a final structure for ranking, screening or selecting different alternatives (Kahraman, 2008).There are several techniques of MCDM approach for land use suitability analysis. The most common methods are Boolean overlay (such as AND or OR) and Weighted Linear Summation. These methods are criticized most for not reflecting the decision makers' views clearly and comprehensively. For example, in Boolean logic, it imposes rigid value (0 and 1; where truth value is 1 or otherwise 0) to different criteria. As a result, some of the alternatives may be totally eliminated based on the strict logic of *Yes* or *No,* which is not the reflection of the real world, as preferences can be subjective which cannot be categorized into two distinct spheres. To overcome these problems, Analytic Hierarchy Process (AHP) is introduced in MCDM approach. The principle of AHP is to express the judgments analytically by breaking down a problem into its smaller constituent and by assigning weights (1 to 9 scale) using pairwise comparison matrix which reduce biasness in the weights (Saaty, 1980).However this technique was criticized as it gives single crisp numbers to the judgments which is not the proper way to deal with the inherent uncertainty and imprecision associated with the decision making process (Malczewski, 2004).To overcome this, a special kind of vagueness in the preferences of the decision makers fuzzy logic technique can be used(Zadeh, 1965).This approach is based on fuzzy set theory which allows decision makers to give interval judgments rather than giving concrete or crisp values to any particular criteria when multifaceted decision making problems are considered. Integrating fuzzy logic into the AHP process provides a much improved and more accurate representation between criteria and alternatives (Malczewski, 2004; Jiang, et. al., 2000; Kahraman, 2008).

For a more efficient decision making process, especially while working with spatial problems like land use suitability analysis, GIS can play a pivotal role. GIS-based land-use suitability techniques are getting popular as an integral component of urban, regional and environmental planning during the last few decades (Malczewski, 2004).Integration of Multi Criteria Decision Making (MCDM) technique in GIS environment for land suitability analysis has beencommon and continuously evolving (Malczewski, 2004).

Though there were many studies on integrating fuzzy AHP in GIS (Prakash 2003, Manlun 2003, Sun, et. al. 2009, Tsiko, et. al., 2011,) no work has been done on this in Bangladesh. Though land use planshave been prepared for development of ecological areas in Bangladesh (For example Cox' Bazar) but none has taken steps considering the issue. Bearing this in mind, this studyhas been undertaken to evaluate a development plan in ecological sensitive area. As mentioned earlier Cox's Bazar is an ecological sensitive but economically prospective area. The preparation Cox's bazaar development plan was initiated in 2010 by Urban Development Directorate and the consultant submitted the plan in 2013 pending approval by the government. This research aimed at evaluatingthis development plan on the basis of land suitability analysis using fuzzy AHP.

1.2 Objectives of the study:

The aimof this study wasto analyze the land use suitability of Cox's Bazar area and evaluate it by a comparison with the recent development plan of this area.To attain the aim the following objectives were set-

- ✓ To analyze the land use suitability of Cox's Bazar *Pourashava* (municipality) and surrounding area using Fuzzy AHP technique of MCDM approach in GIS platform
- ✓ To compare the result with the recent development plan of Cox's Bazar District.

1.3 Rationale of the study:

The outcome of this research will help decision makers, practitioners of different fields to understand about the importance of having a proper guideline for land use suitability analysis in any development plan and to deal with spatial multi-dimensional decision making problems. This study will help to give an understanding that even qualitative data, like experts' opinions or decisions, can also be quantified with some technical approach or tools which will make decision making smoother and more scientific. With a systematic process of land use suitability analysis, development planning and management can be better guided and efficient.

1.4 Scope and limitation of the study:

This study focused on identifying land suitability for Residential and Commercial land uses in the Cox's Bazar *Pourashava* and surrounding areas based on various criteria and factors. During the selection of the factors and their relative importance, literature was reviewed and expert opinions were sought. But this should not be considered as an exhaustive list of criteria. Few criteria were not considered due to the unavailability of a baseline of those criteria in the study area. The existing GIS and other database have limitation of having different projection systems and attributes, incompleteness and errors. These may have influenced the findings. Based on the finding from this analysis, the proposed Residential and commercial land uses in the "development plan" is compared.

This study was focused on only residential and commercial land uses. Further study with larger timeframe, fund and scope is necessary to analyze and compare other types of land uses than residential and commercial uses and collect data on more criteria to incorporate in the analysis, based on the methodology followed in this study.

1.5 Organization of the report:

This study is organized in six chapters. Chapter 1 outlines the background, goal and objectives of the study, rationale and scope and limitation of the study. Chapter 2 outlines the theoretical framework. In this chapter the theories behind multi-criteria decision making approaches, application of GIS and incorporating GIS in land suitability analysis, suitability analysis criteria, ecologically critical areas, global practice in land use suitability analysis etc. are discussed elaborately. Chapter 3 describes the methodology of the analysis in details. Chapter 4 highlights the study area – Cox's Bazar *Pourashava* and its surrounding area. Chapter 5 and 6 presents major input, output, analysis and findings of the study. Thesechapters explain how the criteria were analyzed using Fuzzy AHP, suitability maps were prepared and then the proposed land uses in the development plan were compared to the suitability maps. The last chapter presents the findings and recommendations based on the analysis of the research.

Chapter 2: Theoretical Framework

There are many literatures over the land suitability analysis, its' methodology, different techniques about Multi Criteria Decision Making process, GIS applications in land suitability analysis etc. This chapter describes all these literatures along with their merits and demerits. The selection of the suitability criteria were also discussed here. An overview of Ecologically Critical Areas of Bangladesh was also given in this chapter.

2.1 Land Suitability Analysis:

Land suitability analysis is the process of determining the appropriateness of a given tract of land for a defined use (Hopkins 1977; Steiner 1983). It is the process to determine whether the land resource is suitable for some specific uses and to determine the suitability level. This is the process for determining the most desired future development direction of any site. It is done to determine the suitable factors for any kind of suitability analysis. Initially suitability analysis was developed for planners as a method to connect the spatial factors within the environment. Suitability analysis techniques integrate three factors of an area: location, development activities and biophysical process (Miller, et al. 1998). These techniques help planners, architects and local decision makers to make decisions and establish policies in terms of specific land uses. Though land suitability analysis is a well-known tool among different practitioners, there are few examples where one process of one place is used or transferred in other places (McHarg, 1969 and Lyle 1985). Applications of land use suitability analysis can be found in many fields such as suitable site selection for crop land (natural resource management field), flooding control, and sustainable development (environment management) etc. Over the past few years GIS (Geographical Information System) has been proved the most efficient environment to manage and handle a large volume of spatial data set, associated attributes etc. which cannot be accomplished manually. GIS helps to review data along with a capability for quality control and identification of errors (Johnson, 2009).With addition of the above, GIS also helps to understand the trend and pattern of data which may exist within the dataset and which may not be to understand if the dataset was presented in a tabular format. GIS not only helps to handle with large volume of data set, but also helps to analyze those products which may come out to support decision making process for land suitability analysis. These decisions typically guided by multiple objectives, multiple alternatives and multiple stakeholders with diversified interests which may include not only spatial factors but also social, economic and environmental factors. Therefore it is really very difficult to develop any strategies for a suitable land use for a particular site as it involves lots of issues which are really very complicated. For these reasons, decision makers are going beyond using of only conventional GIS tools and taking decisions to integrate Multi-criteria Decision Analysis (MCDA) approach with GIS (Carver, 1991; Prato, 1999;Malczewski, 1999). In this technique, all parties can explicitly express their preferences. Transparency and accountability, these two inherent characteristics of MCDA technique make it a preferred alternative for making decisions involving more than one or more parties with multiple perspectives (Brown, et. al. 2001;Joubert, et. al. 1997)

2.2 Multi Criteria Decision Making (MCDM):

Identification of a suitable use for a suitable site is a decision making process is not easy. As it is a decision making process and it involves judgmental expressions of different decision makers, a large volume of data set or criteria need to be handled and analyzed carefully. Multi Criteria analysis appeared in the 1960s as a decision-making tool. It is used to make a comparative assessment of alternative projects or heterogeneous measures. With this technique, several criteria can be taken into account simultaneously in a complex situation. The method is designed to help decision-makers to integrate the different options, reflecting the opinions of the actors concerned, into a prospective or retrospective framework. Participation of the decision-makers in the process is a central part of the approach. The results are usually directed at providing operational advice or recommendations for future activities.Multi Criteria evaluation can be organized with a view to producing a single synthetic conclusion at the end of the evaluation or, on the contrary, with a view to producing conclusions adapted to the preferences and priorities of several different partners. It is a tool for comparison in which several points of view are taken into account, and therefore is particularly useful during the formulation of a judgment on complex problems. These approaches can be viewed as alternative methods for combining the information in a problem's decision matrix together with additional information from the decision maker to determine a final ranking, screening or selection from among the alternatives (Kahraman, 2008).

Originally MCDM were developed to select the best alternative from a set of competing options. Over the years, these methods have evolved into a diverse range of decision aid techniques. Now MCDMs includes methods that can be used to: 1) structure the decision problem and improve the understanding of the main issues involved in the decision; 2) identification of pros and cons of various management process in order to improve negotiations; 3) accommodate various types of information (quantitative and qualitative); 4) present the effects of policy alternatives in various forms; 5) support the evaluation of multiple policy alternatives; 6) reduce the amount of information in order to provide comprehensibility; 7) compare multiple policy alternatives; 8) present the choice and priorities made in the transparent and effective way; 9) support reasoning in the negotiations and 10) analyze the sensitivity and robustness of the results. The tool cannot only be used to select the best alternative, but also as a tool for: ranking alternatives, product evaluation, understanding the process, negotiations, assessment the overall impacts etc.

2.3 Land- use suitability analysis using GIS and Multi Criteria Decision Making tools:

There are number of methods of Land-use suitability analysis using MCDM and GIS. All the methods have their own pros and cons. Over time, a number of scientists from different disciplines worked to create a better tool. GIS is a very important set of tools which can successfully apply the MCDM methods on maps and analyze maps depending on various criteria. Applications of different MCDM methods involving GIS to analyze suitability of land use are discussed in the following sections.

2.3.1 Direct overlay:

The method of direct overlay includes map overlay and equal weight summation. Map overlay can be traced back to the beginning of the 20thcentury. According to McHarg (1969), this method can be successfully applied in land use suitability, which enables urban planning efficiently and comprehensively to allow for the social and environmental factors. The main steps of map overlay can be concluded as 1) defining the planning purpose and identifying the factors contributed to the planning. 2) Investigating each factor's situation and distribution (forming ecological purpose), making a classification according to the suitability for some specific land uses and using some gradual colors to identify each factor's suitability class in a single factor map. 3) Overlaying two or more single factor maps to get a composite map. 4) Analyzing the composite map and finally making the land use planning. In the planning of Staten Island, McHarg and his colleagues applied this method to analyze land use suitability of natural conservation, passive recreation, housing development, commerce development and industry development, etc which has made a great effect. Map overlay is a kind of visual method which can integrate environmental factors with socio-economic factors to make the suitability analysis. The disadvantage of this method is that it is essentially a kind of equal weight additive method. Actually each factor's function is different and sometimes the same factor may be considered repeatedly. Another disadvantage is that while the factors increase, it is rather complicate to use the gradual colors to represent different suitability classes and to make the overlay function. Moreover, it is difficult to identify the little differences from the gradual colors of the composite maps. Though it has certain disadvantages, map overlay method plays an important role in the historic development of the suitability analysis. Afterwards many new methods are developed based on this method.

2.3.2 Simple Boolean Overlay:

Ranking and rating method are the two widely used MCDM methods in land suitability analysis. These methods lack theoretical foundation in deciding the weights. These methods rather assign the weights arbitrarily. They don't take comparison among the criteria and classes into considerations. Moreover the outcomes of such analysis are aggregated using simple Boolean overlay. Both the methods are yield to similar results, which they never do. The reason is being with the logic of aggregation. Boolean intersection (AND) results in a very strict output, for example: if it fails to fulfill single criteria a region will be excluded from the results. In contrast, Boolean union (OR) will include an area in the result if that area fulfills single criteria. These ranking and rating methods are criticized for not reflecting the decision maker's views clearly and also for not having rationale behind the approach.

2.3.3 AHP (Analytical Hierarchical Process):

AHP is a widely used method in decision making and is introduced by Saaty(Saaty 1977, Saaty and Vargas 2001). It is developed to select the best from a number of alternatives with respect to several criteria. AHP allows for both the inconsistency in the decision and provide the means to improve the consistency. The decision maker or the user performs simple pair wise comparison which means there would be comparison of two elements at a time. The values for the pair-wise comparison are determined according to the scale Saaty introduced. The available values for the comparison are the number of the set: {9,8,7,6,5,4,3,2,1,1/2,1/3,1/4,1/5,1/6,1/7,1/8,1/9}; 9 represents absolute importance and 1/9 the absolute unimportance (Saaty1980; Triantaphyllou and Mann 1994). Consistency ratio and $\gamma_{max}$are two important concepts for understanding AHP.

Table 2.1: Scales for pair wise comparison

Preferences expressed in numeric variables	**Preferences expressed in linguistic variables**
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate value between the two adjacent judgments
Reciprocals of above non-zero numbers	If an activity has one of the above numbers (e.g., 3) compared with a second activity, then the second activity has the reciprocal value (i.e., 1/3) when compared to the first.

Source: (Saaty, 1980)

- ***Consistency ration:***

CR = Consistency index (CI)/Random Consistency Index (RI)

$$CI = \frac{\lambda_{max} - n}{n-1}$$

λ_{max} is the Principal Eigen Value; n is the number of factors

λ_{max} = ∑ of the products between each element of the priority vector and column totals.

Table 2.2: Random Indices for Consistency Check

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

RI	**0**	**0**	**0.58**	**0.90**	**1.12**	**1.24**	**1.32**	**1.41**	**1.45**	**1.51**

n = dimension of judgment matrix

CR<10% means that the level of inconsistency in the matrix is satisfactory.

AHP method is popular because of its simplicity for obtaining the weights and for its capacity to integrate the heterogeneous data and that's why AHP is used as a wide variety of decision problems. Many authors have suggested that AHP assigned weights in a realistic manner and also have discussed that this is the reason of incorporating pair-wise comparison matrix in the GIS Analysis Decision Support module in the IDRISI32 raster based software package (Eastman, 1997; Sener, et. al. 2006).However, the conventional AHP technique of expressing decision maker‘s judgments in the form of a crisp number does not fully reflect a style of human thinking in the real-world system because of some inherent uncertainty and imprecision associated with the decision making process. An approach which can tolerate this vagueness or ambiguity is called fuzziness, which is based on the fuzzy set theory proposed by Zadeh (1965) and Mikhialo, et. al. (2004).The fuzzy approach allows decision makers to give interval judgments, which can capture a human‘s appraisal of ambiguity when complex multi-attribute decision making problems such as deciding suitable land uses for an ecologically critical area are considered. Integrating fuzzy logic into the AHP process provides a much better and more exact representation between criteria and alternatives (Akbari, et. al. 2008, Ocalir, 2010).

In any decision making process, since human perceptions and judgments are involved and are dynamic in nature, it calls for rational and structural approach towards solution (Saaty, 2000). AHP is one of the most widely used multi attribute decision making methods which involve developing of asset of alternatives and a common set of objectives (Saaty, 2000). The selection of the most appropriate depends upon its ability to the maximum fulfillment of the objectives set. In the conventional AHP, the pair wise comparisons for each level with respect to the goal of the best alternative selection re conducted using a nine-point scale. So, the application of Saaty’s AHP has some shortcomings as follows: (1) The AHP method is mainly used in nearly crisp decision applications, (2) the AHP method creates and deals with a very unbalanced scale of judgment, (3) The AHP method does not take into account the uncertainty associated with the mapping of one’s judgment to a number, (4) Ranking of the AHP method is rather imprecise, (5) the subjective judgment, selection and preference of decision makers have great influence on the AHP results. In addition, a decision-maker’s requirements on evaluating alternatives always contain ambiguity and multiplicity of meaning. Furthermore, it is also recognized that human assessment on qualitative attributes is always subjective and thus imprecise. Therefore, a conventional AHP seems inadequate to capture decision maker’s requirements explicitly.

In order to model this kind of uncertainty in human preferences, fuzzy sets could be incorporated with the pairwise comparison as an extension of AHP. A variant of AHP, called fuzzy AHP, comes into implementation in order to overcome the compensatory approach and the liability of the AHP in handling linguistic variables. The fuzzy AHP approach allows a more accurate description of the decision making process.

2.3.4 Fuzzy Logic approach:

The inability of the normal decision making methods to address the imprecision and uncertainty paved the path for the fuzzy decision makingtechniques. The conventional AHP technique of expressing decision maker‘s judgments in the form of single numbers does not fully reflect a style of human thinking in the real-world system. There is some inherent uncertainty and imprecision associated with the decision making process, which needs to be adequately handled. This uncertainty can be linked to the characteristics of the decision maker. An approach which can tolerate this vagueness or ambiguity is therefore required. According to, a possible approach is to apply a special kind of vagueness called fuzziness, which is based on the fuzzy set theory proposed by. The fuzzy approach allows decision makers to give interval judgments, which can capture a human's appraisal of ambiguity when complex multi-attribute decision making problems such as water reservoir siting are considered.

2.3.4.1 Fuzzy Set Theory:

Zadeh (1965) came out with the fuzzy set theory to deal with vagueness and uncertainty in decision making in order to enhance precision. Thus the vague data may be represented using fuzzy numbers, which can be further subjected to mathematical operation in fuzzy domain. Thus fuzzy numbers can be represented by its membership grade ranging between 0 and 1. A triangular fuzzy number (TFN) is $\tilde{M}$ shown in following figure 2.1:

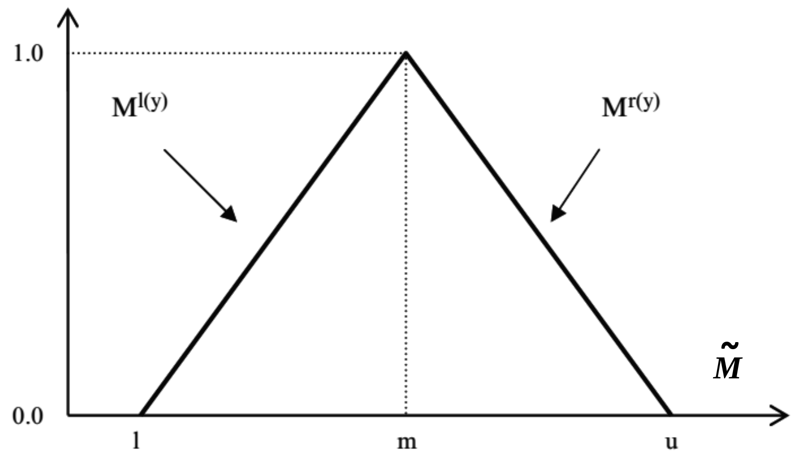


Figure2.1: A Triangular Fuzzy Number

A TFN is denoted simply as (l, m, u), represents the smallest possible value, the most promising value and the largest possible value respectively. The TFN having linear representation on left and right side can be defined in terms of its membership function as:

$$\mu\left(x/\tilde{M}\right)=\begin{cases}0, & x<l\\ (x-l)/(m-l), & l<x<m\\ (u-x)/(u-m), & x>l\end{cases}$$

2.3.4.2 Fuzzy AHP:

In one of the earliest works of fuzzy AHP, Van Laarhoven and Pedrycz (1983) judge the fuzzy comparison scales represented by triangular fuzzy numbers whereas, in another work, fuzzy priorities of comparison ratios are determined by trapezoidal membership functions (Buckley, 1985). Chang (1996) introduced a new approach for handling the pair-wise comparison scale based on triangular fuzzy numbers followed by use of extent analysis method for synthetic extent value of the pairwise comparison. The fuzzy evaluation matrix of the criteria is constructed through the pairwise comparison of different attributes relevant to the overall objective using the linguistic variables (A variable that carries linguistic/expressive/qualitative term as value. e.g: 'age' is 'old') and triangular fuzzy number. Table 2.3 shows these linguistic variables and the triangular fuzzy ranges.

Table 2.3: Linguistic Variables describing weights of the Criteria and values of ratings

Linguistic term	**Fuzzy Number**	**Positive triangular scale (l, m, u)**
Extreme unimportance	9^{-1}	(1/9,1/9,1/9)
Intermediate values between 7^{-1} and 9^{-1}	8^{-1}	(1/9,1/8,1/7)
Very unimportance	7^{-1}	(1/8,1/7,1/6)
Intermediate values between 5^{-1} and7^{-1}	6^{-1}	(1/7,1/6,1/5)
Essential unimportance	5^{-1}	(1/6,1/5,1/4)
Intermediate values between 3^{-1} and 5^{-1}	4^{-1}	(1/5,1/4,1/3)
Moderate unimportance	3^{-1}	(1/4,1/3,1/2)
Intermediate values between 1and 3^{-1}	2^{-1}	(1/3,1/2,1)
Equally importance	1	(1,1,1)
Intermediate values between 1 and 3	2	(1,2,3)
Moderate importance	3	(2,3,4)
Intermediate values between 3 and 5	4	(3,4,5)
Essential importance	5	(4,5,6)
Intermediate values between 5 and 7	6	(5,6,7)
Very vital importance	7	(6,7,8)
Intermediate values between 7 and 9	8	(7,8,9)
Extreme unimportance	9	(9,9,9)

Source: (Sen, C.G. andÇinar, G., 2010; Kabir, G. and Sumi, R.S., 2014)

- **Analysis of fuzzy AHP (Chang Extent Analysis):**

The following section outlines the extent analysis method of FAHP. Let *X= {x1, x2, …………..,xn}* be an object set and *U= {u1, u2, ……..,um}* be a goal set. As per Chang (1996) each object is taken and analysis for each goal, gi, is performed, respectively. Therefore m extent analysis is taken values for each object can be obtained, as under:

$$M_{gi}^{1}, M_{gi}^{2}, \ldots, M_{gi}^{m}, \qquad i = 1, 2, 3,\ldots\ldots\ldots..,n$$

Where all the M_{gi}^{j} *(j= 1, 2,…., m)* are TFNs whose parameters are, depicting least, most and largest possible values respectively and represented as *(l, m, u)*. The steps of Chang's extent analysis (Chang, 1996) can be detailed as follows: (Bozbura et al., 2007; Kahraman et al., 2003, 2004; Wang et al., 2008):

Step1: The value of fuzzy synthetic extent with respect to *i*th object is defined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$$

To obtain, $\sum_{j=i}^{m} M_{gi}^{j}$ perform the fuzzy addition operation of m extent analysis values for a particular matrix such that:

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_i , \sum_{j=1}^{m} m_i , \sum_{j=1}^{m} u_i \right)$$

and to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$ perform the fuzzy addition operation of M_{gi}^{j} *(j= 1, 2,…., m)* values such that

$$\sum_{i=1}^{n}\sum_{j=1}^{m} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right)$$

And then compute the inverse of the vector such that

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right)$$

Step 2. The degree of possibility $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ ofis defined as:

$$V(M_2 \geq M_1) = \sup_{y \geq x}\left[\min\left(\mu_{M1}(x), \mu_{M2}(y)\right)\right]$$

and can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) =$$

$$\mu_{M2}(d) = \begin{cases} 1, & \text{if } \mathrm{m}_2 \geq m_1 \\ 0, & \text{if } \mathrm{l}_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise} \end{cases}$$

where d is the ordinate of highest intersection point D between μ_{M1} and μ_{M2} as shown in figure 2.2.

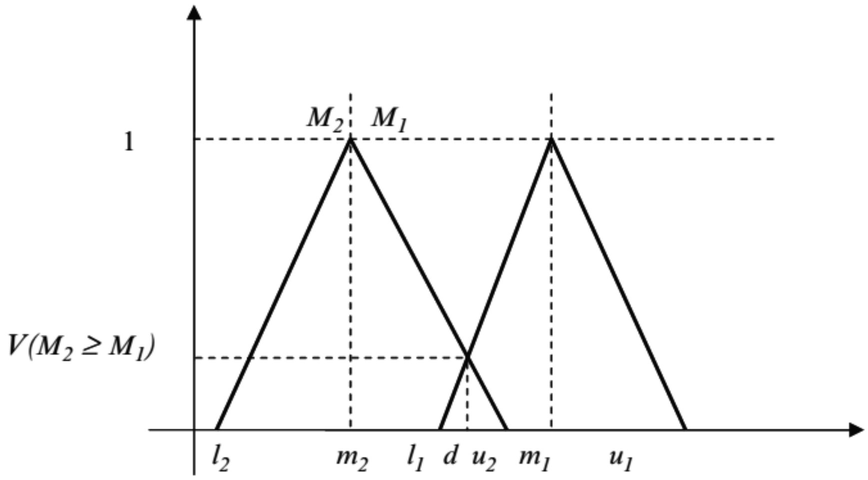


Figure2.2: The intersection between M_1 and M_2

To compare M1 and M2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

Step 3. The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers *Mi (i= 1, 2, ………., k)* can be defined by:

$$V(M \geq M_1, M_2, ..., M_k) = V[(M \geq M_1) \, and \, (M \geq M_2) \text{and ...and} (M \geq M_k)] = \min V(M \geq M_i), \quad \text{i} = 1,2,...,\text{k}$$

Assume that,

$$d'(A_i) = \min V(S_i \geq S_k)$$

For *k = 1, 2, 3……..n*; *k* is not equal to i. Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2'), ..., d'(A_n))^T$$

Where A_i = *(i = 1, 2, 3,……n)* are n elements.

Step 4. By normalization, the normalized weight vectors are

$$W = (d(A_1), d(A_2), \ldots, d(A_n))^T$$

Where W is a non-fuzzy number.

2.4 Criteria for suitability analysis:

Land use suitability analysis requires a number of criteria based on which this process is executed. There are many criteria to evaluate such suitability assessment. Selecting appropriate criteria for the analysis and finding out their relative importance are very important steps in the suitability analysis. It is always very difficult to create an exhaustive list of influencing criteria, but a list of important criteria can be created based on literature review and expert opinion. The following section describes the parameters used for the land suitability analysis for this research.

2.4.1 Criteria for residential land use suitability analysis:

Different studies show that, it is very important to consider the topography factors for assessing the suitability of residential land uses (Dai et al., 2001; Steiner et al., 2000). Elevation such as slope is also need to be considered as areas with high elevation are not suitable from accessibility perspectives and these areas also lack of basic urban facilities such as transportation, water supply, and sewage and sewerage disposal (Dai et al., 2001). Steiner (2000) focused on the compatibility with existing land uses, slope, existing land use, proximity to existing roads, proximity to water systems etc. for residential suitability of a land. It is suggested by Deal 2005, that the land suitability for residential area should comprise travel time to a nearest county road, travel time to a nearest state highway, travel time to a nearest major intersection, distance to a nearest forest patch, distance to a nearest water body etc. Considering all these, physical factors, development factors and environmental factors are set as the criteria for residential development.

For residential development, physical criteria of land like slope, elevations etc. are very important to ensure ease of access, utility provision and reduce chances of water logging. Besides other development factors like proximity to existing residential, industrial, commercial and nearest major road is very necessary to evaluate the living condition, environmental quality, ease of access to daily necessities and accessibility to workplace. Also proximity to the nearestrecreational facility like park/open space/stadium/theatre etc. play a vital role. Several environmental factors like distance from water body, forest area and sea beach area etc. have to be considered. These factors ensures healthy living environment. Besides the critically exposed beach area also needs to be protected from extensive development. Table 2.4 is given below showing the parameters with their suitability ranges from residential land development perspective. Eachof the sub parameter is divided into three ranges: S3 (Highly suitable), S2 (Moderately Suitable) and S1 (Low Suitable) on the basis of FAO framework (FAO 1976) and expert opinion.

Table 2.4: Criteria and suitability ranges for residential land use

Land uses	Criteria	Sub criteria	Suitability classes	Ranges
Residential	Physical factors	Slope (degree)	S3	0-5
			S2	5-10
			S1	>10
		Elevation (m)	S3	0-8
			S2	8-20
			S1	>20
	Development factors	Proximity to existing residential area (km)	S3	0-1
			S2	1-2
			S1	>2
		Proximity to existing commercial area (km)	S3	>5
			S2	2.5-5
			S1	0-2.5
		Proximity to existing nearest paved road (km)	S3	0-2
			S2	2-4
			S1	>4
		Proximity to open space and recreational area (km)	S3	0-2
			S2	2-4
			S1	>4
	Environmental factors	Distance from existing water body (m)	S3	>300
			S2	150-300
			S1	0-150
		Distance from existing forest and vegetation (km)	S3	>4
			S2	2-4
			S1	0-2
		Distance from Sea-beach area (km)	Restricted area: Within 500 m Distance no development will be allowed	

2.4.2 Criteria for commercial land use suitability analysis:

It is more or less obvious that most of commercial development would take place in the more populated areas surrounding the urban area. Things that need to be addressed for the commercial development may include present land use on adjacent or nearby properties, access to major and minor arterials etc. Unsuitable or moderately areas for such development include those with slopes >15% or 3 to 15%, poor or moderate soil drainage areas, and existing residential or agricultural land uses. Whereas slopes <3% with good soil drainage and access to public facilities like transportation will be most suitable for commercial development (Steiner et al., 2000). It is suggested that such land suitability index should comprise of slope, aspect, distance from residence, distance from industry, distance from forest, and distance from nature reserves (Svoray et al., 2005). Like residential development suitability parameters for commercial development also divided into three broad categories: Physical factors, Development factors and Environmental factors.

For commercial development physical factors of land like slope, elevations etc. are very important for similar reasons of residential development. Besides this commercial lands need proximity to residential area to reach the target group easily. A good connectivity to the road network can play a vital role for commercial suitability of a parcel of land. Existing commercial areas provide an already established environment and facilities favorable for commercial development. Protection of sea- beach and other environmentally sensitive areas is necessary to evaluate commercial suitability analysis. Table 2.5 is given below showing the parameters with their suitability ranges for commercial land suitability assessment. Each of the sub parameter is divided into three ranges: S3 (Highly suitable), S2 (Moderately Suitable) and S1 (Low Suitable) on the basis of FAO framework (FAO 1976) and expert opinion.

Table 2.5: Criteria and suitability ranges for commercial land use

Land uses	Criteria	Sub criteria	Suitability classes	Ranges
Commercial	Physical factors	Slope (degree)	S3	0-5
			S2	5-10
			S1	>10
		Elevation (m)	S3	0-8
			S2	8-20
			S1	>20
	Development factors	Proximity to existing residential area (km)	S3	> 5.0
			S2	2.5-5
			S1	0-2.5
		Proximity to existing commercial area (km)	S3	0-1
			S2	1-2
			S1	>2
		Proximity to existing nearest paved road (km)	S3	0-1
			S2	1-2
			S1	>2
	Environmental factors	Distance from existing forest and vegetation (km)	S3	>5
			S2	2.5-5
			S1	0-2.5
		Distance from Sea-beach area (km)	Restricted area: Within 500 m Distance no development will be allowed	

2.5 Ecologically critical area:

According to the **Environmental Conservation Act 1999** (last amended in 2010)Ecologically Critical Areas are those areas or ecosystems which may be adversely affected by human activities. As per Section 5 of ECA 1999:

> *The Government shall take the following factors into consideration while declaring any area as Ecologically Critical Area under sub-section (1) of section 5:(a) human habitat;(b) ancient monument; (c) archeological site; (d) forest sanctuary; (e) national park; (f) game reserve; (g) wild animals habitat; (h) wetland; (i) mangrove; (j) forest*

area; (k) bio-diversity of the relevant area; and (l) other relevant factors.

By the provision of ECA 1995, if any areas where ecosystems is considered to be threatened to reach a critical state due to degradation of environment, the Director General of the Department of Environment (DoE) poses the power to declare it as an Ecologically Critical Area. So far twelve areas are declared as Ecologically Critical Areas since 1999. They are as followings:

Table 2.6: Ecologically Critical Areas according to ECA 1999

Year of declaration of Ecologically Critical Areas	**Ecologically Critical Areas**	**Characteristics of the Ecologically Critical Areas**
1999	1. Outside of Sundarbans Reserved Forest at 10 km extent	
	2. Cox's Bazar -Teknaf Peninsula (10,465 ha)	Breeding areas for four globally threatened species of marine turtles and, lying along international bird migration flyways, with over 81 species recorded. Its inshore water hosts globally threatened marine mammals.
	3. St Martin Island (590 ha, a sedimentary continental island)	One of the few areas in the world where coral-algal communities dominate rocky reefs. The island also supports significant breeding areas for globally threatened marine turtle species and serving as a stepping stone for several globally threatened migratory waders.
	4. Sonadia Island (4,924 ha)	Domination of different mangrove species which are able to tolerate higher levels of salinity than Sundarbans. It also supports a large number ofwaterbirds, mollusks, echinoderms, and marine turtles.

	5. HakalukiHaor	Largesthaor in Bangladesh. It contains about 47 major haors and more than 6,000 beels, or freshwater lakes. The beels cover an area of 4,400 ha (dry season) and of 18,000 ha (rainy season). It is important for a wide variety of waterfowland wintering migratory birds.
	6. TanguarHaor	
	7. Marjatbaor (oxbow lake) at Jhenaidaha	
2001	8. Gulshan - Baridhara Lake	
2009	9. Buriganga River	
	10. Turag River	
	11. Balu River	
	12. Shitalakhya River	

Chapter 3: Methodology

This chapter describes the methodological framework of the study. A systematic procedure was followed to complete this study. From the very first step of literature review and objective selection to the data collection and analysis procedure and finally discussion about the output of the results and giving recommendations, these all steps were completed through an organized framework.

3.1 Literature Review:

This study pursued an extensive literature survey for possible secondary sources of land suitability analysis, MCDM tools and techniques etc. Articles and chapters from journals, books, websites, reports etc. were reviewed to have an overview on land suitability analysis tools and techniques, to know about MCDM tools specially to have an understanding on AHP and fuzzy AHP, to identify factors for analyzing suitability of a specific type of land use etc. This part of the research described elaborately in the theoretical framework chapter (refer to chapter Two).

3.2 Selection of Study Area:

Cox's Bazar *Paurashava* and the surrounding areas were selected as study area Unplanned growth, rapid development, pressure of tourists and incompatible land uses has affected the district of Cox's Bazar, the most preferred tourist spot of the country, severely. However it was not possible to select Cox's Bazar district as a whole due to resource constraint. So *Paurashava* and the surrounding areas were selected as study area considering following issues:

- It is one of the most important Ecologically Critical Areas of Bangladesh. At the same time it is also the tourism hub of the country with fast growing residential and commercial development activities.

- There is development pressure in the *Paurashava* and the surrounding area
- A development plan has been prepared for the area

3.3 Data collection:

The research used mainly secondary data. However for selection of criteria experts' opinion were sought. The expert opinion survey was conducted to find out suitable criteria and the relative importance of the criteria weight.

3.3.1 Primary data collection:

Expert opinion and interview was one of the important primary data collection methods in this study. Experts were interviewed during various time periods for various reasons. At the beginning of the study, they were interviewed for understanding the prospects of developing the Cox's Bazar master plan and importance of land suitability analysis for preparing such development plans. Then they were interviewed for selection of the suitability criteria. It needs to be mentioned here that some secondary studies were also reviewed for selecting the criteria (refer to 2.4). The experts were interviewed for one last time to determine the relative weightage of the selected suitability criteria. For this purpose, evaluation forms were prepared (Appendix A). Five experts (List of the experts could be found in Appendix B) were interviewed for determining the criteria weight.

3.3.2 Secondary data collection:

It was mentioned earlier that an extensive literature review was conducted in order to identify the criteria for suitability analysis, to have an overview of the various multi-criteria decision making tools and to identify the method for suitability analysis, guidelines for land use planning of other countries etc**.**All the secondary data related with the study like: necessary documents of recent development plan of Cox's Bazar district and GIS database and some other literatures on Cox's Bazar were collected from different organizations like: DoE, UDD, Sheltech, BBS etc.

3.4 Data analysis:

This study used Fuzzy AHP (FAHP) tool for land suitability analysis. Unlike AHP, instead of a crisp value for the linguistic variables, FAHP uses a range of value to incorporate the decision maker's uncertainty. There are many membership functions of FAHP: fuzzy triangular numbers, fuzzy trapezoidal numbers etc. Van Laarhoven and Pedrycz(1983) used triangular fuzzy numbers for comparison scales whereas Buckley (1985) used trapezoidal membership functions. Chang (1992) introduced a new approach for handling pair-wise comparison scale based on triangular fuzzy numbers followed by use of extent analysis method for synthetic extent value of the pairwise comparison in. From land use suitability analysis perspective, Triangular Fuzzy Numbers (TFN's) are widely used as a fuzzy membership functions (2.3.4.1)In this process, the expert's preferences is expressed by an interval defined by three real numberssuch as (a, b, c) where a, b and c denotes the lowest possible value, the most promising value and the largest possible value respectively. Each TFN is associated with a triangular membership function, which describes the TFN domain.

The collected data were evaluated based on Fuzzy AHP technique of MCDM approach and Using GIS Platform.

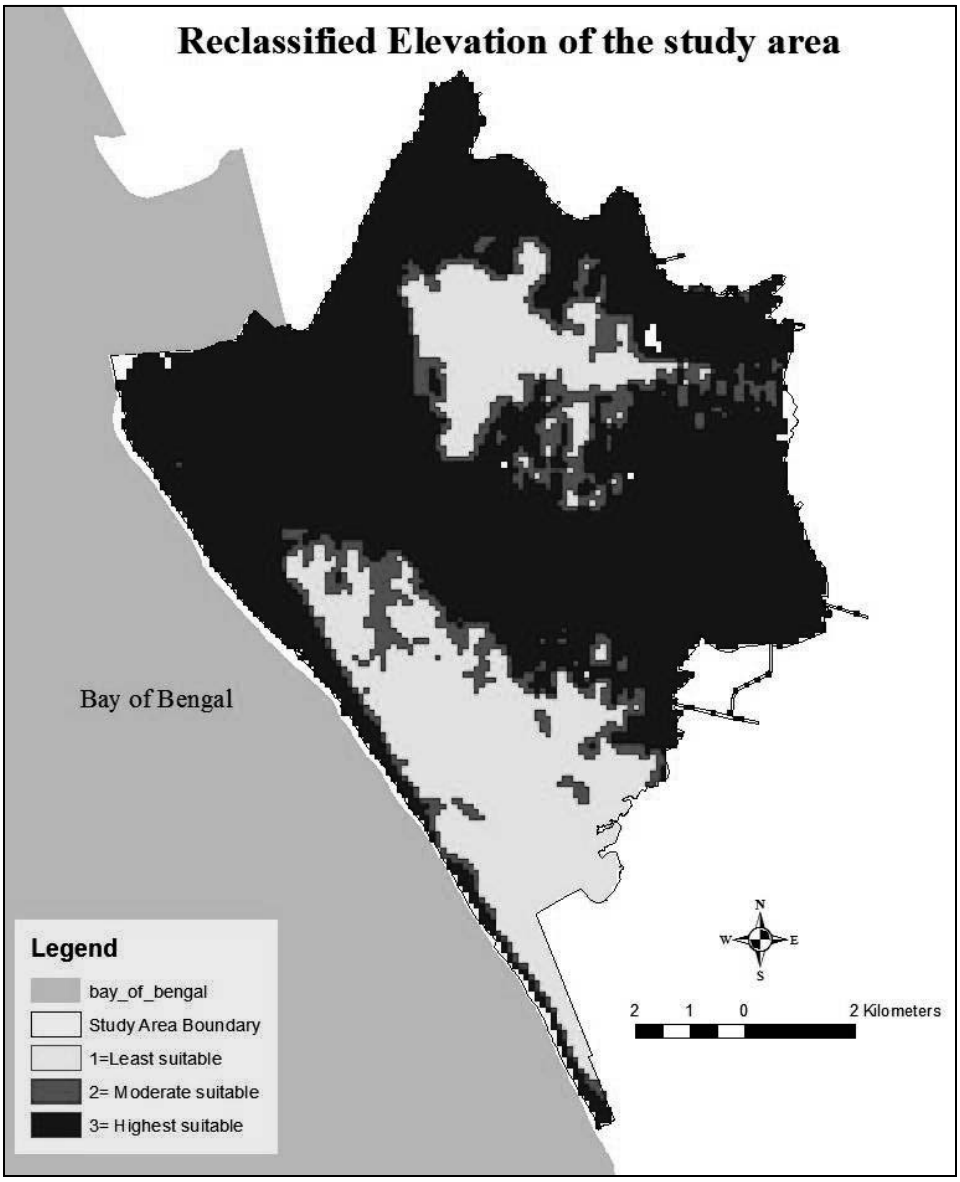
3.4.1 Determination of the criteria weight:

Once the criteria for residential and commercial land suitability analysis were fixed, the relative weights of the parameters were determined using Fuzzy AHP technique. There are two levels of criteria (First level criteria weight is denoted by W1 and second level criteria weight is W2). At first level the criteria are: Physical (P), Development (D) and Environmental (E). And at second level the criteria are: Slope (degree), Elevation (m), Proximity to existing residential area (km), Proximity to existing commercial area (km), Proximity to existing nearest paved road (km), Proximity to open space and recreational area (km), Distance from existing water body (m), Distance from existing forest and vegetation (km), Distance from Sea-beach area (km) (refer to Chapter 2). From these two levels, the overall weight of the each of the layer (W) was derived which finally used in GIS platform. An example is given in the analysis chapter for understanding the process of determining the criteria weight (refer to 5.1). The weightages at first level (W1), second level (W2) and the overall weight (W) are given in chapter 5 (refer to table 5.5 and table 5.6)

3.4.2 Model building:

After finishing all the above mentioned steps, then the GIS Model builder (Geoprocessing tool) in ArcGIS (version 10.1) was used to develop two models for analyzing the residential and commercial land use suitability based on different criteria and their weight.

Initially different raster files for each sub-parameter: (Slope (degree), Elevation (m), Proximity to existing residential area (km), Proximity to existing commercial area (km), Proximity to existing nearest paved road (km), Proximity to open space and recreational area (km), Distance from existing water body (m), Distance from existing forest and vegetation (km) and Distance from Sea-beach area (km) were prepared from the existing Geo-database (.gdb) files. These raster files were then reclassified according to the suitability ranges (refer to Chapter 2). For calculating the suitability ranges Euclidian distance was followed. A '1-3' scale was used for reclassifying suitability ranges: '1' being least suitable and '3' being the most suitable area (i.e. the reclassified map of the elevation is given in Map 3.1).Zero (0) values were assigned to those areas which were not considered at all. For example: a restriction is given for no development around 500 m distance of sea-beach area. So 500 m buffer from sea-beach area, zero values is assigned.



Map 3.1: Reclassified map of the slope

Finally when all the layers were reclassified, these were overlaid following "weighted overlay method" to get the final result. An example of the weighted overlay method is given in Figure 3.1.

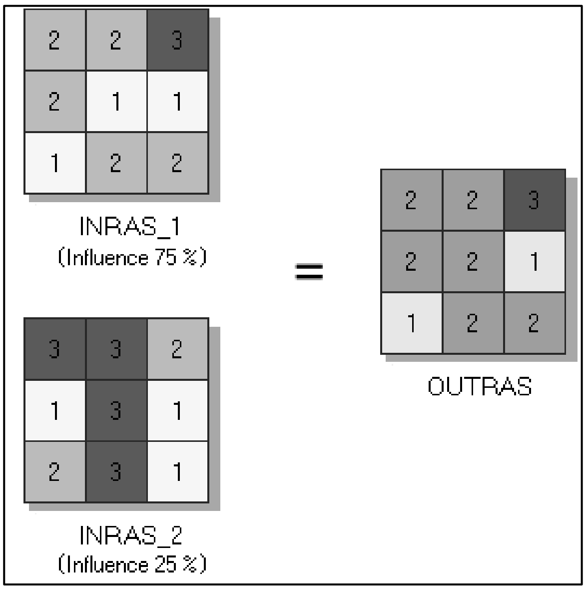


Figure3.1: Weighted Overlay Method
Source: Arc Map 10.1

In the illustration, the two input rasters have been reclassified to a common measurement scale of 1 to 3. Each raster is assigned a percentage influence. The cell values are multiplied by their percentage influence, and the results are added together to create the output raster. For example, consider the top left cell. The values for the two inputs become (2 * 0.75) = 1.5 and (3 * 0.25) = 0.75. The sum of 1.5 and 0.75 is 2.25. Because the output raster from Weighted Overlay is integer, the final value is rounded to 2.

Following this 'Weighted Overlay Method' all the reclassified sub-parameters shape files (found from second step) were assigned relative percentage influence (denoted as overall weight 'W') in the models. Then the final output came out as a raster file showing the suitable areas. This was then converted into vector polygon file.

Once the suitability maps were prepared, then thesewere compared with the proposed development plan of cox's bazar area. This was done through overlaying to find out the match and mismatch of the development plan with the suitability map.

3.4.3 Report submission and final presentation:

The final output of this research was prepared in the written format using Microsoft word 2010 and a final presentation was given using the MS Power Point 2010 version.

The methodology of this research is given below (Figure 3.2)

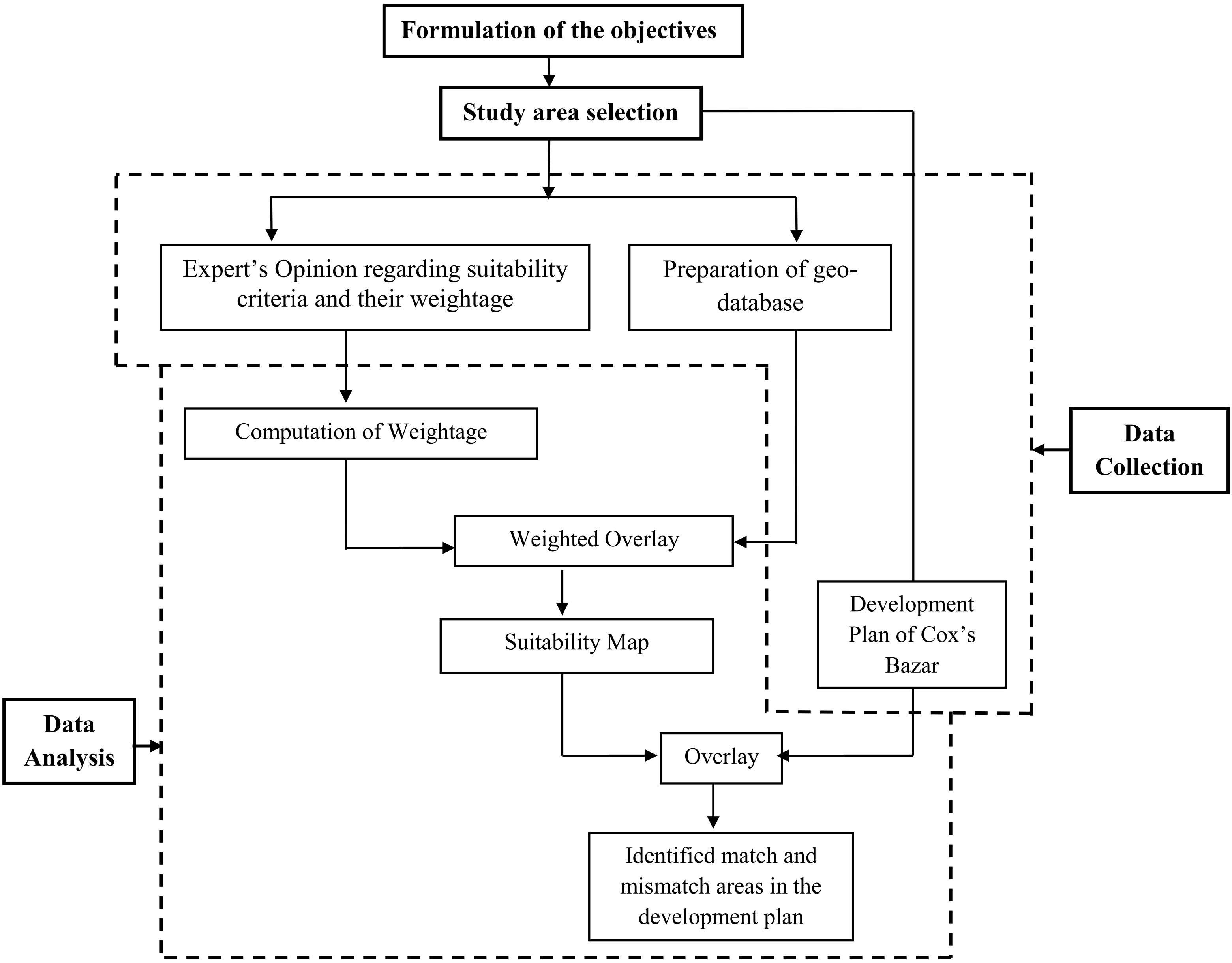


Figure 3.2: Methodology of the study

Chapter 4: Study Area Profile

Cox's bazar is recognized as the tourism capital of Bangladesh. The district and the city are named after Mr. Cox. It was a sub division under Chittagong district till. In 1984 it was declared a district. Cox's bazar district has four *Paurashvas* of which Cox's bazar is the largest. Cox's Bazar municipality was constituted in 1869 and was turn into a town committee in 1959. The town committee was again replaced by municipality in 1972 and it was upgraded into B-grade town in 1989. It was upgraded to first class *Pourashava* in 1994. This study covers Cox's Bazar *Pourashava* and the surrounding areas.

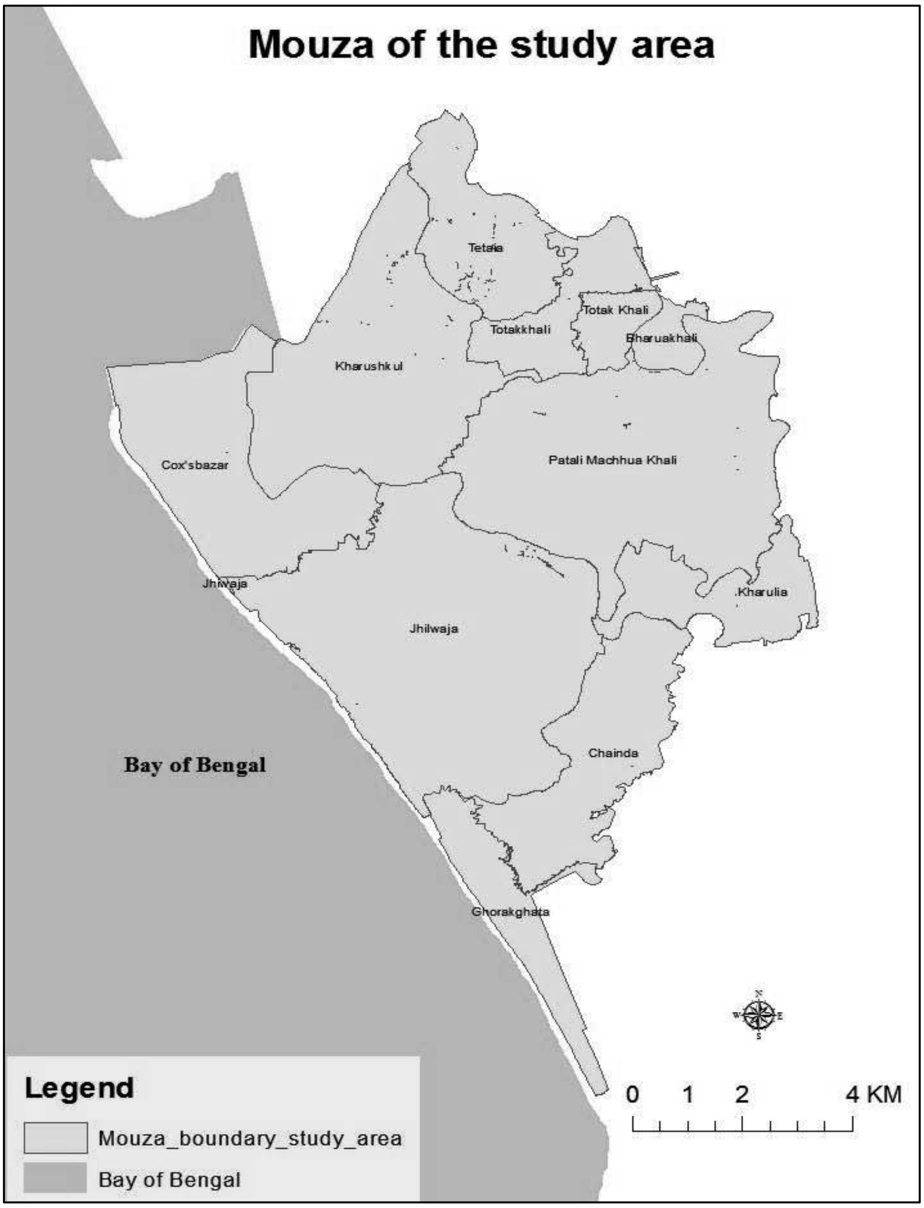
4.1 Location and Area:

The total area of Cox's Bazar *Pourashava* and surrounding areas is 24825.59 acres. Cox's Bazar *Pourashava* is bounded by Chakaria Upazila on the North, Bay of Bengal on the west and the south, Ramu Upazilla on the East, Maheshkhali Upazilla, Maheshkhali channel and Bay of Bengal on the West.The municipality covers an area of 6.85 sq. km. in 27 mahallas of nine wards. The study area consists of nine *Mouzas* (a type of administrative district, corresponding to a specific land area within which there may be one or more settlements). They are as follows: Bharuakhali, Chainda, Cox'sbazar, Jhilwaja, Kharulia, Kharushkul, Patali Machhua Khali and Tetaia, Totak Khali. The study area map showing the *Mouzas* is given in Map 4.1.

4.2 Demographic Information:

Total population of the study area is 316,891 which is around 13.84% of the total population of Cox's Bazar district. The density is 1,444.22 persons per sq. km. There are 56,890 households and the average size of the household is 5.57. Most of the people are somehow related with agricultural activities.

Other activities are business, employment, construction, religious services, transport and communication etc. (BBS, 2012)



Map 4.1: *Mouzas* of the Cox's Bazar *Pourashava* and surrounding areas
Source: Cox's Bazar Development Plan, UDD.

4.3 Land uses of the study area

Agricultural land uses possess the highest amount of land coverage in the study area (42.70% of the total land use). After that the residential land uses cover most of the land area (22.29%). Forest and vegetation covers 16.56 % of the total area and water body covers 9.53%. The following figure (Figure 4.1) shows the percentage of land uses in the study area.

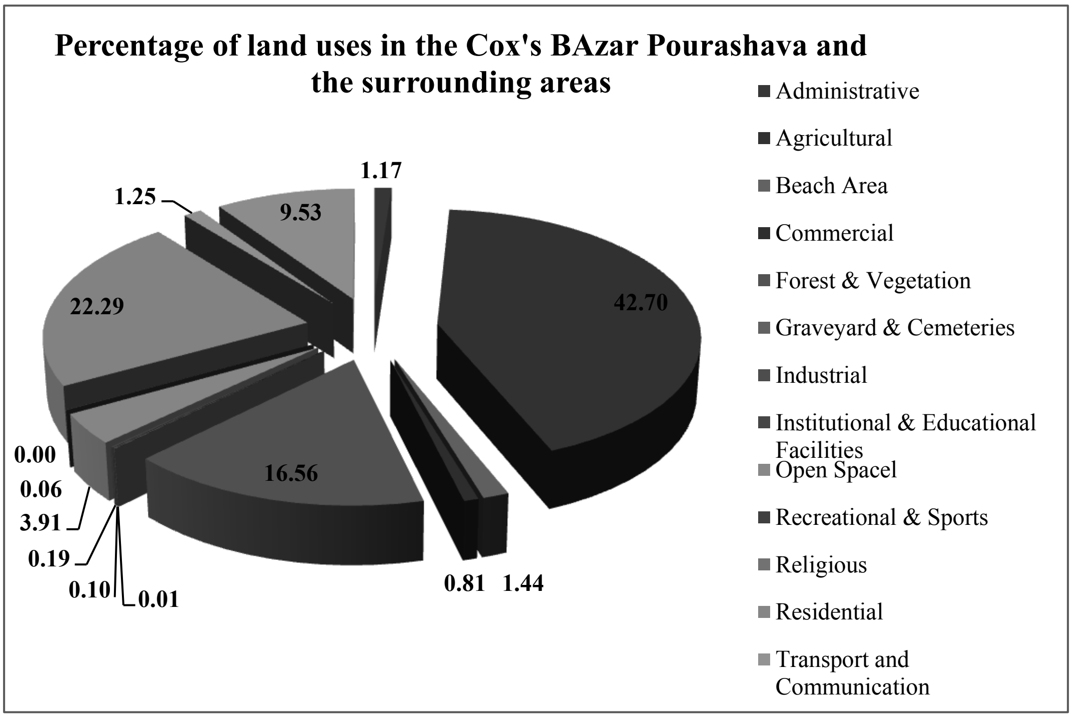
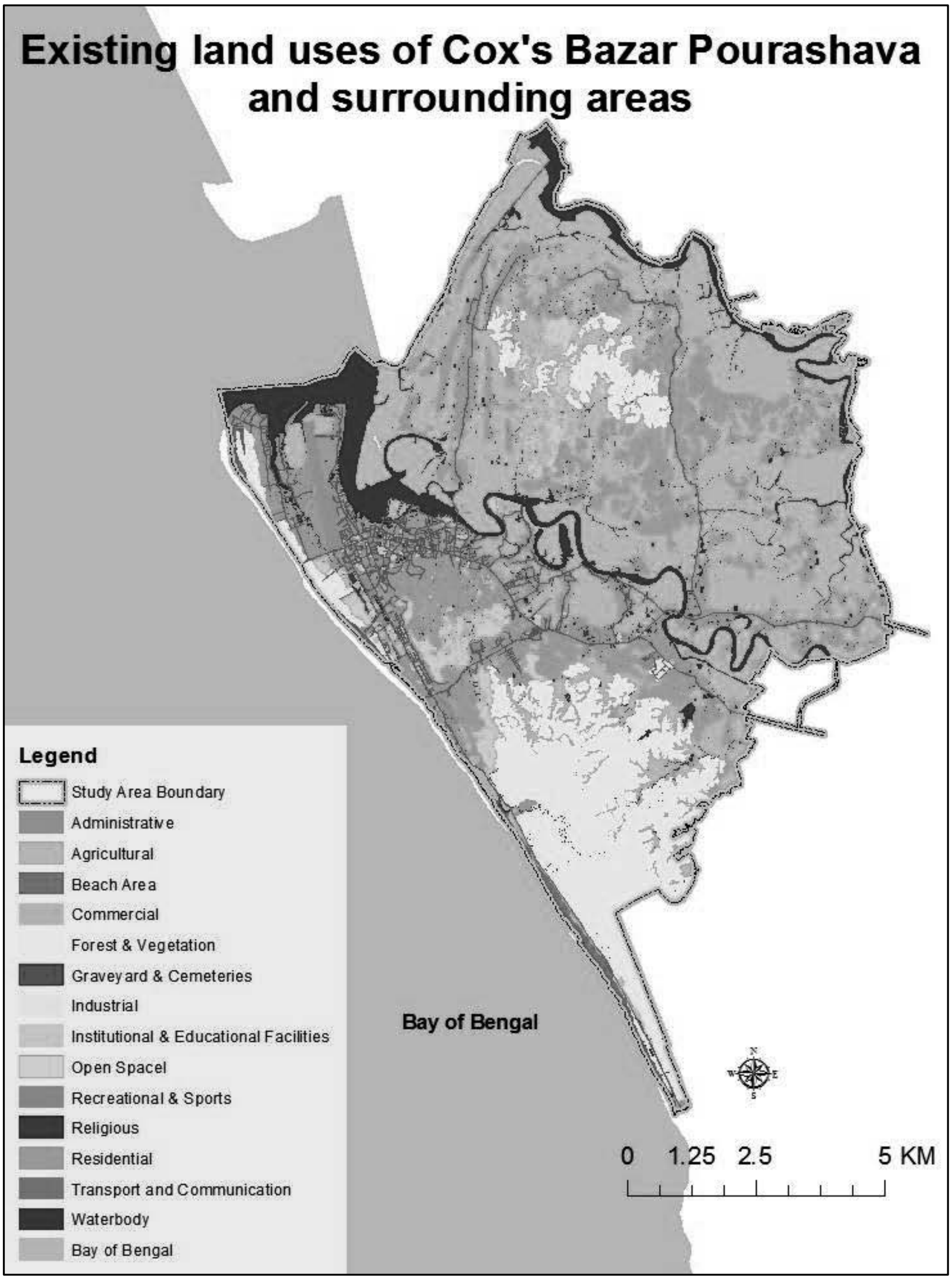


Figure 4.1: Land uses of the Cox's Bazar *Pourashava* and the surrounding areas
Source: Cox's Bazar Development Plan, UDD.

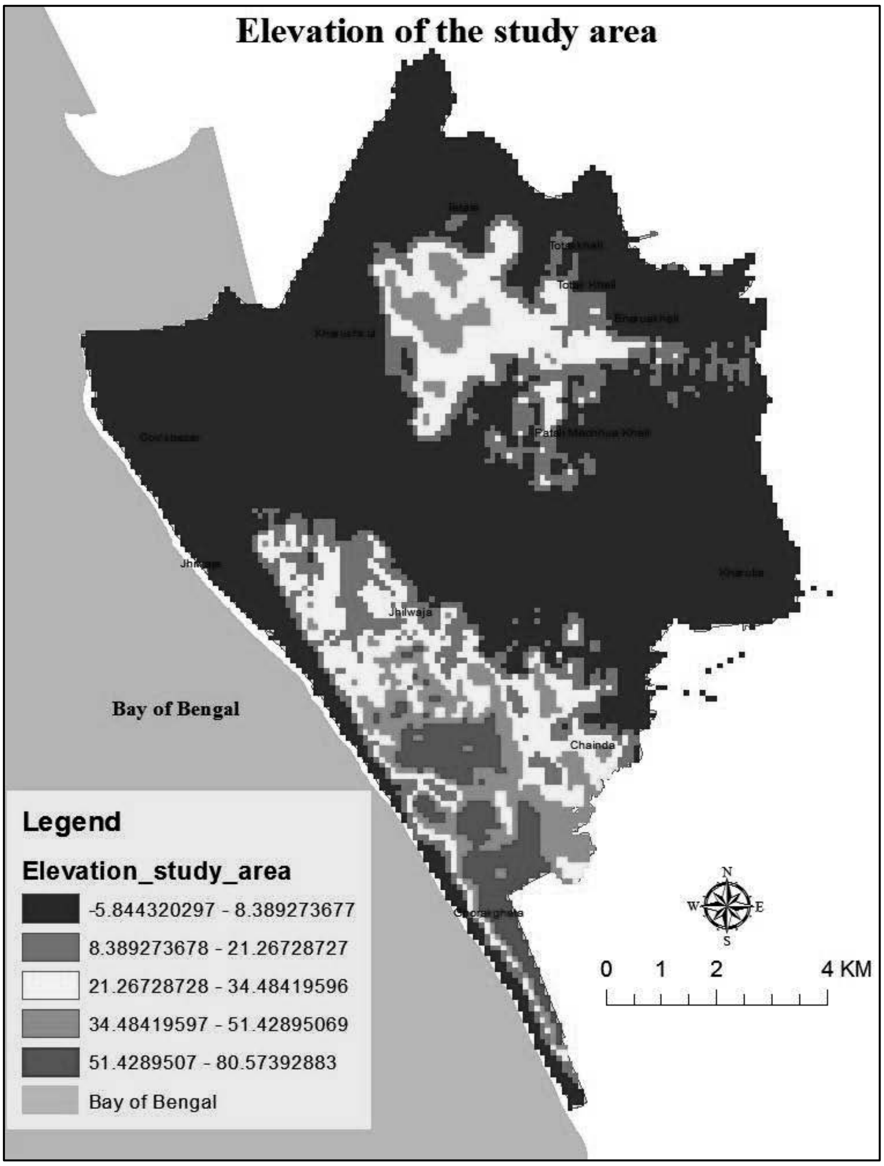
The land use map of the study area is given in the Map 4.2.

4.4 Elevation of the area:

The study area has both the hilly and plain areas. Map 4.3 shows the elevations of the study area. From the map it can be seen that, the some part of the Kharushkul, Totak Khali, Bharuakhali, Patali Machhua Khali and Tetaia *Mouza* has higher elevation in the range from 21 m to 51 m. On the other hand the, Jhilwaja and Chainda *Mouza* has most of the hilly areas (height near 51-80 m).



Map 4.2: Land use map of the Cox's Bazar *Pourashava* and surrounding areas
Source: Cox's Bazar Development Plan, UDD.



Map 4.3: Elevation of the Cox’s Bazar *Pourashava* and surrounding areas

Source: Cox’s Bazar Development Plan, UDD.

4.5 Cox's Bazar Development Plan at a glance:

In 2010 government decided to prepare a development plan for Cox's Bazar area with intention to stop the unplanned development in this area.

The size of Cox's Bazar Master Plan area was 79657.00 acres (322.36 sq. km.) which includes Cox's Bazar *Pourashava*, Maheshkhali *Pourashava*, Tefnaf *Pourashava*, St. Martin's Island and sea-beach area from Cox's Bazar to Teknaf. The following table (Table 4.1) shows the *Mouza* wise coverage of the study areas of the development plan:

Table 4.1: *Mouza* wise coverage of the study areas of the development plan:

<table>
<tr><th>Study area</th><th>Mouza name</th><th>Remarks</th></tr>
<tr><td rowspan="4">Maheskhali Pourashava and surrounding areas</td><td>Gorakghata</td><td rowspan="4">This is the northern boundary of the project areas. These Mouzas covered mainly the areas under the MaheshkhaliPousashava. These areas are declared as urban area by the Bangladesh government, the areas have great potentialities of tourism development for its natural beauty and ancient temples. If the communication can be upgraded it will serve as an important tourism spot of the Country.</td></tr>
<tr><td>Hamidardia</td></tr>
<tr><td>Putibila</td></tr>
<tr><td>Thakurtala</td></tr>
<tr><td rowspan="10">Cox's Bazar Pourashava and surrounding areas</td><td>Cox's Bazar</td><td rowspan="10">These Mouzas covered the most important places of the project. These Mouzas are mainly in the Cox's Bazar Pourashava. This area is more important for its tourism activities (Cox's Bazar sea beach, important administrative buildings, Hotels/Motels etc). Furthermore this area is the main hub of tourism not only for the project area but also for the whole country. This area is being developed in an unplanned way which is a thread for the ecosystem of the country as well as constraint for tourism. Immediate action is needed to control the development of this area.</td></tr>
<tr><td>Jhilwanja</td></tr>
<tr><td>Tetaia</td></tr>
<tr><td>Khurushkul</td></tr>
<tr><td>PataliMachhuakhali</td></tr>
<tr><td>Khurulia</td></tr>
<tr><td>Totak Khali</td></tr>
<tr><td>Bharuakhali</td></tr>
<tr><td>Chainda</td></tr>
<tr><td>Jungle KhuniaPalong</td></tr>
<tr><td rowspan="4">Ramu and surrounding areas</td><td>Pechardwip</td><td rowspan="4">Holds a bigger opportunity for the tourism development of our country.</td></tr>
<tr><td>DhoaPalong</td></tr>
<tr><td>GoaliaPalong</td></tr>
<tr><td>Ghandung</td></tr>
<tr><td rowspan="2">Ukhia and surrounding</td><td>JaliaPalong</td><td rowspan="2">Holds a bigger opportunity for the tourism development of our country.</td></tr>
<tr><td>RumkhaPalong</td></tr>
</table>

areas	MarichaPalong Ukhiarghat Palong Khali Ghandung	
Tefnaf*Pourashava* and surrounding area	Teknaf*Pourashava* ShahporirDwip Sabrang Uttar Nhilla	This *Mouzas* includes Teknaf *Pourashava* and the beach areas of Teknaf. Teknaf beach is unspoiled and remains as a virgin beach. There is a beach with coral which may be the alternative place of St martin.
St. Martin Area	ZinziraDwip	St. Martin Island is a small island in the northeast part of the Bay of Bengal, about 9 km south of the tip of the Cox's Bazar-Teknaf peninsula, and forming the southernmost part of Bangladesh. It is the only coral island in Bangladesh. It is about 8 km west of the northwest coast of Mayanmar at the mouth of the Naf river. The local name of the island is "NaricalGingira" also spelled "NarikelJanjina/Jinjera", translated from Bangla, meaning 'Coconut Island'. It is the only coral Island of our country and hold lots of opportunities for tourism development.

Source: Cox's Bazar Development Plan, UDD.

4.5.1 Structure plan:

The structure plan indicates the direction and extent of urban growth over a period of next 20 years and defines a set of policy guidelines with an aim to achieve the overall objectives of the structure plan. The structure plan identifies basic strategic options to accommodate anticipated growth, basic spatial and structural issues relating to overall development of an area and also provides area-wise strategies for expansion of different urban activities. Structural plan outlines major sectoral policies to guide development in the desired manner over the long run.

The fundamental idea behind the structure planning approach is that the future is not certain and therefore, it is not possible to predict the future circumstances of a city with any degree of precision beyond short of medium term. Such concept is reflected well in a strategy rather than in a plan. As it is not possible to predict future, it is also not possible to give an appropriate physical form of an area beyond medium term. Because of uncertainties of the future events, Structure Plan calls for concentrating on fundamental aspects immediately leaves the more detailed treatment of the problems nearer the time they occur. Thus, certain decisions affecting the development of the city in the medium and long term cannot be incorporated in the strategy immediately. However the scope must be created to take immediate actions to tackle current development problems. That's the reason structure plan has flexibility to modify fundamental development strategies for details problems whenever they occur; provides an open-ended broad policy framework for action plans and develop programs to formulate the plans in greater detail within shorter time frame and formulates responsibilities of all development agencies to a common goal, development by sector wise specific action charts (Sheltech, 2011).

4.5.2 Objectives of the plan:

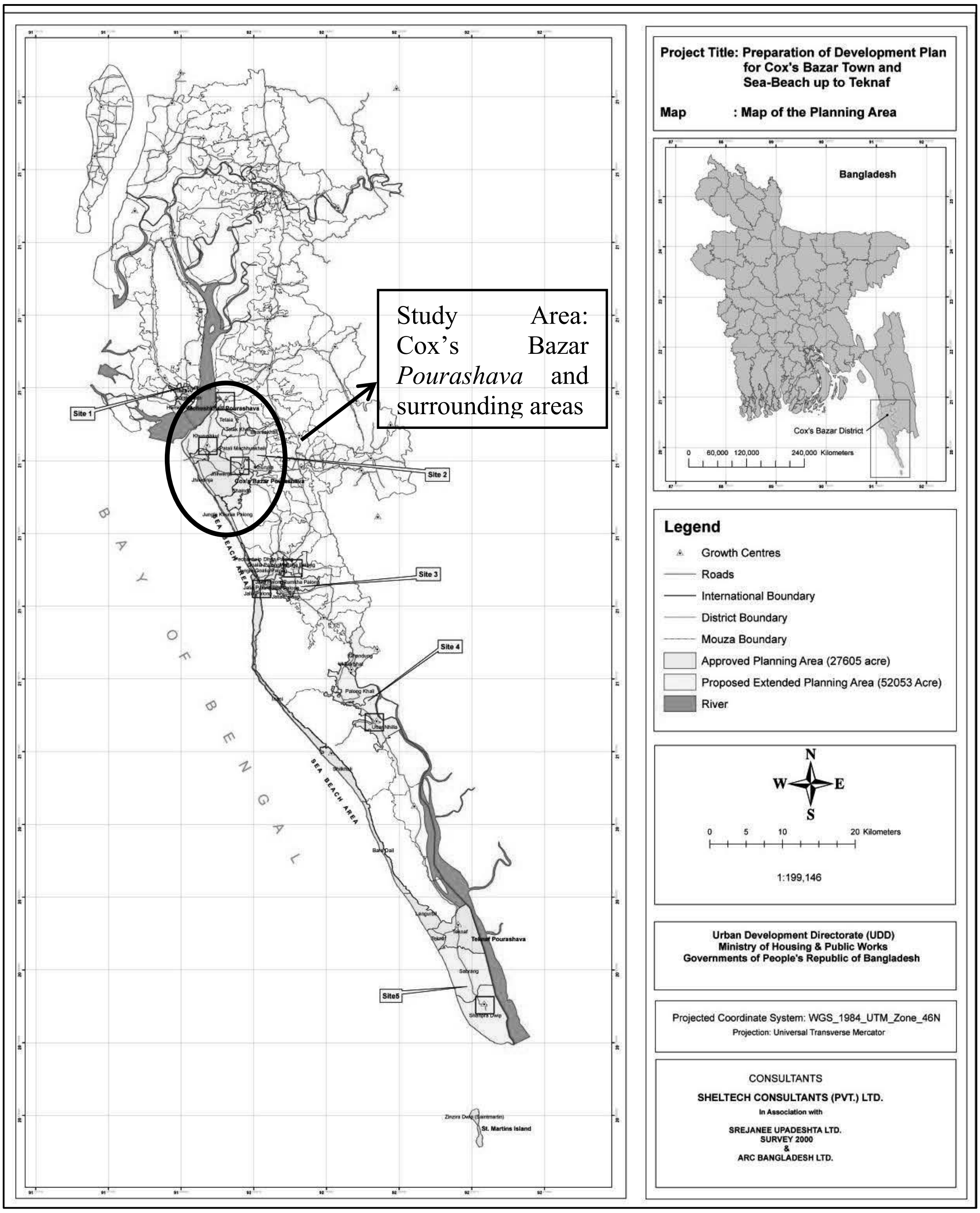
- Interpretation and Elaboration of national urban strategies and policies for local authority
- Establishment of inter sectoral goals, policies and general proposals for urban spatial development
- Identification of the development options that offer maximum benefit to the people
- Proposing suitable urban standards that minimizing the cost of public infrastructures
- Providing framework for the next hierarchy of plans, in this case, for the Master Plan and Detailed area Plan:
- Justification of policies and proposals for urban development (Sheltech, 2011).

4.5.3 Functions of the plan:

- Structure plan will interpret the urban Development policies to create the context for development.
- It will identify and establish objectives, policies and broad brush proposals for long term growth and development of the region.
- It will serve as a framework for development within the structure plan boundary by all public and private agencies.
- It will work out a mechanism for coordination and prioritizing development activities by public sector agencies.
- It will expose and disseminate the key planning issues and draw attention of all concerned interest groups including government and private agencies.
- It will set the context for details area plans by identification of development needs of specific areas and the time period for action
- It will provide the framework and the basis for management of development by setting forth policies for items of strategies and structural importance.

  (Sheltech, 2011).

The map of the Cox's Bazar Development Plan is given in map 4.4



Map 4.4: Map of the Cox's Bazar Development Plan
Source: Cox's Bazar Development Plan, UDD.

Chapter 05: Residential and Commercial Land Use Suitability Analysis of the Study Area

In order to identify the suitable uses of land, it was necessary to identify the criteria. Two types of land uses - residential and commercial were evaluated for suitability analysis.

Cox's Bazar *Pourashava* and the surrounding areas is one of the main tourist hubs of the whole Cox's Bazar district. Commercial and residential development flourished in Cox's Bazar area due to the increasing number of tourists and demand of tourism industry. These developments created pressure upon the ecosystem- natural environment of this Ecologically Critical Area. A proper land use plan is needed to guide the development which eventually raises the importance of having a land use suitability analysis. From this perspective, those two type land uses have been chosen for the evaluation of suitability analysis. The analysis is done based on some parameters which are fixed from literature surveys and expert opinions (refer to chapter 2). After fixing the criteria, a questionnaire survey was conducted to determine the relative weightages of the criteria through fuzzy AHP method. For this reason, five experts from different arena like: planner, geographer, environmentalists, academician etc. were interviewed. Once the weightages of the criteria is determined, GIS is used for showing the suitable maps for residential and commercial uses of Cox's Bazar *Pourashava* and surrounding areas.

5.1 Determination of the weights of criteria:

Once the criteria for residential and commercial land suitability analysis were fixed, the next step is to determine the relative weight of the parameters. It has already been discussed (refer to chapter 2) the reason behind using the Fuzzy AHP for determining the criteria weight. Questions were developed to elicit the judgments about the relative importance of each of the selected criteria

(Appendix A). The questionnaire was completed by five experts (Appendix B).Fuzzy evaluation matrixes of the five decision maker's at different level are presented in Appendix C.

An example of determining the weights of the criteria is given below:

Five pairwise comparison matrixes (at first level 3×3 matrix) were developed after the evaluation from five experts:

Table 5.1: Evaluation matrices of the criteria of experts

Evaluation matrix of Decision maker 1:			
	Physical (P)	Development (D)	Environment (E)
Physical (P)	1	5	1/3
Development (D)	1/5	1	1/7
Environment (E)	3	7	1
λmax = 3.08564; CR = 0.0649 < 0.1			
Evaluation matrix of Decision maker 2:			
	Physical (P)	Development (D)	Environment (E)
Physical (P)	1	1/7	¼
Development (D)	7	1	4
Environment (E)	4	1/4	1
λmax = 3.11473; CR = 0.0869< 0.1			
Evaluation matrix of Decision maker 3:			
	Physical (P)	Development (D)	Environment (E)
Physical (P)	1	3	7
Development (D)	1/3	1	6
Environment (E)	1/7	1/6	1
λmax = 3.12788; CR = 0.0969 < 0.1			
Evaluation matrix of Decision maker 4:			
	Physical (P)	Development (D)	Environment (E)
Physical (P)	1	1/8	1/7
Development (D)	8	1	½
Environment (E)	7	2	1
λmax = 3.09607; CR = 0.0728 < 0.1			
Evaluation matrix of Decision maker 5:			
	Physical (P)	Development (D)	Environment (E)
Physical (P)	1	1/5	3
Development (D)	5	1	7
Environment (E)	1/3	1/7	1
λmax = 3.10168; CR = 0.077 < 0.1			

* λmax is the principle Eigen value and CR is the consistency ration which describes (in percentage) whether the judgments of the experts are consistent or not. If CR< 10%, then the values given by the experts is satisfactory and consistent. (Saaty, 1980) (refer to chapter 2, section 2.3.3)

The consistency ration (CR) of all the matrices is given below the each table which shows that in all cases the CR is less than 0.1 (10%). So it the level of inconsistency present in the information stored in comparison matrix is satisfactory. After that, the five fuzzy evaluation matrices were developed based on the triangular fuzzy numbers (Table 5.1). The fuzzy evaluation matrix is given in table 5.2:

Table 5.2: Fuzzy Evaluation matrices of the criteria of experts

Fuzzy evaluation matrix of Decision maker 1:			
	Physical (P)	Development (D)	Environment (E)
Physical (P)	1,1,1	4, 5, 6	¼, 1/3, 1/2
Development (D)	1/6, 1/5, ¼	1,1,1	1/8, 1/7, 1/6
Environment (E)	2, 3, 4	6, 7, 8	1,1,1
Fuzzy evaluation matrix of Decision maker 2:			
	Physical (P)	Development (D)	Environment (E)
Physical (P)	1,1,1	1/8, 1/7, 1/6	1/5, ¼, 1/3
Development (D)	6, 7, 8	1,1,1	3, 4, 5
Environment (E)	3, 4, 5	1/5, ¼, 1/3	1,1,1
Fuzzy evaluation matrix of Decision maker 3:			
	Physical (P)	Development (D)	Environment (E)
Physical (P)	1,1,1	2, 3, 4	6, 7, 8
Development (D)	¼, 1/3, 1/2	1,1,1	5, 6, 7
Environment (E)	1/8, 1/7, 1/6	1/7, 1/6, /1/5	1,1,1
Fuzzy evaluation matrix of Decision maker 4:			
	Physical (P)	Development (D)	Environment (E)
Physical (P)	1,1,1	1/9, 1/8, 1/7	1/8, 1/7, 1/6
Development (D)	7, 8, 9	1,1,1	1/3, ½, 1
Environment (E)	6, 7, 8	1, 2, 3	1,1,1
Fuzzy evaluation matrix of Decision maker 5:			
	Physical (P)	Development (D)	Environment (E)

Physical (P)	1,1,1	1/6, 1/5, 1/4	2, 3, 4
Development (D)	4, 5, 6	1,1,1	6, 7, 8
Environment (E)	¼, 1/3, 1/2	1/8, 1/7, 1/6	1,1,1

From these five fuzzy evaluation matrixes, an aggregated fuzzy pairwise comparison matrix is developed through of geometric mean method. Like: all the first values of the first cells of each second column of all the five matrices were taken. Those values are: 4, 1/8, 2, 1/9, 1/6. Then the geometric mean of these values were computed which was 0.45 (Table 5.4). In this way an aggregated matrix (Table 5.3) was developed which is given below:

Table 5.3: Aggregated Fuzzy Comparison Matrix of the criteria

	Physical (P)	Development (D)	Environment (E)
Physical (P)	1, 1, 1	0.45, 0.56, 0.68	0.6, 0.76, 0.98
Development (D)	1.48, 1.8, 2.22	1, 1, 1	1.3, 1.64, 2.16
Environment (E)	1.02, 1.31, 1.68	0.46, 0.6, 0.77	1, 1, 1

After finding out the aggregate matrix, all the equations were followed (described in Chapter 2) to derive the weights of the criteria. The steps are given below:

$S_P = (2.05, 2.32, 2.66) \times (1/11.49, 1/9.67, 1/8.32) = (0.18, 0.24, 0.32)$

$S_D = (3.79, 4.44, 5.38) \times (1/11.49, 1/9.67, 1/8.32) = (0.33, 0.46, 0.65)$

$S_E = (2.48, 2.91, 3.45) \times (1/11.49, 1/9.67, 1/8.32) = (0.22, 0.3, 0.41)$

The degree of possibility of superiority of $S_P$is calculated and is denoted by $V (S_P \geq S_D)$. Therefore the degree of possibility of superiority for the first requirement- the values calculated as:

$V (S_P \geq S_D) = 1$

$V (S_P \geq S_E) = 0.5$

For the second requirement- the values are calculated as:

$V (S_D \geq S_P) = 1$,

$V (S_D \geq S_E) = 1$.

For the third requirement- the values are calculated as:

$V (S_E \geq S_P) = 1$,

V ($S_{E} \geq S_{D}$) = 0.625

The minimum degree of possibility of superiority of each criterion over another is obtained. This further decides the weight vectors of the criteria.

The weight vector is W'= (0.5, 1, 0.625)

The normalized value of this vector decides the priority weights of each criterion over another. The normalized weight vectors are calculated as:

W = (0.24, 0.46, 0.3)

Following the above procedure all the weights of the parameters at first level (W1) and second level (W2) were determined. From these two levels, the overall weight of the each of the layer (W) was derived which finally used in GIS platform. The following tables (Table 5.4 and Table 5.6) show the final output of the weights at these two levels:

Table 5.4: Criteria weights at two levels for residential land use suitability

Land uses	**Criteria**	**W1**	**Sub criteria**	**W2**	**Overall weight W=W1*W2**
Residential	Physical factors	0.24	Slope (degree)	0.37	0.09
			Elevation (m)	0.63	0.15
	Development factor	0.46	Proximity to existing residential area (km)	0.22	0.10
			Proximity to existing commercial area (km)	0.07	0.03
			Proximity to existing nearest paved road (km)	0.47	0.22
			Proximity to open space and recreational area (km)	0.25	0.12
	Environmental factor	0.3	Distance from existing water body (m)	0.29	0.09
			Distance from existing forest and vegetation (km)	0.18	0.05
			Distance from Sea-beach area (km)	0.53	0.15
Total weight value		1.00			1.00

Table 5.5: Criteria weights at two levels for commercial land use suitability

Land uses	Criteria	W1	Sub criteria	W2	Overall weight W=W1*W2
Commercial	Physical factors	0.17	Slope (degree)	0.39	0.07
			Elevation (m)	0.61	0.10
	Development factor	0.58	Proximity to existing residential area (km)	0.07	0.04
			Proximity to existing commercial area (km)	0.53	0.31
			Proximity to existing nearest paved road (km)	0.4	0.23
	Environmental factor	0.25	Distance from existing forest and vegetation (km)	0.21	0.05
			Distance from Sea-beach area (km)	0.79	0.2
Total weight value		1.00			1.00

5.2 Criteria weights for residential land use suitability:

Following Chart (Figure 5.1) provides the relative weightage of the criteria for residential land use at first level. It is clear that development criterion weightout environmental and development criteria. At second level, (Figure 5.2) of all development factors existence of paved road is most important (47%) while for environmental factors it is distance from sea beach (53%).

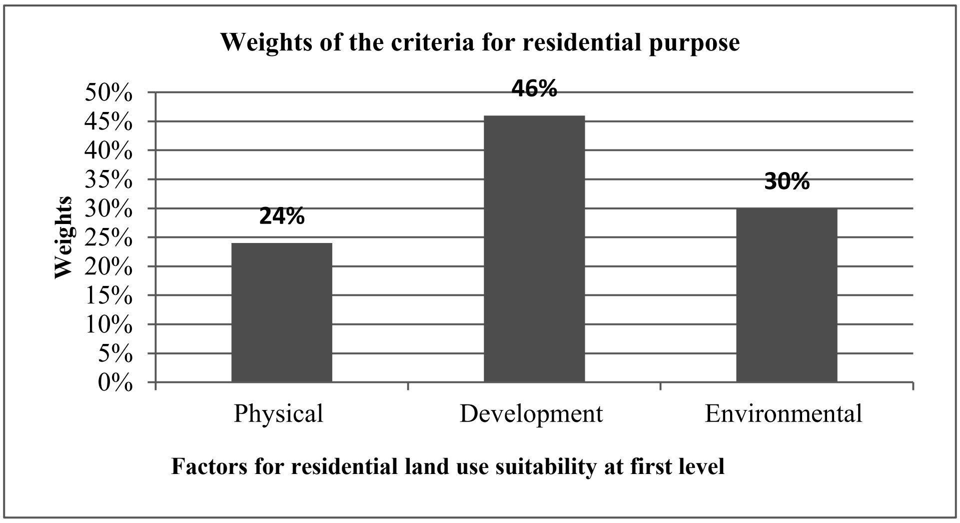


Figure 5.1: Percentage of weights of the criteria at first level for residential development

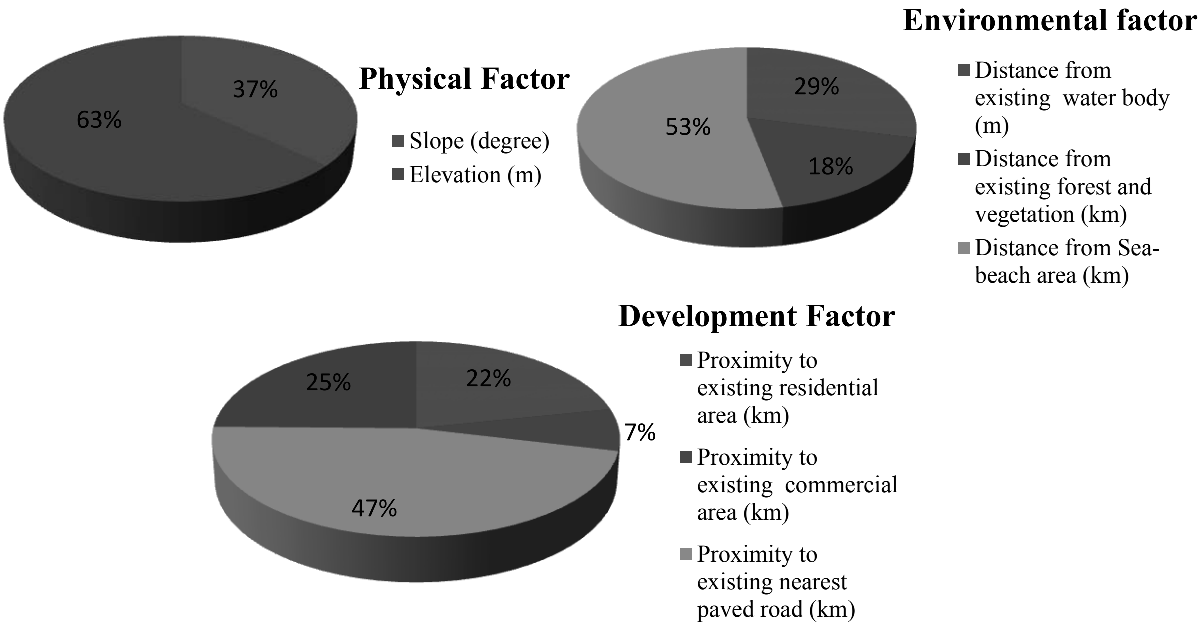


Figure 5.2: Percentage of weights of the criteria at second level for residential land use suitability

5.3 Criteria weights for commercial land use suitability:

Following Chart (Figure 5.3) provides the relative weightage of the criteria for residential land use at first level.

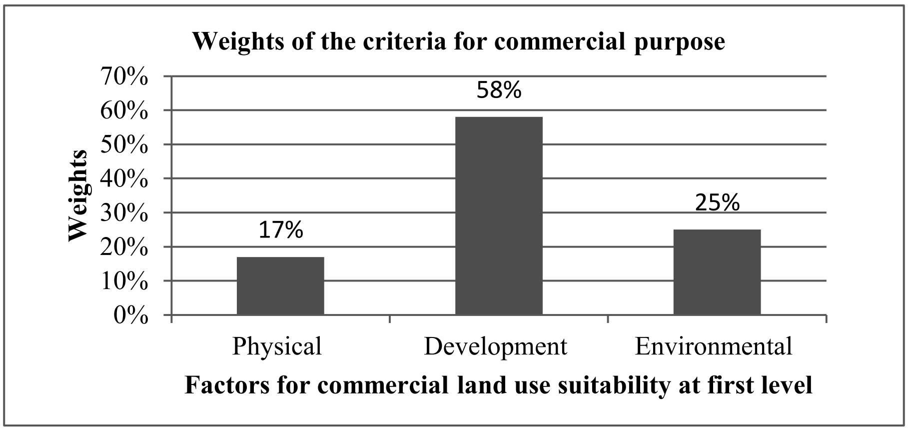


Figure 5.3: Percentage of weights of the criteria at first level for commercial development

From commercial perspective, experts give the highest priority to the development factors (58%). These factors are very important factor while assessing the land use suitability for any kind of commercial development. They dominate more over commercial development than the physical factors like slope or elevation. People preference for close proximity to roads for commercial development is somehow related with the easy movement of their products or of their customers (in case of hotels, restaurants etc.). In Cox's Bazararea, tourism business is growing too fast which leads to develop commercial activities in the same pace. Figure 5.4 provides the sub-factors of the categories:

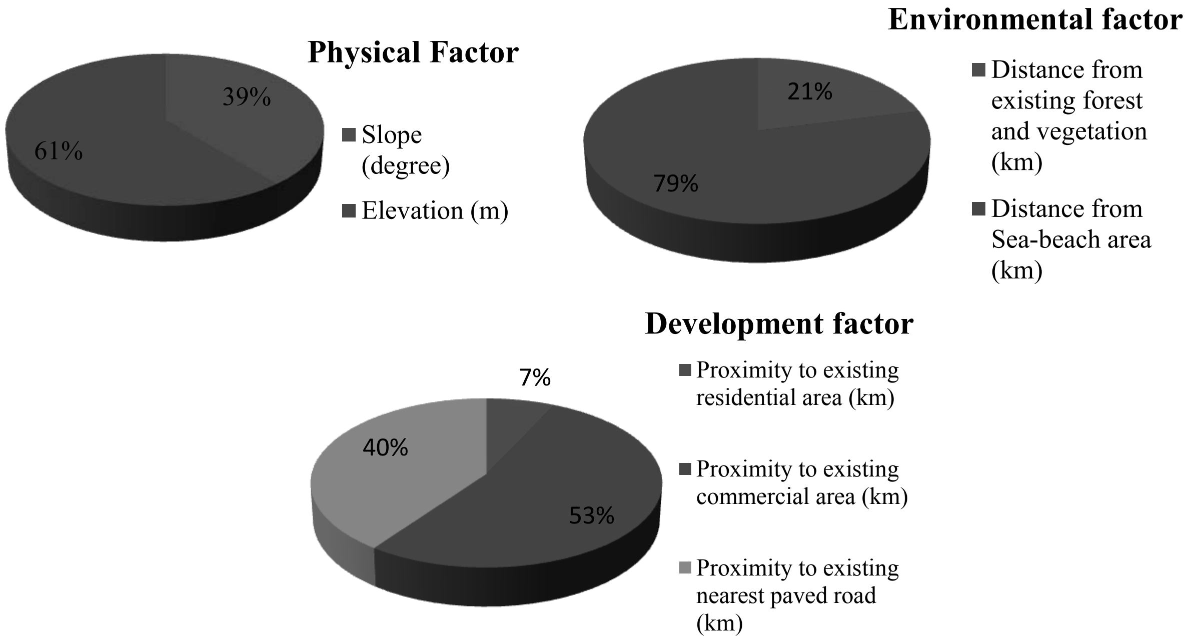


Figure 5.4: Percentage of weights of the criteria at second level for commercial land use suitability

Considering the physical factors for commercial development, again the elevation (61%) dominates over slope for the same reason as residential. Areas with high elevation are inaccessible to reach and also it is very difficult and costly to provide all the necessary facilities there to support the commercial activities.

Proximity to existing commercial area (53%) gets high preference among the factors in the category of development criteria. Competition among businessmen always tends to increase in the already built up commercial area rather than any other areas. People try to develop their own business in the more concentrated commercial area than in a very distant area. For this, this factor gets the highest weightage. Following this factor, proximity to existing paved road (40%) is in the second place as for any kind of commercial development ease of accessibility is necessary.

5.4 Suitable areas for residential and commercial development:

5.4.1 Residential land use suitability in the Cox's Bazar area:

Once the maps were overlaid the final suitability maps were prepared (Map5.1 and Map 5.4). In the map, the study area was classified into four classes:

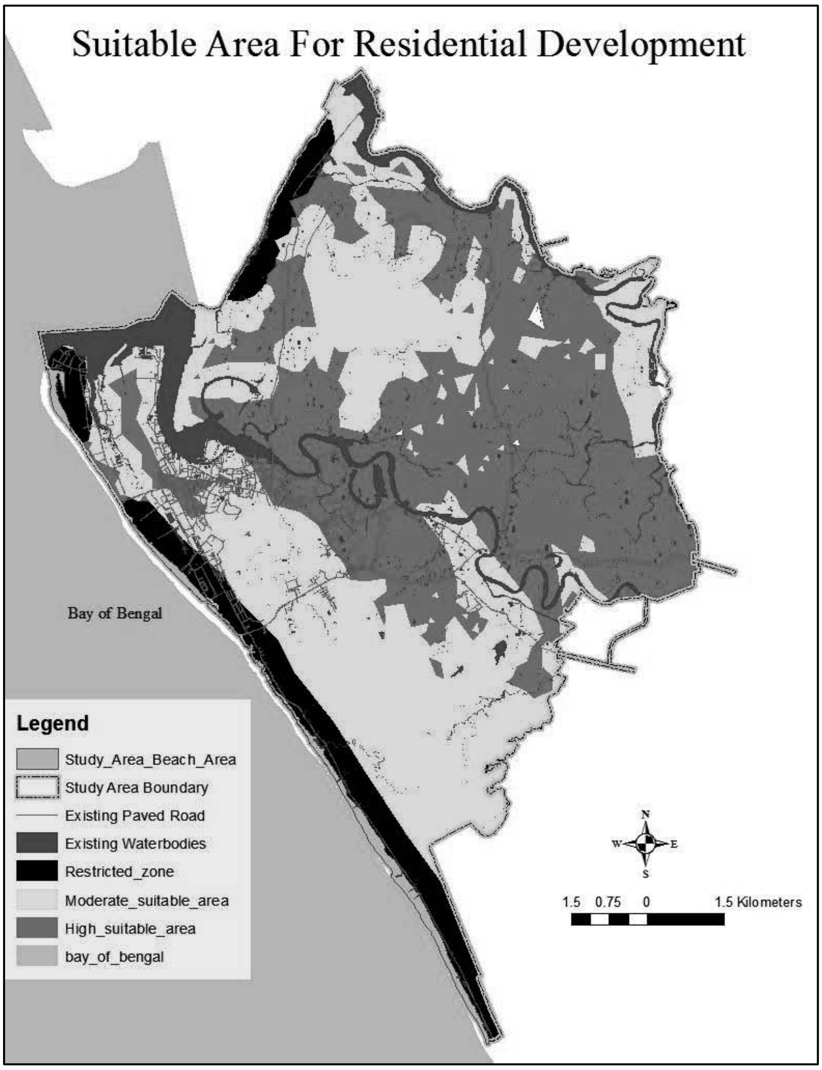
1) Highly suitable area
2) Moderately suitable area
3) Low suitable area
4) Restricted zone for development/not suitable area for development

The following table (Table 5.6) shows the suitable area for each type of suitability ranges:

Table 5.6: Suitable areas for residential land use

Suitability ranges	Suitable area (in sq. km.)	Percentage (%)
Highly Suitable area	45.14	42
Moderately Suitable area	52.54	49
Restricted zone	10.25	9
	107.93	100

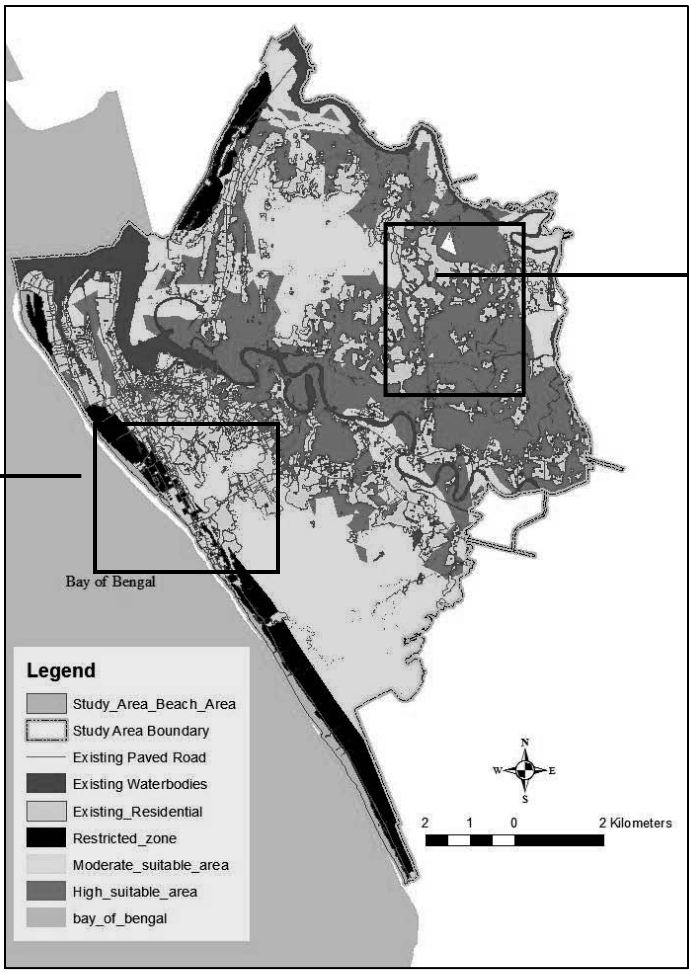
The area covering high suitable land for residential development is 45.14 sq. km (42% of the total area) whereas the moderate suitable area is 52.54 sq. km (49% of the total area) which is the largest among all suitability types. No area is found for low suitable range for residential land use type. Also, development is restricted around the 500m buffer area of the sea beach. The suitable map for residential development is given below (Map 5.1):



Map 5.1: Map showing the suitable areas for residential land use

From the map, it can be seen that most of the highly suitable areas lie far away from the beach area as in the criteria table (Refer to figure 5.3) the distance from the beach area parameter gets highest weightage (53%) in the environmental factor category. It has been discussed earlier that the development pressure is growing very fast in this area and slowly they are hampering the diversified ecology of this area. A part of the existing residential areas are situated in the moderately suitable areas and in the restricted zone whereas most of the areas are situated in the highly suitable areas (Map 5.2)

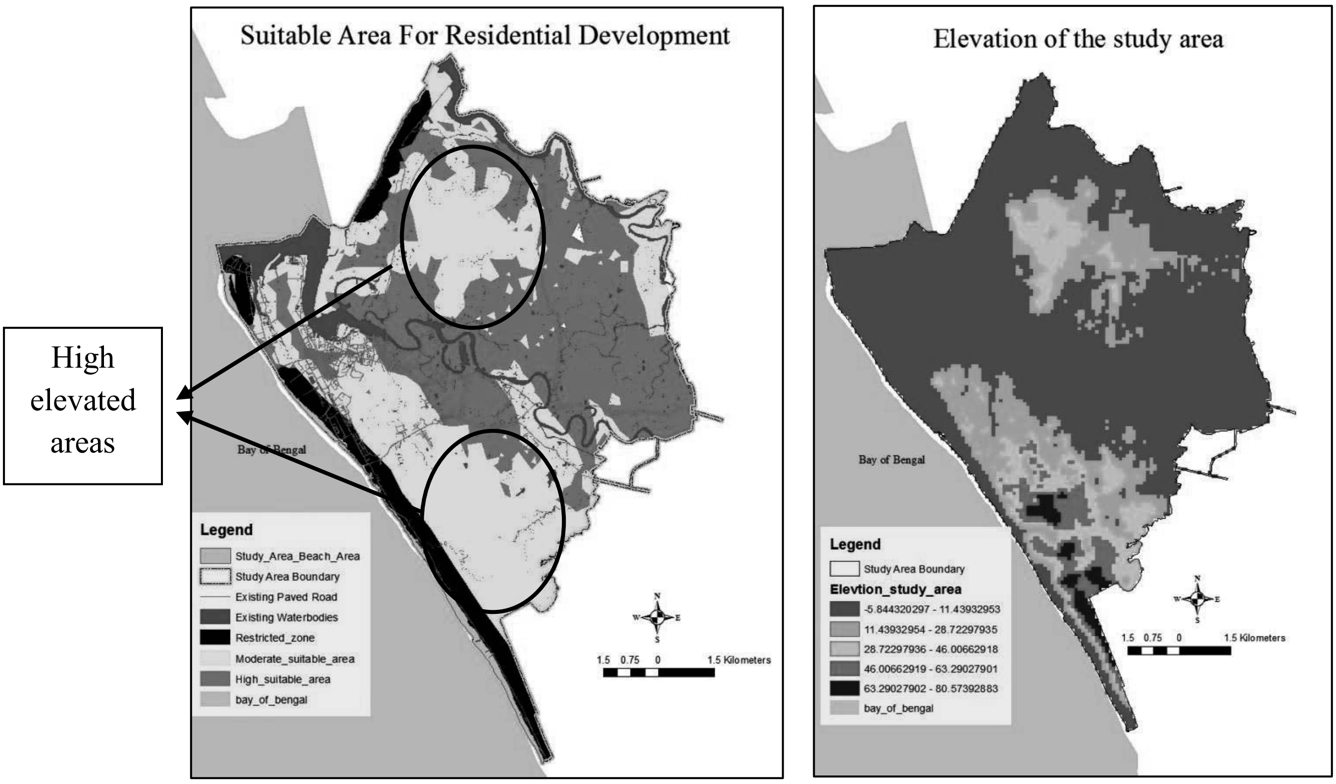
Existing residential areas in the moderately suitable areas and in the restricted areas.



Existing residential areas in the highly suitable land areas

Map 5.2: Map showing the existing residential set up in the highly, moderately suitable areas and in the restricted zone

No areas of highly suitable land fall under the hilly areas which are shown in the following Map 5.3.



Map 5.3: Map showing the suitable areas for residential development and the elevation of the study area.

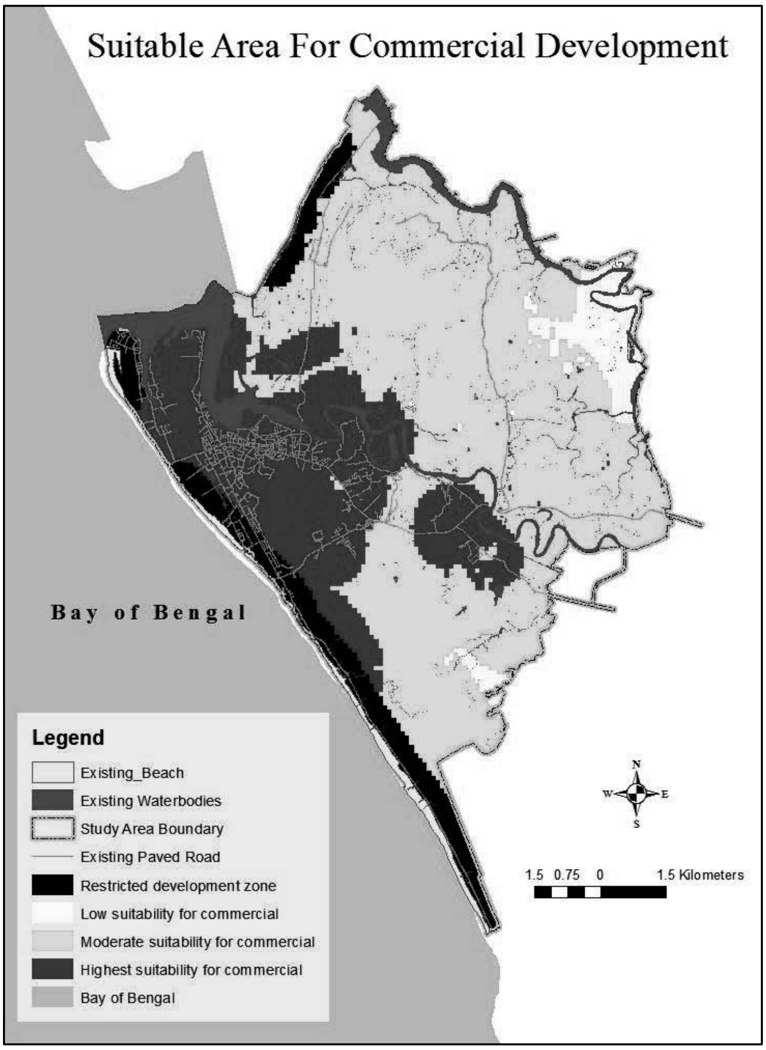
5.4.2 Commercial land use suitability in the Cox's Bazar area:

For finding out the areas for commercial land use suitability, same procedure for the residential land use suitability was followed. Here also the suitability classeswere divided into four ranges. The final output of the result for suitablecommercial land area is given the table 5.7:

Table 5.7: Suitable areas for commercial land use

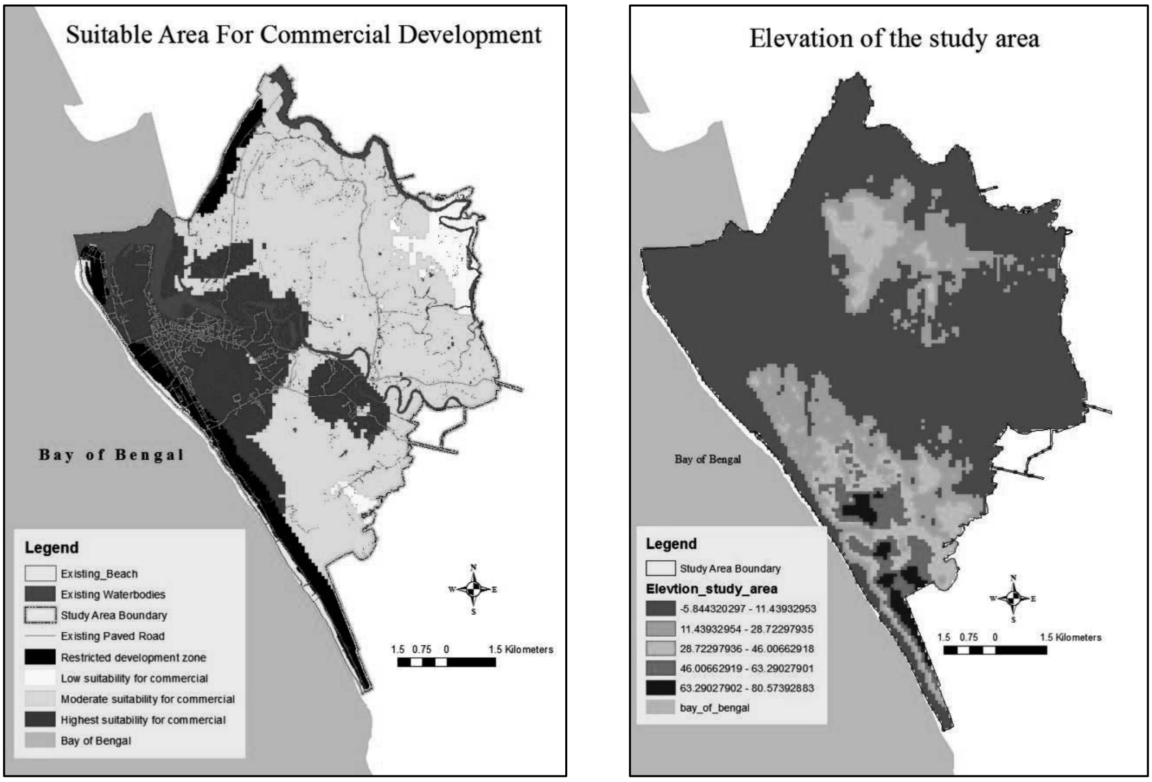
Suitability ranges	Suitable area (in sq. km.)	Percentage (%)
Highly Suitable	29.55	27
Moderately Suitable	62.95	58
Low Suitable	5.19	5
Restricted zone	10.25	9
	107.93	100

From the above table it can be seen that the moderately suitable area gets the highest percentage (58% of the total area) with an area of 29.55 sq. km. whereas the highest suitable area for commercial development covers 62.95 sq. km of the total area. The suitable map for commercial development is given below (Map 5.4):



Map 5.4: Map showing the suitable areas for commercial land use

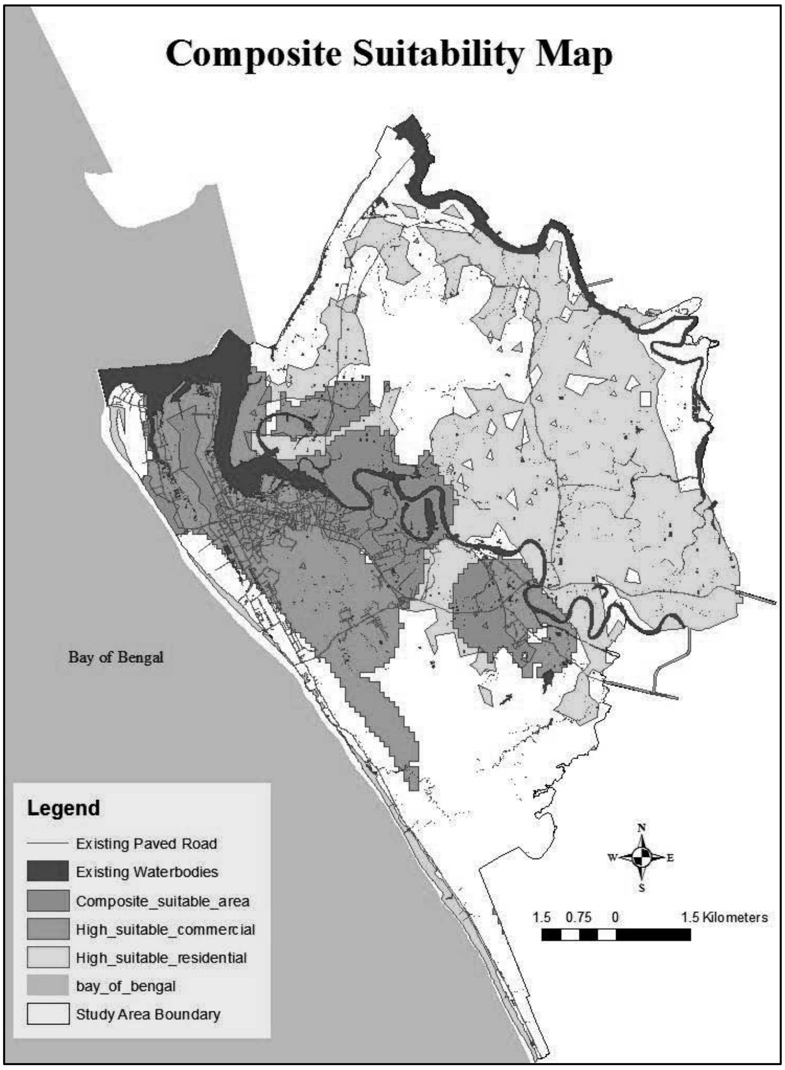
From the above map, it can be seen that most of the commercial suitable land area are concentrated around the restricted buffer zone. From expert's perspectives, the sea beach area is an ecologically critical area and that's why development should be discouraged. On the other hand, for tourism business sea front view commercial development is very lucrative for the investors. A vast portion of the existing commercial developments can be found in the restricted zone area and some are found in the high suitable area. Again if we consider the physical factors like elevation, a small area can be found in the high elevated zone which is shown in the following map (Map 5.5)



Map 5.5: Map showing the suitable areas for commercial development and the elevation of the study area.

5.4.3 Composite land use suitability:

After finding out the suitable land area for residential and commercial development, a composite suitability map was prepared by taking only the highly suitable range of the two types land uses. The following map (Map) shows the composite suitable map of the study area:



Map 5.6: Composite suitability map for both commercial and residential development

The grey portion of the map is the composite suitable area where both the commercial and residential development possible. But this type of decisions need an investigation that which type of land uses best suited for this area. The following table shows the statistics of this composite map area:

Table 5.8: Areas for composite suitable land

Name of the suitability range	Area in Sq. km.
Highly Suitable Commercial	29.55
Highly Suitable Residential	45.14
Composite Suitable area	10.64

Chapter 6: Comparison of the Land Suitability Analysis with the Proposed Land Uses of Cox's Bazar Development Plan

One of the objectives of this study is to compare the output result of the land use suitability with the proposed land uses of the development plan of Cox's Bazar area. For this purpose, proposed residential and commercial areas were extracted from the "proposed land use map" of the Cox's Bazar Development Plan. Then these proposed "residential" and proposed "commercial" maps were overlaid on the residential and commercial suitability maps. From the overlay map, the mismatches were identified.

6.1 Comparison of the land suitability analysis with the development plan of Cox's Bazar:

6.1.1 Proposed residential land uses in the Development plan:

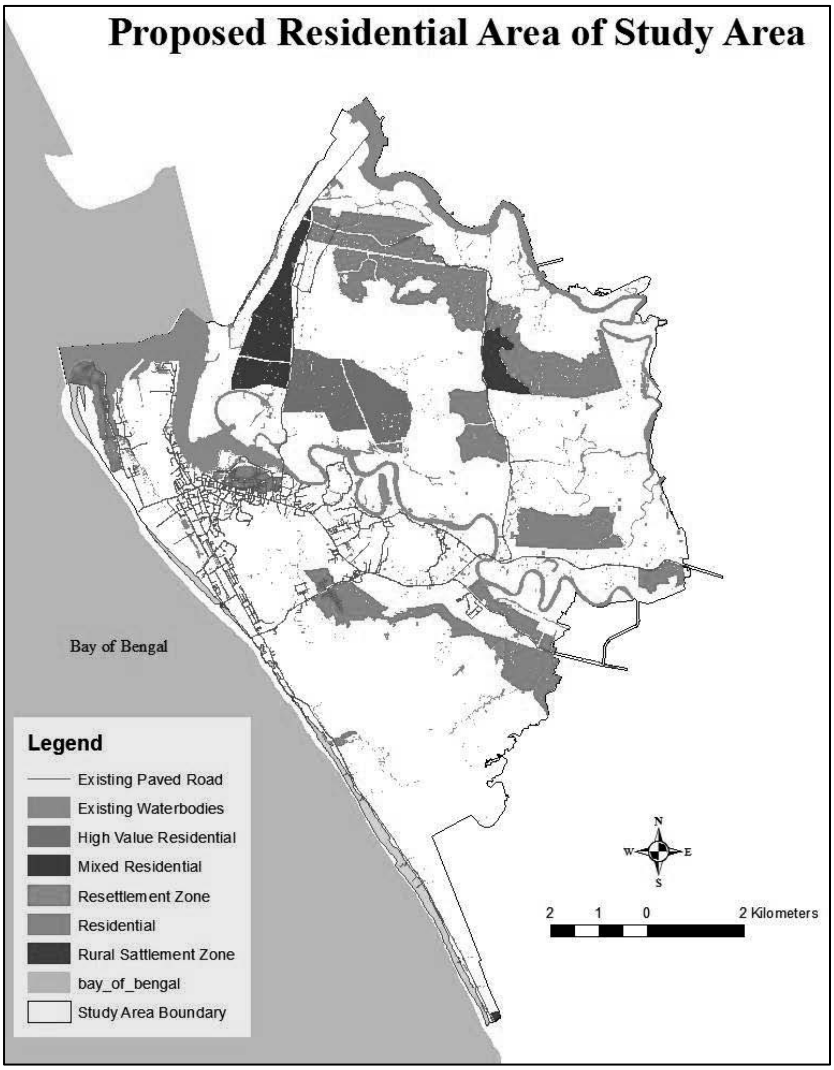
The proposed residential area is divided into three classes: High Value Residential, Mixed Residential, Residential, Rural Settlement Zone, and Resettlement Zone. A statistics of these categories is given in the Table 5.9.

Table 5.9: Proposed residential land uses in the development plan

MOUZA	Proposed Residential Land Use Category	Area in sq. km.	Percentage (%)
Kharushkul	High Value Residential	3.28	16.01
Patali Machhua Khali			
Kharushkul	Mixed Residential	2.40	11.46
Jhilwaja	Residential	13.43	68.84
Chainda			
Kharulia			
Cox'sbazar			
Totak Khali			
Kharushkul			

Tetaia			
Cox's bazar	Resettlement Zone	0.79	3.57
Total proposed area		19.92	100

From the above table it can be seen that the residential area possess the higher percentage (68.84%) in the proposed land use category with 13.43 sq. km. followed by the high value residential (luxurious apartment buildings) area (3.28 sq. km). The following map (Map 5.7) shows the proposed residential area of the study area.



Map 5.7: Proposed residential land uses of the study area

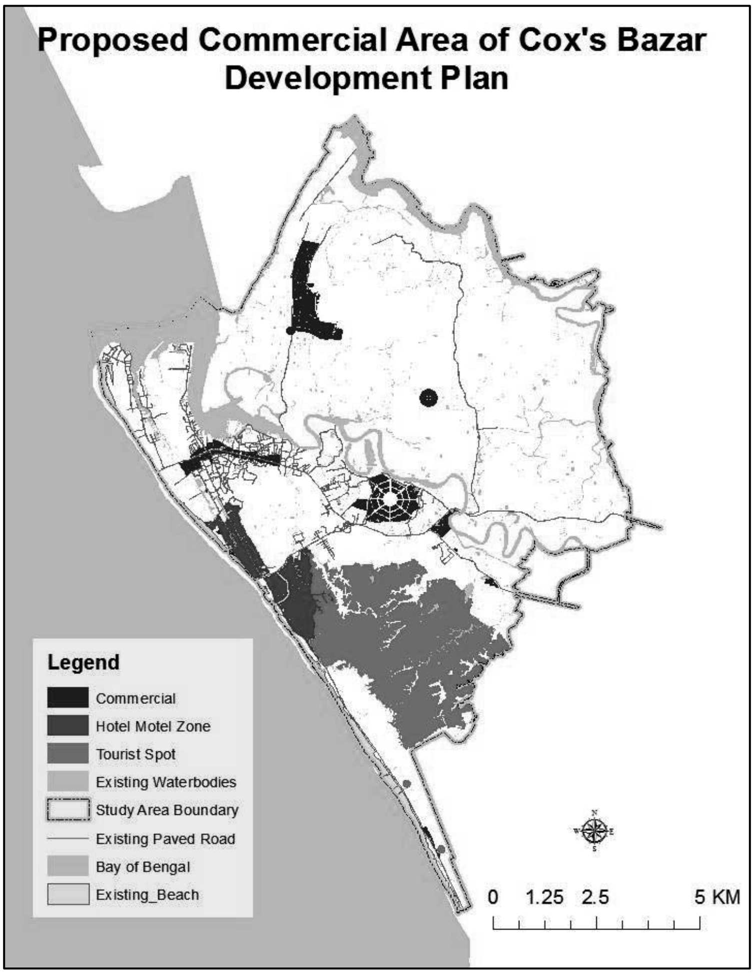
6.1.2 Proposed commercial land uses in the Development plan:

The proposed commercial area includes: Commercial area, Hotel Motel zone, CBD, Mixed Commercial, Natural Forest for Eco tourism, Picnic Spot and Tourist Zone. A table is given below showing the total area of the proposed commercial area:

Table 5.10: Proposed commercial land uses in the development plan

MOUZA	Proposed commercial land use category	Area in sq. km.	Percentage
Jhilwaja	CBD	0.8590	4.89
Jhilwaja	Commercial	0.9318	5.31
Cox's bazar			
Chainda			
Patali Machhua Khali			
Kharushkul			
Jhilwaja	Hotel Motel Zone	2.4250	13.81
Kharushkul	Mixed Commercial	1.2525	7.13
Chainda	Natural Forest for Eco tourism	10.8564	61.84
Jhilwaja			
Chainda	Picnic Spot	1.1620	6.62
	Tourist Zone	0.0677	0.39
Total		17.5544	100.00

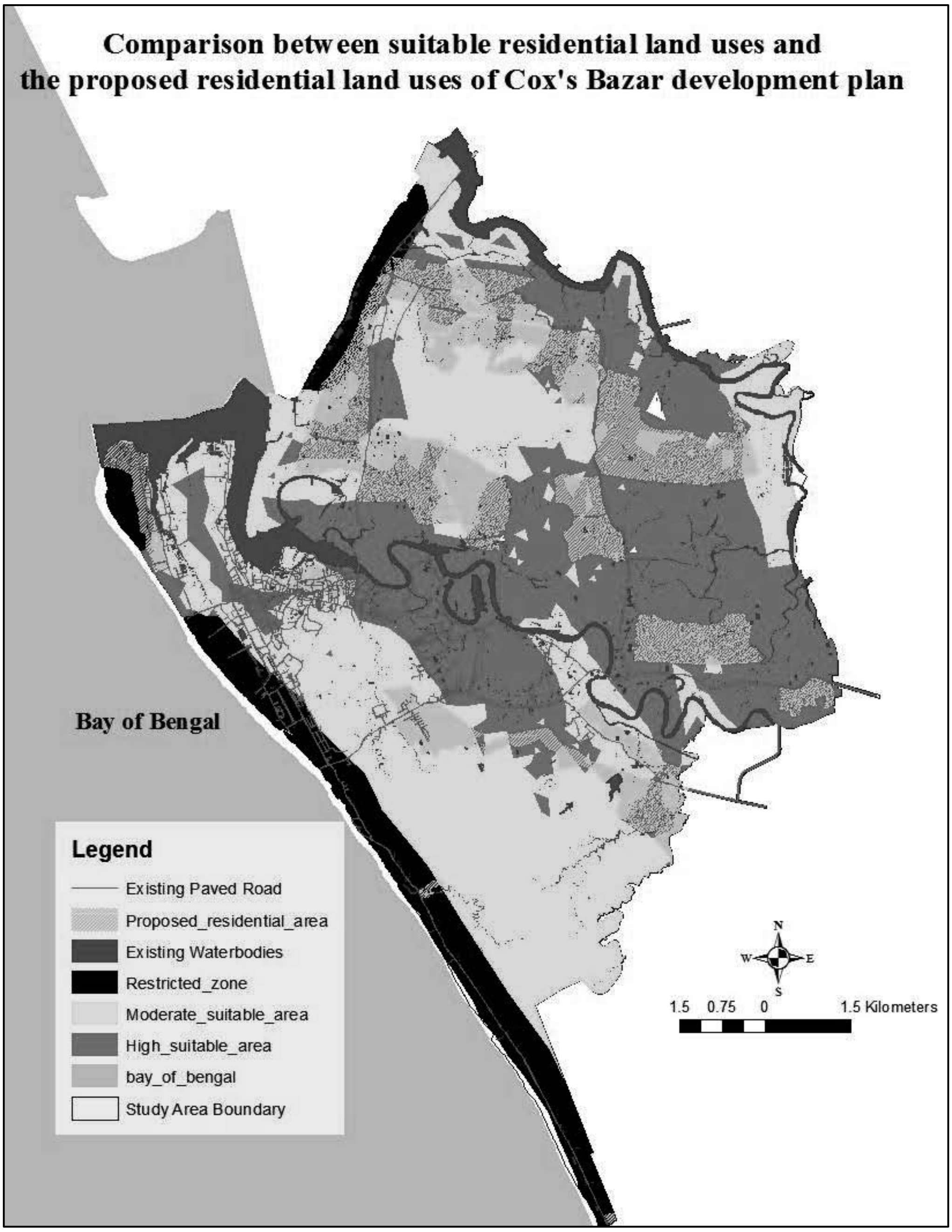
From the above table it can be seen that the Natural Forest for Eco tourism possess highest percentage (61.84%) in the proposed land use category with 10.8564sq. km. on the other hand hotel motel zone covers only 13.81% of total commercial land use.



Map 5.8: Proposed commercial land uses of the study area

6.1.3 Comparison between proposed and suitable residential landuses:

The proposed residential land use map was compared with the residential suitable land use map which is given below:



Map 5.9: Comparison of the proposed residential land uses of Cox's Bazar plan with the findings of the residential land use suitability

The scenario of the overlay can be shown in the following table (Table 5.11) which is followed by a description of the scenario:

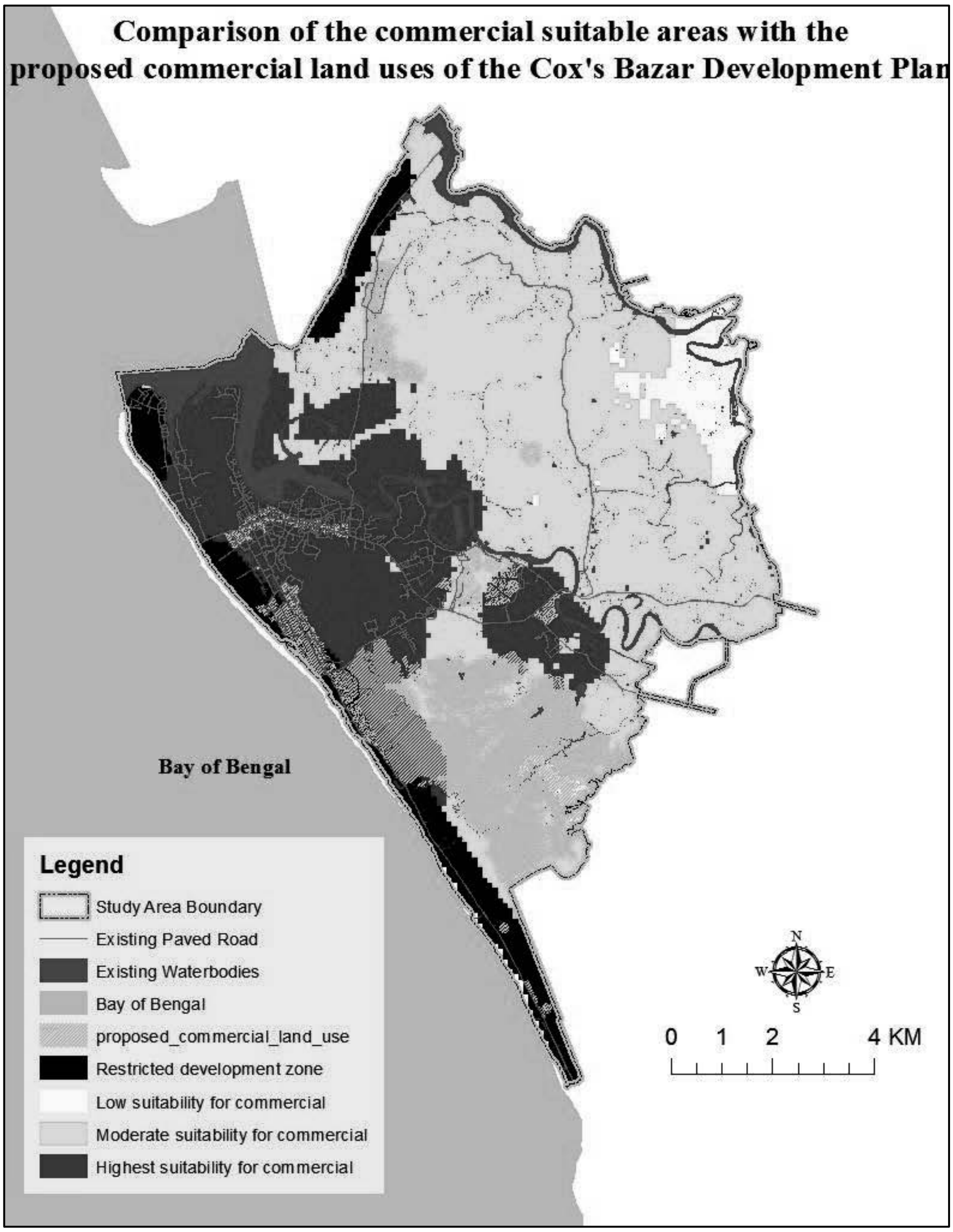
Table 5.11: Comparison of proposed residential areas to suitable residential areas

Land use	Proposed area (sq. km.)	Proposed area in highly suitable zone	Unutilized highly suitbale area	Proposed area in moderately suitable zone	Unutilized moderately suitbale area	Proposed area in low suitable zone	Unutilized low suitable area	Proposed area in restricted zone
Resid-ential	19.92	53.74%	76.29%	41.18%	84.39%	0	0	5.08%

It was found that 53.74% of the total proposed residential area falls in the highly suitable zone and only 23.71% (10.70 sq. km) of the highly suitable residential area can be utilized by this. 41.18% of the total proposed residential area falls in the moderately suitable residential zone (covering only 15.61% of moderately suitable zone). However, most strikingly, 5.08% of the total proposed residential area is proposed to be built in the restricted zone as defined by the suitability analysis. The land use proposed in the moderately suitable and restricted zone could have easily been shifted to the highly suitable area, had there been a suitability analysis done. In the long run this would have helped in achieving the goal of sustainable development.

6.1.4 Comparison between proposed and suitable commercial landuses:

The proposed commercial land use map is overlaid on the commercial suitable land use map which is given below:



Map 5.10: Comparison of the proposed commercial land uses of Cox's Bazar plan with the findings of the commercial land use suitability

The scenario of the overlay can be shown in the following table 5.12 which is followed by a description of the scenario:

Table 5.12: Comparison of proposed commercial areas to suitable commercial areas

Land use	Proposed area (sq. km.)	Proposed area in highly suitable zone	Unutilized highly suitable area	Proposed area in moderately suitable zone	Unutilized moderately suitable area	Proposed area in low suitable zone	Unutilized low suitable area	Proposed area in restricted zone
Commercial	17.55	19.23%	88.58%	66.66%	60.4%	3.43 %	97.96 %	10.68 %

19.23% of the proposed commercial land use falls in the highly suitable zone covering only 11.42% of the highly suitable commercial area. Around 11.7 sq. km of the proposed commercial area (66.66% of the total proposed commercial area) falls in the moderately suitable commercial zone. Most importantly 14.11% of the total proposed commercial area falls in the low suitable and restricted zone.

So, almost 80.77% of the total proposed commercial zone falls in the moderate, low and restricted zone where these can easily be shifted in the highly suitable area. A big chunk of the proposed commercial land use (61.84% of the total proposed commercial area) is proposed to be “Natural Forest for Eco tourism” and the proposed location is at the existing natural forest zone. For the purpose of the suitability analysis this area was categorized as not suitable for development. In light of present development and tourism trend in the Cox’s Bazar area, protecting any natural resource is of utmost importance. Even provision for eco-friendly tourism activities can create pollution and hamper the bio-diversity considering the present management system of tourism facilities in Cox’s Bazar. So any kind of commercial activities or development in this zone should be prohibited.

Chapter 7: Recommendations and Conclusion

This research is mainly focused on evaluating the land use suitability analysis for the development plan of Cox's Bazar area with a focus on residential and commercial land uses. The study used Fuzzy AHP tool for calculating the criteria weight and GIS platform for overlaying all the weighted layers. The final output of this research is the suitable areas for residential and commercial development in this ecologically critical area. Also the similarities and mismatches of these suitable areas are also revealed by making a comparison with the recent development plan of Cox's Bazar area. However, this research can be considered as a model for land use suitability analysis which is very important for any of kind of land use planning. Thus, this research has a national level policy implication which can help to determine practical policies for urban land development.

7.1 Policy implications:

The outcome of this research will help decision makers, practitioners of different fields to understand about the importance of having a proper guideline for land use suitability analysis in any development plan and to deal with spatial multi-dimensional decision making problems. This study will help to give an understanding that even qualitative data, like experts' opinions or decisions, can also be quantified with some technical approach or tools which will make decision making smoother and more scientific. With a systematic process of land use suitability analysis, development planning and management can be better guided and efficient. The study has following policy implications:

- The findings of this study are suitable for strategic land use policy planning. For the purpose of formulation of strategy for development of certain area, it is very much important to understand the suitable alternatives for the optimum use of land resources in that particulararea.

From this understanding a strategy can be correctly form which can guide the development plan formulation

- The ultimate result of this research is a set of maps showing areas which are suitable for development under existing physical condition. Recent development trend of the study area has created concerns of Urban sprawl- replacing non-urban, forest and vegetation, sea beaches and agricultural uses. It is expected that this study will identify such sensitive and stressed areas through the comparison of the suitable maps with the development plan and may provide valuable insights for formulating planning policies.
- This study will be helpful for central authority- for formulating planning policy and development goals. It will also help the local authority, involved in planning and development control, to formulate development plan, zoning etc. Different private developers involved in housing and commercial development can also be benefitted from such analyses to conduct development work sustainably.
- It would also be replicable for any other geographical area. Only the research parameters and scope would change depending on the geographic and socio-economic scenario and development trend of the area in focus.

7.2 Conclusion:

Cox's Bazar is an ecologically critical but economically prospective area. Government has a vast opportunity of revenue earning through a proper tourism sector development in this area. At the same time, the unique biodiversity and the sensitive sea beach area are also needed to be protected. Unplanned development of both commercial and residential area along with the increasing number of tourists and a poor tourism management plan, all these are acting as a negative reinforcement in the development of this environmentally critical area. From this understanding, the development plan was initiated to control development and to propose a sustainable tourism development plan in Cox's Bazar area. But it needs to bear in mind that not all of our land is equal in terms of development potential-some areas are better suited for physical development than others. And to identify this potential land, suitability analysis following a proper land use planning guideline is must. The study provides a comprehensive overview of the quantity of developable land in future. The entire area will benefit if development is planned and executed in a manner that takes full advantage of our existinginfrastructure and not threatening the quality of our naturalresources.

Appendix A

Questionnaire form for determining the weights of the suitability criteria

Questionnaires were developed to elicit the judgments about the relative importance of each of the selected criteria (Appendix A). The questionnaire was completed by five experts, among them one was Chief Town Planner of RAJUK and other five were academicians from Geography Department of Dhaka University, Urban planning Department of Jahangirnagar University and Urban Planning Department of BUET. The criteria were divided into two levels which are given in the following tables:

Preference weight values for different level of importance are shown in the following table:

Preferences expressed in numeric variables	Preferences expressed in linguistic variables
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate value between the two adjacent judgments
Reciprocals of above non-zero numbers	If an activity has one of the above numbers (e.g., 3) compared with a second activity, then the second activity has the reciprocal value (i.e., 1/3) when compared to the first.

<u>Criteria for Residential Land Use Suitability:</u>

Land uses	Criteria	Sub criteria	Suitability classes	Ranges
Residential	Physical factors	Slope (degree)	S3	0-5
			S2	5-10
			S1	>10
		Elevation (m)	S3	0-8
			S2	8-20
			S1	>20
	Development factors	Proximity to existing residential area (km)	S3	0-1
			S2	1-2
			S1	>2
		Proximity to existing commercial area (km)	S3	>5
			S2	2.5-5
			S1	0-2.5
		Proximity to existing nearest paved road (km)	S3	0-2
			S2	2-4
			S1	>4
		Proximity to open space and recreational area (km)	S3	0-2
			S2	2-4
			S1	>4
	Environmental factors	Distance from existing water body (m)	S3	>300
			S2	150-300
			S1	0-150
		Distance from existing forest and vegetation (km)	S3	>4
			S2	2-4
			S1	0-2
		Distance from Sea-beach area (km)	Restricted area: Within 500 m Distance no development will be allowed	

Question Form for Evaluation for residential land use suitability analysis:

Read the following questions and put check marks on the pair wise comparison matrices. If a criterion on the left is more important than the matching one on the right, put your check mark to the left of the importance ‘‘Equal’’ under the importance level you prefer. If a criterion on the left is less important than the matching one on the right, put your check mark to the right of the importance ‘Equal’ under the importance level you.

With respect to the main Goal “Residential land use suitability”
Question 1: How important is “Physical Factors” when it is compared with “Development Factors”?
Question 2: How important is “Physical Factors” when it is compared with “Environmental Factors”?
Question 3: How important is “Development Factors” when it is compared with “Environmental Factors”?

Importance (or preference) of one criterion over another																			
Question	**Criteria**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Criteria**
1.	**Physical Factors**																		**Development Factors**
2.	**Physical Factors**																		**Environmental Factor**
3.	**Develop ment Factors**																		**Environmental Factor**

With respect to the attribute “Physical Factors”
Question 1: How important is “Slope” when it is compared with “Elevation”?

Importance (or preference) of one criterion over another																			
Question	**Criteria**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Criteria**
1.	**Slope**																		**Elevation**

With respect to the attribute "Development factor"

Question 1: How important is "Proximity to existing residential area (km)" when it is compared with "Proximity to existing commercial area (km)"?

Question 2: How important is "Proximity to existing residential area (km)" when it is compared with "Proximity to existing nearest paved road (km)"?

Question 3: How important is "Proximity to existing residential area (km)" when it is compared with "Proximity to open space and recreational area (km)"?

Question 4: How important is "Proximity to existing commercial area (km)" when it is compared with "Proximity to existing nearest paved road (km)"?

Question 5: How important is "Proximity to existing commercial area (km)" when it is compared with "Proximity to open space and recreational area (km)"?

Question 6: How important is "Proximity to existing nearest paved road (km)" when it is compared with "Proximity to open space and recreational area (km)"?

Importance (or preference) of one criterion over another																			
Question	**Criteria**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Criteria**
1.	Proximity to existing residential area (km)																		Proximity to existing commercial area (km)
2.	Proximity to existing residential area (km)																		Proximity to existing nearest paved road (km)
3.	Proximity to existing residential area (km)																		Proximity to open space and recreational area (km)
4.	Proximity to existing commercial area (km)																		Proximity to existing nearest paved road (km)
5.	Proximity to existing commercial area (km)																		Proximity to open space and recreational area (km)
6.	Proximity to existing nearest paved road (km)																		Proximity to open space and recreational area (km)

With respect to the attribute "Environmental factor"
Question 1: How important is "Distance from existing water body (m)" when it is compared with "Distance from existing forest and vegetation (km)"?
Question 2: How important is "Distance from existing water body (m)" when it is compared with "Distance from Sea-beach area (km)"?
Question 3: How important is "Distance from existing forest and vegetation" when it is compared with "Distance from Sea-beach area (km)"?

Importance (or preference) of one criterion over another																			
Question	**Criteria**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Criteria**
1.	Distance from existing water body (m)																		Distance from existing forest and vegetation (km)
2.	Distance from existing water body (m)																		Distance from Sea-beach area (km)
3.	Distance from existing forest and vegetation																		Distance from Sea-beach area (km)

Criteria for Commercial Land Use Suitability:

Land uses	Criteria	Sub criteria	Suitability classes	Ranges
Commercial	Physical factors	Slope (degree)	S3	0-5
			S2	5-10
			S1	>10
		Elevation (m)	S3	0-8
			S2	8-20
			S1	>20
	Development factors	Proximity to existing residential area (km)	S3	> 5.0
			S2	2.5-5
			S1	0-2.5
		Proximity to existing commercial area (km)	S3	0-1
			S2	1-2
			S1	>2
		Proximity to existing nearest paved road (km)	S3	0-1
			S2	1-2
			S1	>2
	Environmental factors	Distance from existing forest and vegetation (km)	S3	>5
			S2	2.5-5
			S1	0-2.5
		Distance from Sea-beach area (km)	Restricted area: Within 500 m Distance no development will be allowed	

Question Form for Evaluation Commercial Land Use Suitability:

Read the following questions and put check marks on the pair wise comparison matrices. If a criterion on the left is more important than the matching one on the right, put your check mark to the left of the importance ‘‘Equal’’ under the importance level you prefer. If a criterion on the left is less important than the matching one on the right, put your check mark to the right of the importance ‘Equal’ under the importance level you.

With respect to the main Goal “Commercial land use suitability”
Question 1: How important is “Physical Factors” when it is compared with “Development Factors”?
Question 2: How important is “Physical Factors” when it is compared with “Environmental Factors”?
Question 3: How important is “Development Factors” when it is compared with “Environmental Factors”?

Importance (or preference) of one criterion over another																			
Question	**Criteria**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Criteria**
1.	**Physical Factors**																		**Development Factors**
2.	**Physical Factors**																		**Environmental Factor**
3.	**Development Factors**																		**Environmental Factor**

With respect to the attribute “Physical Factors”
Question 1: How important is “Slope” when it is compared with “Elevation”?

Importance (or preference) of one criterion over another																			
Question	**Criteria**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Criteria**
1.	**Slope**																		**Elevation**

With respect to the attribute "Development factor"

Question 1: How important is "Proximity to existing residential area (km)" when it is compared with "Proximity to existing commercial area (km)"?

Question 2: How important is "Proximity to existing residential area (km)" when it is compared with "Proximity to existing nearest paved road (km)"?

Question 3: How important is "Proximity to existing commercial area (km)" when it is compared with "Proximity to existing nearest paved road (km)"?

Importance (or preference) of one criterion over another																			
Question	**Criteria**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Criteria**
1.	Proximity to existing residential area (km)																		Proximity to existing commercial area (km)
2.	Proximity to existing residential area (km)																		Proximity to existing nearest paved road (km)
3.	Proximity to existing commercial area (km)																		Proximity to existing nearest paved road (km)

With respect to the attribute "Environmental factor"

Question 1: How important is "Distance from existing forest and vegetation (km)" when it is compared with "Distance from Sea-beach area (km)"?

Importance (or preference) of one criterion over another																			
Question	**Criteria**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Criteria**
1.	Distance from existing forest and vegetation (km)																		Distance from Sea-beach area (km)

Appendix B

List of Experts

Questionnaires were developed to elicit the judgments about the relative importance of each of the selected criteria (Appendix A). The questionnaire was completed by five experts, among them one was Chief Town Planner of RAJUK and other five were academicians from Geography Department of Dhaka University, Urban planning Department of Jahangirnagar University and Urban Planning Department of BUET. The list of the experts is given below:

Experts	**Designations**
1. Dr. Ishrat Islam	Professor, DURP, BUET, Dhaka.
2. Dr. Akter Mahmud	Professor, DURP, Jahangir Nagar University, Dhaka.
3. Dr. Mohhamad Nurul Islam Nazem	Professor, Department of Geography and Environment, Dhaka University, Dhaka.
4. Dr. Abul Kalam	Professor, DURP, Jahangir Nagar University, Dhaka.
5. Dr. K. Z. H. Taufiq	Former Chief Town Planner, RAJUK, Dhaka.

Appendix C

Evaluation matrices of the experts

Evaluation matrices for Residential land use suitability

Decision maker 1		
	Slope (S)	Elevation (E)
Slope (S)	1, 1, 1	4, 5, 6
Elevation (E)	1/6, 1/5, 1/4	1, 1, 1
Decision maker 2		
	Slope (S)	Elevation (E)
Slope (S)	1, 1, 1	2, 3, 4
Elevation (E)	¼, 1/3, 1/2	1, 1, 1
Decision maker 3		
	Slope (S)	Elevation (E)
Slope (S)	1, 1, 1	1/6, 1/5, 1/4
Elevation (E)	4, 5, 6	1, 1, 1
Decision maker 4		
	Slope (S)	Elevation (E)
Slope (S)	1, 1, 1	1/8, 1/7, 1/6
Elevation (E)	6, 7, 8	1, 1, 1
Decision maker 5		
	Slope (S)	Elevation (E)
Slope (S)	1, 1, 1	1/7, 1/6, 1/5
Elevation (E)	5, 6, 7	1, 1, 1

Proximity to existing residential area (km) (P1)

Proximity to existing commercial area (km) (P2)

Proximity to existing nearest paved road (km) (P3)

Proximity to open space and recreational area (km) (P4)

Decision maker 1				
	P1	P2	P3	P4
P1	1, 1, 1	2, 3, 4	1, 1, 1	1/8, 1/7, 1/6
P2	¼, 1/3, ½	1, 1, 1		1/8, 1/7, 1/6
P3	1, 1, 1	1, 2, 3	1, 1, 1	1/6, 1/5, ¼
P4	6, 7, 8	6, 7, 8	4, 5, 6	1, 1, 1
Decision maker 2				
	P1	P2	P3	P4
P1	1, 1, 1	4, 5, 6	1/6, 1/5, 1/4	1/3, ½, 1
P2	1/6, 1/5, 1/4	1, 1, 1	1/8, 1/7, 1/6	1/6, 1/5, 1/4
P3	4, 5, 6	6, 7, 8	1, 1, 1	2, 3, 4
P4	1, 2, 3	4, 5, 6	¼, 1/3, 1/2	1, 1, 1
Decision maker 3				
	P1	P2	P3	P4
P1	1, 1, 1	4, 5, 6	¼, 1/3, 1/2	5, 6, 7
P2	1/6, 1/5, 1/4	1, 1, 1	1/6, 1/5, 1/4	2, 3, 4
P3	2, 3, 4	4, 5, 6	1, 1, 1	7, 8, 9
P4	1/7, 1/6, 1/5	¼, 1/3, 1/2	1/9, 1/8, 1/7	1, 1, 1
Decision maker 4				
	P1	P2	P3	P4
P1	1, 1, 1	6, 7, 8	¼, 1/3, 1/2	1, 1, 1
P2	1/8, 1/7, 1/6	1, 1, 1	1/7, 1/6, 1/5	1/8, 1/7, 1/6
P3	2, 3, 4	5, 6, 7	1, 1, 1	2, 3, 4
P4	1, 1, 1	6, 7, 8	¼, 1/3, ½	1, 1, 1
Decision maker 5				
	P1	P2	P3	P4
P1	1, 1, 1	5, 6, 7	1/5, ¼, 1/3	¼, 1/3, ½
P2	1/7, 1/6, 1/5	1, 1, 1	1/9, 1/9, 1/9	1/7, 1/6, 1/5
P3	3, 4, 5	9, 9, 9	1, 1, 1	2, 3, 4
P4	2, 3, 4	5, 6, 7	¼, 1/3, 1/2	1, 1, 1

Distance from existing water body (m) (D1)

Distance from existing forest and vegetation (km) (D2)

Distance from Sea-beach area (km) (D3)

Decision maker 1			
	D1	D2	D3
D1	1, 1, 1	1, 2, 3	1/6, 1/5, ¼
D2	1/3, ½, 1	1, 1, 1	1/6, 1/5. ¼
D3	4, 5, 6	4, 5, 6	1, 1, 1
Decision maker 2			
	D1	D2	D3
D1	1, 1, 1	1/5, ¼, 1/3	1/6, 1/5, ¼
D2	3, 4, 5	1, 1, 1	¼, 1/3, ½
D3	4, 5, 6	2, 3, 4	1, 1, 1
Decision maker 3			
	D1	D2	D3
D1	1, 1, 1	1, 1, 1	5, 6, 7
D2	1, 1, 1	1, 1, 1	5, 6, 7
D3	1/7, 1/6, 1/5	1/7, 1/6, 1/5	1, 1, 1
Decision maker 4			
	D1	D2	D3
D1	1, 1, 1	6, 7, 8	1/3, ½, 1
D2	1/8, 1/7, 1/6	1, 1, 1	1/9, 1/8, 1/7
D3	1, 2, 3	7, 8, 9	1, 1, 1
Decision maker 5			
	D1	D2	D3
D1	1, 1, 1	3, 4, 5	1/5, ¼, 1/3
D2	1/5, ¼, 1/3	1, 1, 1	1/8, 1/7, 1/6
D3	3, 4, 5	6, 7, 8	1, 1, 1

Evaluation matrices for commercial land use suitability:

Physical factors (P)

Development factors (D)

Environmental factors (E)

Decision maker 1			
	P	D	E
P	1, 1, 1	1/6, 1/5, 1/4	1, 1, 1
D	4, 5, 6	1, 1, 1	4, 5, 6
E	1, 1, 1	1/6, 1/5, ¼	1, 1, 1
Decision maker 2			
	P	D	E
P	1, 1, 1	1/6, 1/5, 1/4	2, 3, 4
D	4, 5, 6	1, 1, 1	6, 7, 8
E	¼, 1/3, 1/2	1/8, 1/7, 1/6	1, 1, 1
Decision maker 3			
	P	D	E
P	1, 1, 1	1/3, ½, 1	4, 5, 6
D	1, 2, 3	1, 1, 1	5, 6, 7
E	1/6, 1/5, 1/4	1/7, 1/6, 1/5	1, 1, 1
Decision maker 4			
	P	D	E
P	1, 1, 1	1/7, 1/6, 1/5	1/8, 1/7, 1/6
D	5, 6, 7	1, 1, 1	¼, 1/3, ½
E	6, 7, 8	2, 3, 4	1, 1, 1
Decision maker 5			
	P	D	E
P	1, 1, 1	1/7, 1/6, 1/5	1/8, 1/7, 1/6
D	5, 6, 7	1, 1, 1	¼, 1/3, ½
E	6, 7, 8	2, 3, 4	1, 1, 1

Decision maker 1		
	Slope (S)	Elevation (E)
Slope (S)	1, 1, 1	4, 5, 6
Elevation (E)	1/6, 1/5, 1/4	1, 1, 1
Decision maker 2		
	Slope (S)	Elevation (E)
Slope (S)	1, 1, 1	4, 5, 6
Elevation (E)	1/6, 1/5, 1/4	1, 1, 1
Decision maker 3		
	Slope (S)	Elevation (E)
Slope (S)	1, 1, 1	1/6, 1/5, 1/4
Elevation (E)	4, 5, 6	1, 1, 1
Decision maker 4		
	Slope (S)	Elevation (E)
Slope (S)	1, 1, 1	1/6, 1/5, 1/4
Elevation (E)	4, 5, 6	1, 1, 1
Decision maker 5		
	Slope (S)	Elevation (E)
Slope (S)	1, 1, 1	1/9, 1/9, 1/9
Elevation (E)	9, 9, 9	1, 1, 1

Proximity to existing residential area (km) (P1)

Proximity to existing commercial area (km) (P2)

Proximity to existing nearest paved road (km) (P3)

Decision maker 1			
	P1	P2	P3
P1	1, 1, 1	1/6, 1/5, 1/4	1/6, 1/5, 1/4
P2	4, 5, 6	1, 1, 1	1, 1, 1
P3	4, 5, 6	1, 1, 1	1, 1, 1
Decision maker 2			
	P1	P2	P3
P1	1, 1, 1	1/9, 1/8, 1/7	1/7, 1/6, 1/5
P2	7, 8, 9	1, 1, 1	2, 3, 4
P3	5, 6, 7	¼, 1/3, ½	1, 1, 1
Decision maker 3			
	P1	P2	P3
P1	1, 1, 1	1/9, 1/8, 1/7	1/7, 1/6, 1/5
P2	7, 8, 9	1, 1, 1	2, 3, 4
P3	5, 6, 7	¼, 1/3, ½	1, 1, 1
Decision maker 4			
	P1	P2	P3
P1	1, 1, 1	1/9, 1/8, 1/7	1/6, 1/5, ¼
P2	7, 8, 9	1, 1, 1	1, 1, 1
P3	4, 5, 6	1, 1, 1	1, 1, 1
Decision maker 5			
	P1	P2	P3
P1	1, 1, 1	1/9, 1/9, 1/9	1/9, 1/9, 1/9
P2	9, 9, 9	1, 1, 1	1/3, ½, 1
P3	9, 9, 9	1, 2, 3	1, 1, 1

Distance from existing forest and vegetation (km) (D1)

Distance from Sea-beach area (km) (D2)

Decision maker 1		
	D1	D2
D1	1, 1, 1	1/8, 1/7, 1/6
D2	6, 7, 8	1, 1, 1
Decision maker 2		
	D1	D2
D1	1, 1, 1	1/9, 1/8, 1/7
D2	7, 8, 9	1, 1, 1
Decision maker 3		
	D1	D2
D1	1, 1, 1	5, 6, 7
D2	1/7, 1/6, 1/5	1, 1, 1
Decision maker 4		
	D1	D2
D1	1, 1, 1	1/9, 1/8, 1/7
D2	7, 8, 9	1, 1, 1
Decision maker 5		
	D1	D2
D1	1, 1, 1	1/9, 1/9, 1/9
D2	9, 9, 9	1, 1, 1

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