LUMA-GIS Thesis nr 35

URBAN LAND-USE PLANNING USING GEOGRAPHICAL INFORMATION SYSTEM AND ANALYTICAL HIERARCHY PROCESS: CASE STUDY DHAKA CITY

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Master thesis, 30 credits, in Geographical Information Sciences

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Abstract

Urban land-use planning, which is a useful tool for the sustainable development of a city, is a complex decision making process. However, the modern GIS technologies facilitate such complex jobs in two ways – (i) GIS allows to work with large numbr of datasets, (ii) a number of methods, techniques or models could be embeded in GIS for land-use suitability analysis. Analytical Hierarchy Process (AHP), which is a kind of Multi-Criteria Decision Making (MCDM) technique, could be used for urban land-use planning with support of GIS technology. The aim of this thesis is preparing urban land-use planning using GIS and AHP, where the case study is Dhaka city.

Dhaka, which is one of the fastest growing mega cities in the world and is the capital city of Bangladesh, is facing acute pressure of increasing population and unplanned urbanization, despite, a number of planning interventions have been taken for the planned development of the city. Recent Detail Area Planning (DAP) for Dhaka city was a cumbersome job but brought little benefits. DAP primarily prepared a land-use plan at city scale using GIS technology. Although huge resources and times were used to build the GIS database, it had promlems on (i) specifying data requirements, (ii) ensuring quality database (having topological rules, elimination of sliver polygons etc.) and (iii) using the database for spatial analysis in view to make better planning decision. In this connection, this thesis tried to conceptualize a model to build geographical database for urban land-use planning to address first two problems and applied GIS-based AHP technique for more sophisticated analysis (problem-iii).

After literature review and selection of the study area (Group-E of DAP), the study set a number of criteria through sharing experts' opinions. Based on those criteria the collected GIS data was transformed into the Geodatabase, where the geodatabase was conceptualized using Unified Modelling Language (UML). Five experts' opinions were shared and further literature reviews were done for calculating Eigen Values using AHP methodological operations. The Eigen Values show the degree of priority of the criteria. Using Eigen Values, raster criterion maps were prepared from data available in the geodatabase. These criterion maps were overlaid to develop a composite map which was later classified to prepare suitability map.

The research result shows that highly suitable area (13%) should be used for urban residential zone; moderately suitable area (35%) should be designated as mixed use zone; low suitable area (42%) should be reserved for agricultural use and open spaces; and not suitable area (10%) should be protected from any types of activities except agriculture. The research approached an urban land-use planning at a regional scale. The research results were also validated with Detail Area Plan of Dhaka Metropolitan Development Plan package in some order. Such validation concludes that Geographical Information System based Analytical Hierarchy Process can be applied successfully for preparing urban land-use planning at the regional level.

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Chapter 1: Introduction

1.1 Introduction

Urban land-use planning is a useful tool for the sustainable development of a city (Van Lier 1998). Land-use planning tries to formulate activities to be proposed, administer potential changes and protect incompatible changes. Such administrative and management strategies through land-use planning guide to ensure sustainability of a city. So, land-use planning is an essential component of urban planning.

Although it's a complex decision making process to prepare a perfect land-use planning, however, the invention of modern GIS technologies has eased such complex jobs in two ways – (i) GIS allows to work with large number of datasets, (ii) a number of methods, techniques or models could be embeded with GIS for land-use suitability analysis. A wide number of social, economic, physical and environmental indicators are considered for better urban land-use planning. Gepgraphical data in a GIS environment supports to use those indicators in more sophisticated way in the decision making process of urban land-use planning. However, for dealing with the datasets in a GIS environment, a geographical database management system is required, especially, when the datasets are robust and complex. To build such geographical database, at first, it is essential to prepare a conceptual model so that the data requirements and their interrelations are well defined, and database can be used to store, modify and query the data with security. Then, a number of Multi-Criteria Decision Making (MCDM) models or techniques embeded with GIS could be used for land-use suitability analysis, where the importance of each indicators of land-use planning are determined in more sophisticated way through subjective and or objective judgments. From a literature survey it was found that Analytical Hierarchy Process (AHP), which is a kind of MCDM technique, could be used for urban land-use planning with support of GIS technology. Thus, the aim of this thesis is preparing urban land-use planning using GIS and AHP, where the case study is Dhaka city.

1.2 Background

Dhaka, the capital city of Bangladesh, is one of the fastest growing megacities in the world. Its current population is around 15 million, which would be around 20 million in 2020 as projected by World Bank (2007) that would make Dhaka the world's third largest city. But, the city is expanding in an unplanned way (Islam *et al.* 2009). Although a number of plans and control mechanisms have been prepared since 1959, but, the city never experienced planned development rather rapid haphazard expansion from the city centers to its outskirts. To control the unplanned spatial development, the city land development and management authority, Rajdhani Unnyon Kartipakkha (RAJUK), formerly named as Capital Improvement Trust, adopted Dhaka Metropolitan Development Plan (DMDP) in early nineties of the last century. It was a paradigm shift in the history of urban planning in Bangladesh. It avoided the traditional master plan concept which was quite rigid in nature for planning process and plan implementation (Nallathiga 2009). Besides, it was the first time when Bangladesh tried to prepare a GIS-based urban plan through DMDP. The development plan was in three tiers – Structure Plan, Urban Area Plan and Detail Area Plan (DAP). The first two tiers were completed during 1992-1995. It was supposed to start the work of DAP preparation immediate after the completion of first two tiers of the DMDP plan package. But due to budgetary constraints and bureaucratic complexities, the actual works of DAP preparation were commenced in 2004. The allotted time for the DAP preparation was 2 years, but, the draft final report of the DAP was completed in 2008 and after going through the review processes it's official gazette was published in 2010 (GOB 2010). That is, the DAP got its legitimate identity after 15 years of the structure plan. However, the DAP has not become operational in reality where RAJUK claim that they have limited staffs to supervise the plan. Moreover, the plan period of DMDP will be finished in 2015, where it was the commitment to finish the DAP within 2000. So, the entire DMDP package seems useless although huge resources were used in vision of this plan. The DAP primarily prepared land-use plan according to the structure plan guidelines. Here, GIS technology was used and entire 590 sq. km of DMDP area were surveyed (physical, topographical and socio-economic survey) to build the database. To do these tedious jobs huge resources and time were used. So, this research tried to look an alternative way so that such resource and time taking jobs could be minimized for such urban land-use planning.

Around 50 datasets on different topographical, physical, land-uses, administrative and other features were prepared to build the GIS database according to the Term of Reference (ToR) of the DAP project. The problems in this GIS database were in three folds – i) Actual datasets required for a comprehensive plan, the types of data, their relationship classes etc. were not well defined <u>before preparing the database</u>. As a result, during data acquisition, database preparation and at the moment of plan preparation surplus data, data shortage or data redundancy prevailed. ii) <u>During preparing database,</u> neither any format of geographical database management system nor any topology rules were followed. So, data is not clean. Overlapping, sliver polygons and associated problems exist significantly. iii) During taking planning decisions, databases were usually used for getting map supports only. GIS is unique and very useful tool to make spatial analysis and modeling using its spatial and non-spatial data for making better decision. However, in DAP such implication was not followed. So, a real benefit of using GIS was neglected. In this connection, this study tried to conceptualize a model to build geographical database for urban land-use planning to address problem (i) and problem (ii); and tried to apply a GIS-based AHP technique to make more sophisticated analysis for urban land-use planning so that an example can be shown to address problem (iii).

1.3 Objectives

Considering the above problem statements, the aim of this research is preparing an urban land-use plan for Dhaka city using GIS and AHP. To fulfill this aim following set of objectives were satisfied -

1. Requirement analysis for fixing datasets and for selecting criteria affecting urban land-use planning.
2. Designing and construction of a geographical database.
3. Prioritizing the criteria using AHP
4. MCDM analysis for land-use planning.

1.4 Methodology

A stepwise methodology was followed in this research. The workflow of the research can be shown by figure -1. During the preliminary studies a number of literatures were reviewed and the study area was selected. Based on preliminary studies and considering experts' opinions, the requirement analysis was done for setting data requirements and for getting criteria affecting the land-use planning. Then, the model of geodatabase was designed using Unified Modelling Language (UML). During designing the model, the criteria of land-use planning were considered. Then data was collected and was exported into geodatabase under the designed structure of UML modeling. Five experts' opinions were shared and further literature reviews were done for calculating Eigen Values using AHP methodological operations. The Eigen Values show the degree of priority of the criteria. Using Eigen Values raster criterion maps were prepared from data available in geodatabase. These criterion maps were overlaid to develop a composite map which later was classified to prepare suitability map. Finally, using the suitability map land-use plan was suggested. A detail discussion on how the methodological works have been done will be found in chapter-5.

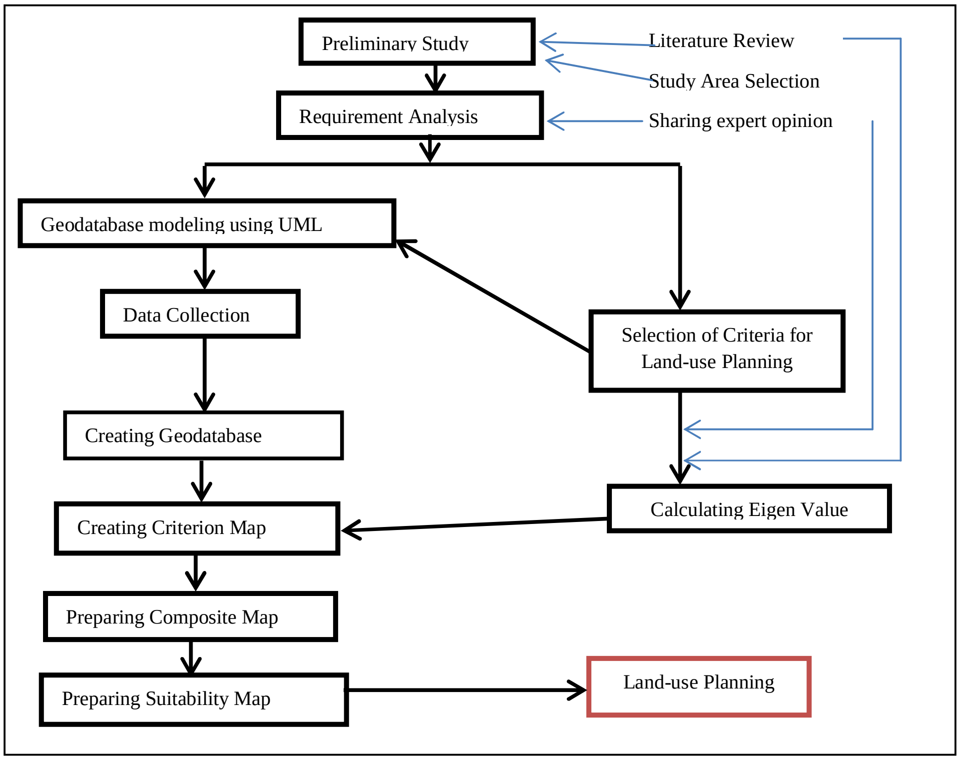


Figure 1: Flowchart of methodology

1.5 Thesis Structure

The thesis is organized in six chapters and two appendices. Chapter 1 is the introductory chapter, which shows the background, objectives and outline of methodologies of the thesis. Then, the chapter 2 briefs the justification of selecting study area, data sources and the demographic, administrative, geographic and other related profiles of the study area. Chapter 3 and chapter 4 discuss the findings from the literature reviews. Chapter 3 highlights the theoretical discussions on database, geographical database and their conceptual modelling in Unified Modelling Language (UML). Chapter 4 clarifies the importance of the use of GIS-based MCDM techniques for land-use planning. In the same chapter it is also explained why Analytical Hierarchy Model, which is a kind of MCDM technique, was used for this study. The major methodological operations for the study, which are preparing geodatabase and application of GIS-based AHP for evaluating land-use suitability, are discussed in chapter 5. Based on those land suitability indexes, the chapter 6 analyzes the existences of different land-use criteria on different suitability indexes, makes land-use proposal on the basis of those results and analytical discussions and finally, compares the proposals with existing DAP. Then, the thesis makes the conclusion at the end of the same chapter. Besides, experts' given scores for different factors and criteria are shown in appendix 1 and their combined factors and criteria weights are mentioned in appendix 2.

Chapter 2: Study Area

This chapter covers some basic information about the study area. The information has been collected mainly from the survey data and report of Detail Area Plan (DAP) prepared for Dhaka Metropolitan Development Plan (DMDP) area (RAJUK 2010).

2.1 Selection of the Study Area

There was no single database for DMDP area. The DMDP area was divided into 5 groups (Group A, B, C, D and E) during preparing DAP. Each group has separate database. It would be a huge job to combine the five databases into one and to conduct study for whole DMDP area. So, the area of group E was selected for the study as the area has huge potentiality for future urban growth.

2.2 Data Collection

Different secondary data were collected for this study. The datasets and their sources are as the following Table -1 –

Table 1: Sources of data

Datasets	**Source**
Land-use	RAJUK
Structure	RAJUK
Sport height/contour/DEM	Water Development Board
Road networks	RAJUK, LGED
Gas supply	Titas Gas Transmission and Distribution Company Ltd.
Electric supply	RAJUK
Community facilities	RAJUK

2.3 Location

The study area is located in the north-western part of DMDP area (Figure-2). The planning authority of DMDP area, RAJUK, has 26 Strategic Planning Zones (SPZ). For preparing Detail Area Plan (DAP), the RAJUK's jurisdiction area was divided into five separate groups and a number of locations. The study area falls within the Group-E.

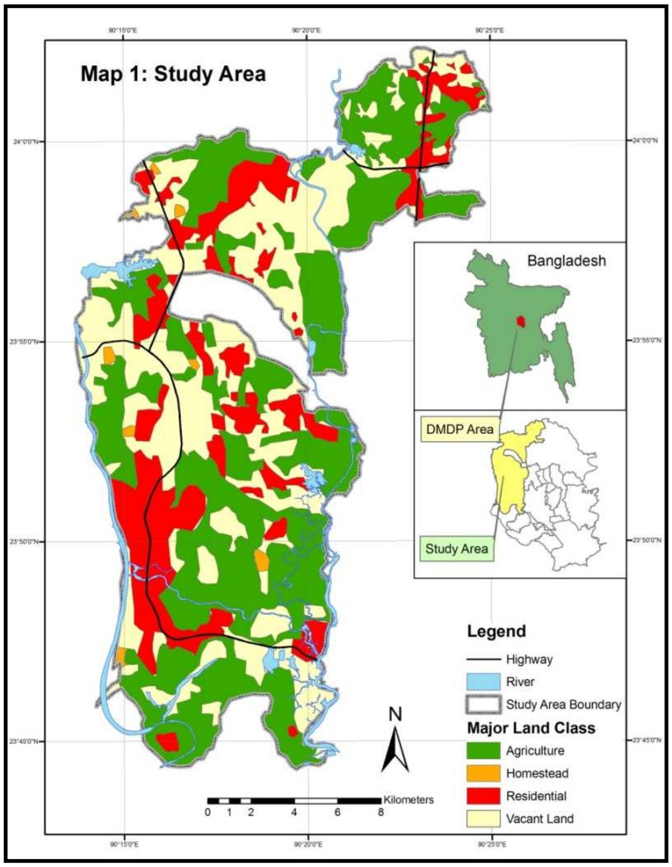


Figure 2: Study area map

2.4 Area and Population

The study area covers around 75,789 acres. According to Bangladesh Bureau of Statistics (BBS), in 1991, the population of the study area was 4,16,682, which rose to about 6,42,320 in 2001. During preparing the Detail Area Plan, the projected population of the area for 2015 was estimated as 11,77,272 that would be almost 24% increase over that of 2010.

2.5 Administrative

The study area consists of entire Savar Upazila (sub-district) of Dhaka district and part of Gazipur district. It has one municipality, namely, Savar Pourashava and has 14 unions (local rural government unit). Following Table-2 shows the administrative units of the study area –

Table 2: Administrative units of the study area

Administrative unit	**Name**
District	Dhaka, Gazipur (partially)
Upazila (sub-district)	Savar, Gazipur (partly)
Pourashava (municipality)	Savar
Union (local rural	Simulia (Part), Tetuljhora, Yearpur, Pathalia, Kaundia,

government unit)	Dhamsona, Bhakurta, Banagram, Ashulia, Biralia, Savar Cantonment, Basan (Part), Kayaltia (Part), and Kasimpur (Part)
Police Station	Savar

Source: BBS 2001 and DAP.

There are some special or restricted areas within the study area, like as Jahangirnagar University, Savar Cantonment. These areas are served by their own governing ordinances.

2.6 Land-use

A more detail land-use classification can be found from DAP's database (Table-3). According to DAP information, most dominant land-use is agriculture, which comprises around 40.7% of total area followed by vacant land (20.8%), residential (20.2%) and water bodies (7.6%).

Table 3: Detail land-use classes of the study area

Land-use Type	**Proportion of the Area**
Agriculture	40.727%
Circulation Network	1.617%
Commercial Activity	0.217%
Community Service	0.003%
Education & Research	1.444%
Forest Area	2.601%
Governmental Services	0.078%
Homestead	0.848%
Manufacturing and Processing Activity	2.499%
Mixed Use	0.092%
Open Space	0.233%
Recreational Facilities	0.006%
Residential	20.239%
Restricted Area	0.886%
Service Activity	0.058%
Transport & Communication	0.071%
Vacant Land	20.787%
Water Body	7.594%
Total	**100.00%**

The land-use data was processed from each parcel of land under cadastral plots. Such huge detail data could not be used for this thesis work. Because it was not possible to convert that detail data in raster format from shape file format. Besides, this study purposes to make a land-use plan at regional level, but not at detail level. So, in this study the land-use classes were divided into four classes (gross land-use class) based on existing dominant use and importance of proposed development (Figure-2). The land-use classes applied in this study and their proportions have been shown in Table – 4.

Table 4: Gross land-use classes of the study area

Land-use	**Area (sq. m)**	**Proportion of the Area**
Agriculture	34531.09	46%
Homestead	600.15	1%
Residential	14970.82	20%
Vacant Land	25730.05	34%
Total	**75832.12**	**100%**

2.7 Physical and Geological Characteristics

The soil characteristics of the study area are mainly alluvial soil originated from the Pleistocene period. The southern part of the study area is composed of alluvial soil of the Bangshi and Dhalashwari rivers. Main rivers are Bangshi, Turag, Buriganga and Karnatali. A substantial part of the study area is geographically a part of the Pleistocene Terrace, popularly known as Madhupur Tract. Such lands are characterized by high, undulated land surface with red soil, crisscrossed by flood plains and streams. Except the southern part, almost entire land of the planning area falls in this category.

The elevation of the area ranges from 2m to 13m. Most of the places the slopes are gentle except some patches of high land. These high lands are free from flood.

Some big tectonic faults exist in Bangladesh. Dhaka city and its surrounding areas are also located within a seismic zone, so, the risk of earthquake exists in Dhaka metropolitan area as well as in the study area. Some geologists in Bangladesh claim that the rivers within and around the city are fault lines.

2.8 Utilities and Infrastructure

There was no systematic and planned development in the study area. The road networks of the area were not built following proper planning standard. The study area is served by about

3190 km of road in which 42 km of national highway, 13 km of regional highway and 3135 km of local and other roads. There is no municipal water supply system in the area. Most of the cases people use tube-well. All over the study area has electricity connection. Gas supply is only provided to the urban areas and to the areas through the major highway but the rural areas.

2.9 Community Facilities

In Group-E area there are one public, one private university, two private medical colleges along with a number of schools and madrasha (religious schools). There are 33 daily kitchen markets, 10 hats and 4 wholesale markets within the planning area. The bus stops exist mainly through the major highways. Bus stops are available after 2-5 km distances. Around 40 healthcare centers could be identified from the DAP survey data. According to the DAP report, most of the community facilities are below the standard. There are few or no recreational parks or open spaces in the study area.

Chapter -3: Conceptualizing Geodatabase

This chapter presents relevant concepts on Geodatabase design. As Geodatabase is itself a database, so, the topic starts from defining database and database management system before defining geodatabase. Then, it highlights a major requirement for any database building, that is, the conceptual modeling of database. Later, it explores the usefulness of UML for designing database. Then, the use of UML in the geographical database framework is discussed.

3.1 Database and DBMS

A database is collection of data organized in a structured way, so that; information can be retrieved quickly and reliably (Closa *et al*. 2010; Yeung and Hall 2007). The invention of Information Technology has led the database to be used in a management system, which is called Database Management System (DBMS). DBMS is a set of programs, in other words software systems that enables following actions to be performed in a database –

- Stores and extracts information from a database
- Modification of database by adding, editing, deleting and sorting of data
- Supports queries and produces reports based on those queries
- Provides facilities to maintain integrity, quality, performance and concurrency within database
- Ensuring security of database that controls data accessibility and allows protection and recovery from hardware failures.

There are several models of DBMS. Among them Relational Database Management System (RDBMS) is most widely used. RDBMS stores data in the form of related table, which is much efficient for the users to query data in many different ways.

3.2 Geodatabase

Modern GIS uses Spatial Database to integrate the geometry or features data with other types of data (Yeung and Hall 2007). Spatial database facilitates storing and querying data that is related to objects in space, including points, lines and polygons. Other typical databases can understand various numeric and character types of data, while, spatial databases need additional supports to process spatial data in the form of geometry or feature. Spatial data, which is also called *geographical referenced data* or *geospatial data*, focuses cartographic or mapping perspectives. Some common features of a perfect spatial database system are storing and managing capacity of both spatial and non-spatial data; maintaining spatial references; allowing all possible geometrical representations, like, point, curve, surfaces etc.; ensuring topology for managing spatial relationships among geometric objects and maintaining data security, integrity and allowing spatial data query. In this sense, ESRI Geodatabase can be viewed as a good example of a spatial database system.

3.3 Conceptual modeling of database

Real world is much complex. So, we use model as "model is a simplification of reality" (Booch, Rumbaugh and Jacobson 2005). The model synthesizes important aspects of a purposeful activity to be modeled and eliminates the unnecessary things (Rumbaugh, Jacobson and Booch 1999). Model is expressed in any convenient form, for example, model of a building can be presented by drawing on a paper or 3-D figures made of cardboard.

Database modeling in the software system has similar consideration – abstraction of the essential elements of the observed reality from nonessential elements (Lisbao Filho and Iochpe 2008). A conceptual database modeling describes possible data content, structures and constraints applicable to them. Like other models, to express the database modeling descriptions in a convenient way, conceptual data modeling language is used. A conceptual data modeling language is use of formal expressions (notational and semantics) of tools and techniques used for data modeling.

Use of a conceptual data modeling language is must to prepare the data schema at the conceptual phase (Lisbao Filho and Iochpe 2008). The schema is the collection of linguistic and graphical representations that describe the data structure of a database and database processing operations (Yeung and Hall 2007). A lot of modeling languages have been evolved (Booch, Rumbaugh and Jacobson 2005). Different modeling techniques used for database management systems can be classified in the following categories (Yeung and Hall 2007) –

- Hierarchical Systems
- Network Systems
- Relational Systems
- Object-oriented Systems

The hierarchical systems and network systems are now out-of-date. Those systems are much rigid to implement the database. Relational database became much popular for its greater flexibility. The basic foundation of a relational database management system is ‘tables’, where each table contains a unique name that distinguishes it from other tables. One or more column of a table serves as the key (primary and or secondary key) of a table, which relates one record with another. Traditional databases were only limited to text-based applications. Growing demand of information other than text data, like, graphics, video, sounds, maps and elements of other multimedia environment led the development of object-oriented database systems. The systems mainly evolved from object-oriented programming languages (Yeung and Hall 2007).

Contemporary views of modeling processes in the field of computer science are based on object-oriented perspective. The main building block of this approach is the object or class. Classes are treated as a set of objects. The system of defining objects and classes consists a large number of occurrences. The relations between these occurrences and their properties or attributes can be set in this approach (Jacobson, Ericson and Jacobson 1994). Such approach is easily expandable. A number of authors in late 80s to early 90s tried to formulate different object-oriented methodologies. But the concepts and ideas of those methodologies were almost similar. So, later efforts were made to unify all the object-oriented approaches into a common standardize language (Rumbaugh, Jacobson and Booch 1999). Such endeavor developed Unified Modeling Language (UML), which got strong tendency for to be adopted in computer science as well as in database design (OMG n.d.).

3.4 What is the UML

“UML is a graphical language for visualizing, specifying, constructing, and documenting the artifacts of a software-intensive system” (Rumbaugh, Jacobson and Booch 1999). Following are UML capabilities those are much useful for human and machine –

- UML is used to understand, design, browse, configure, maintain, and control information which is essential to construct a system.
- UML includes semantic concepts, notation, and guidelines that offer a standard way to write a system’s blueprints.

There is no distinct demarcation between various concepts and constructs in UML, but, for the conveniences they can be categorized into several views. At the top level, views can be divided into three areas: structural classification, dynamic behavior, and model management

(Booch, Rumbaugh and Jacobson 2005). Structural classification describes the things in the system and their relationships to other things. Dynamic behavior describes the behavior of a system over time, and Model management describes the organization of the models themselves into hierarchical units. There are many UML diagrams to model a system under the above views or similar other aspects. Some UML defined graphical diagrams are –

- class diagram
- use case diagram
- behaviour diagrams:
  - statechart diagram
  - activity diagram
- interaction diagrams:
  - sequence diagram
  - collaboration diagram
- implementation diagrams:
  - component diagram
  - deployment diagram

UML class diagram provides the semantic constructs for a conceptual modeling language of geographic database (Lisbao Filho and Iochpe 2008). So, here we will only describe about the class diagram. Discussion about class diagram was made from (Booch, Rumbaugh and Jacobson 2005; Shekhar and Chawla 2003).

Class Diagram

Class diagrams are the most common diagram found in modeling object-oriented systems. Class diagrams describe the classes in the system, and the static relationships between classes.

Class:

A class is represented by a rectangle. Figure-3 shows a typical class in a class diagram.

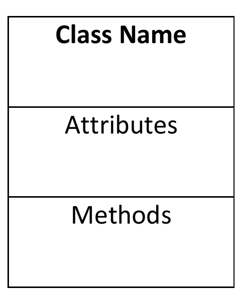


Figure 3: Class Structure

A class has three rows -

- The first row is the class name. A class is representation of an object or variable that can be anything like a person, place, thing, concept, event, screen, or a report applicable to the given system. So, class name is the object name which allows identifying the object. The class name typically has the first alphabet capitalized. If there are two or more words in a class name, then first alphabet of each word is capitalized and is joined with all the words.
- In the second row list of attributes of the class is presented. The syntax is:

- Attribute: Type = 'default value'

- A list of methods goes in the third row. The syntax is:
    - MethodName(List of parameters): Return Type.

Like object-oriented concepts, access modifier can be applied in the class. Access modifier determines the scope of visibility of the class and its methods and attribute. Documentation information, like notes and constraints, can be also added to a class.

Relationships between classes:

A relationship is a semantic connection between classes. The attributes, operations and relationships of a class can be known with another class using semantic notations (symbols) representing UML relationships. Followings are some common relationships used in UML:

Association:

Association is semantic connections between two or more classes. In an association relationship, the public attributes and operations of one class are known by another class. Associations are drawn on a class diagram with a single line. For example, an elementary school exists within a residential neighborhood boundary. Here it is an association relationship and can be shown by the following diagram –

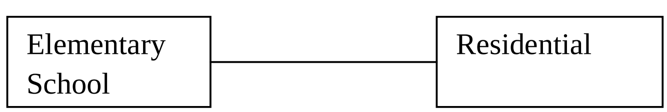


Figure 4: Association between two classes.

Aggregation:

Aggregation is a specified association. It is a relation between a whole and its parts. Aggregation is applied when one class is collection of another class. But the collected class does not have strong *life cycle dependency* on the collector class. It is also called "has a" relationship. Figure-5 is an example of aggregation relationship.

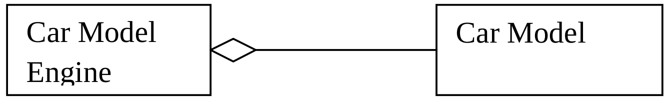


Figure 5: Aggregation between two classes.

Composition:

Composition is more specified association. It connotes that there is a strong *life cycle dependency* between classes. Unlike aggregation, when a part must belong to a whole, then composition is used. Following diagram is an example of composition.

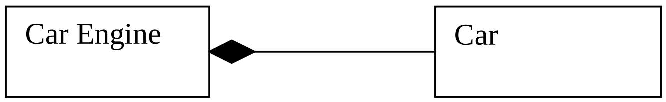


Figure 6: Composition between two classes.

Multiplicity:

Multiplicity notations are placed near the ends of an association. Such symbols indicate the number of instances of class linked to one instance of other class. For example, one residential neighborhood has one or more elementary school, but each elementary school exists within a particular residential neighborhood. See Figure-7.

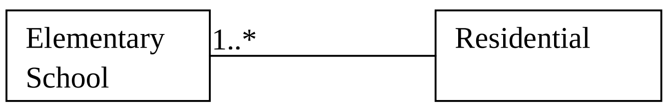


Figure 7: Multiplicity of a class with other.

Following Table shows different indicators of multiplicity to express different meanings.

Indicator	**Meaning**
0..1	Zero or one
1	One only
0..*	Zero or more
1..*	One or more
n	Only *n* (where *n*>1
0..n	Zero to *n* (where *n*>1)
1..n	One to *n* (where *n*>1)

Generalization:

Generalization shows an inheritance relationship. When one class (subclass) is inherited from other class (super class), then, the super class is considered as a **Generalization** of subclass. Generalization allows one class to inherit all of the attributes, operations, and relationships of another class. In UML, the subclass is treated as *child class* and the super class is treated as *parent class*. An example of generalization for a city database may be Districts. Several types of districts, like residential districts, business/commercial districts, industrial districts etc., may be generalized by the super class District. See Figure-8.

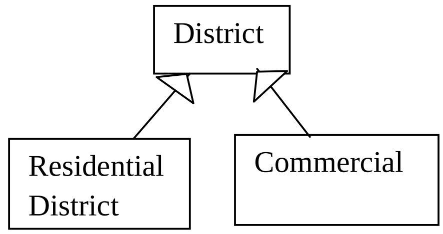


Figure 8: Generalization between classes.

3.5 Conceptual Modeling of Geographic Database

Geographic Database (GeoDB) integrates spatial data and data relationships into database management system. Spatial Database Management System supports to build, storage, structure and assist basic operations for spatial data manipulation, while, GIS provides mechanisms for analysis and visualization of geographic data (Shekhar and Chawla 2003). Like any traditional database, GeoDB must include conceptual, logical and physical design phases during its designing stage. Among different modeling languages used for conceptual modeling of GeoDB, the UML-GeoFrame modeling language is one of the most recent uses developed by Lisbao Filho and Iochpe (1999). The modeling process based on the UML-GeoFrame comprises five steps (Lisbao Filho and Iochpe 2008):

• Step 1: to identify themes and subthemes for each target region of the application. See Figure-9.

• Step 2: to draw a class diagram for each theme specified in step 1, associating classes of different themes, if this is the case. At this stage, modeling of the data is carried out. For each theme, the several elements of the real world that is being modeled are abstracted.

• Step 3: to model the spatial characteristic of each geographic phenomenon. Stereotypes are defined for different spatial representations. See Figure-10.

• Step 4: to model spatial relationships

• Step 5: to model temporal aspects. This step is not widely used.

Figure-11 shows a final class diagram on land distribution theme for a hypothetical system in view to making agricultural reform.

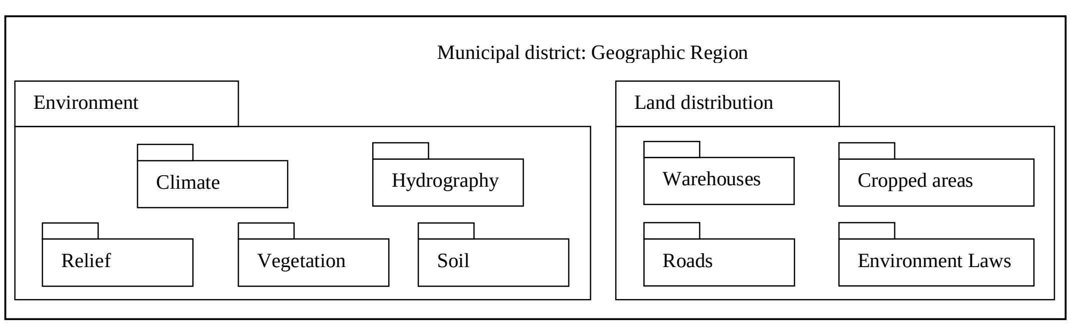


Figure 9: An example of theme diagram (Lisbao Filho and Iochpe 2008).

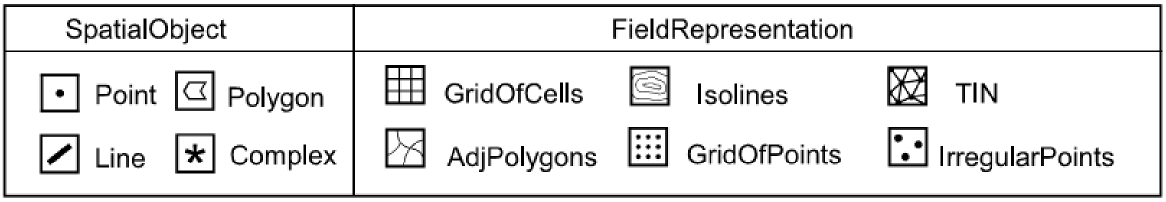


Figure 10: Stereotypes for spatial representations (Lisbao Filho and Iochpe 2008).

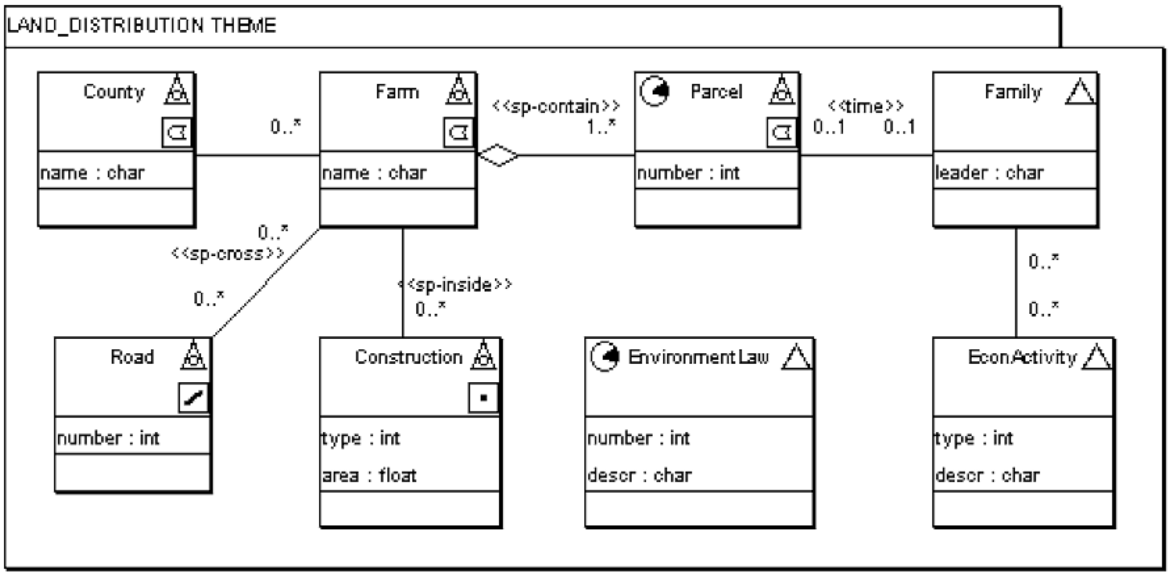


Figure 11: Final class diagram for land distribution theme (Lisbao Filho and Iochpe 2008).

Chapter 4: MCDM and GIS for Urban Land-use Planning

4.1. Land-use Planning

Generally, land-use is determined by the human activities on land. Most clarified definition of land-use was first pronounced by Burley (1961). Burley defined land-use by two interrelated phenomena – land cover and land utilization. Land cover describes both the natural and human altered land surface where human actions take place. While, human actions determine the land utilization, both phenomena are significantly important for land-use planning. Because, on the one hand, human actions are limited by the land cover settings and on the other hand, human activities alter the land cover (Wang and Hofe 2007). The main purpose of land-use planning is to designate land-use types for an area where change is expected. Land-use planning help to answer following questions –

1. What should be built?
2. Where should it be built?
3. When and how should it be built?
4. What impact will it generate?

According to Wang and Hofe (2007), answering such questions help to produce 'good' community, although, they also found controversy to define a good community. However, the implication of their questions for large city scale or regional scale may be complicated. It would make a complex discussion to show how different human activities can be distributed over the land mass of a city or region.

Human activities can be divided into three major categories—residential (where people live); employment (where people work); and others (non-residential and non-employment activities) (Wang and Hofe 2007). Human activities and land have an interrelated function. Land provides space, materials, energy etc. to meet human demand for performing activities. On the other hand, human activities are dependent on the availability of land, its characteristics and resource availability.

From the modern era human activities are growing in manifold and with great intensity. Such activities are contributing rapid urbanization, which has adverse environmental impacts if the urban development is not managed sustainably. Land-use planning can play a great role for sustainable development (Van Lier 1998). A basic proponent for land-use planning is to classify land based on human activities to be proposed and human activities that exist. Some discussions on land-use classification have been made in the next section. Before that we need more clarifications on land-use planning.

FAO (1996) defines land-use planning as "the systematic assessment of land and water potential, alternatives for land-use and economic and social conditions in order to select and adopt the best land-use options." So, Land-use planning involves decision making process so that best alternative option can be attained. Growing urbanization demands expansion of urban areas, at the same time, alteration of existing land-uses within the urban area. To make such changes in sustainable manner land-use planning is a useful tool to administer the potential changes and to protect incompatible changes. Decision in land-use plan formulates goals and objective for resource management (United States Department of the Interior Bureau of Land Management 2005). Within these goals and objectives, measurements for future land management actions are adopted. Land-use planning also assists to device site-specific implementation mechanism.

According to FAO (1996) guidelines there are 10 steps in land-use planning –

1) Establish goals and terms of reference
2) Organize the work
3) Analyze the problems
4) Identify opportunities for change
5) Evaluate land suitability
6) Appraise the alternatives: environmental, economic and social analysis
7) Choose the best option
8) Prepare the land-use plan
9) Implement the plan
10) Monitor and revise the plan

A crucial stage in land-use planning is the suitability analysis, which is central part of land-use evaluation. The purpose of land suitability is identifying an area which is suitable for a given type of land-use. For example, finding the areas which are suitable for residential use. Nowadays, people are widely using the modern GIS technologies for land suitability analysis. Scientists, researchers and experts are trying to develop tools and techniques for land-use evaluation that fit with the social, environmental, economic and physical requirements and at the same time, ensures the involvement of different stakeholders. Better land-use evaluation helps to prepare more sustainable land-use plan. But, fitting different social, economic, environmental, physical and stakeholders' requirements during land-use evaluation is a tricky job. It's a complex decision making process. Different Multi-Criteria Decision Making (MCDM) techniques can be useful to ease such complex decisions. So, from section-4.3 some brief discussion on MCDM has been highlighted.

4.2 Land-use Classification

Harland Bartholomew approached the first land-use classification technique, where he applied a two-level land-use classification system (please see Table-5) (Lovelace 1993). In his land-use categories he considered activity based classification, like, residential, commercial and industrial; designated public uses; and separated vacant or undeveloped land from others. In the second level he further classified some first level land-uses in terms of intensity of activities and types of activities. Thus, Bartholomew developed the first land-use classification system that helped to build a standard form for data collection and comparisons for land-use analysis.

Table 5: Bartholomew land-use classification (Lovelace 1993)

Level 1	Level 2
Residential	Single-family homes
	Two-family homes
	Multiple dwellings (apartments)
Commercial	
Industrial	Light industry
	Heavy industry
Public and semi-public	Schools, churches, hospitals, institutions, golf courses, etc.
Public parks	
Railroads	
Streets	
Vacant land	Undeveloped or agricultural

Bartholomew classified land-use based on USA cities. Later, due to improvement of technologies in surveying, data collections and data management systems, more modern and detail land-use classification techniques evolved. In this evolutionary process the most cited documents on land-use classification systems can be also found from USA context.

Urban Renewal Administration of USA *et al.* (1965) introduced a code wise land-use classification using different level of numeric digits like, one-digit, two-digit, three-digit and so on to represent a particular land class. They published a Standard Land-Use Coding Manual (SLUCM).

Due to advent of remote sensing images, Anderson (1976) suggested a four level land-use classification system. At the first level, land-use categories were urban or built-up land; agricultural land; rangeland; forest land; water; wetland; barren land; tundra; and perennial snow or ice. This classification is based on land-cover, which, can be interpreted by using remote sensing images. The first level land-use classification can be used for a large scale area, like nationwide. The second, third and fourth level classification permits much flexibility to adjust with local level needs, like city planning.

In 1994, the Research Department of the American Planning Association assisted Federal agencies to set a Land-Based Classification Standards (LBCS), which was an updated version of 1965 SLCUM (Jeer 2001). LBCS is a land-use classification model, which consists five dimensions and each dimension has different levels. The dimensions are activities, functions, building types, site development character, and ownership. In briefly, the dimensions can be explained by the following ways (Wang and Hofe 2007) –

- Activity dimension – it directly describes human use of land, like, residential, shopping, business or trade, travel, leisure, natural resources etc.
- Functional dimension – it reflects economic function rather than actual activity. For example, the activity of an establishment is shopping, but, it falls under the retail sales and service category according to the functional dimension. Besides, when one establishment shows multiple activities, but, has single function, then functional dimension is used to classify land. For example, one establishment may have different activities like offices and factory, but, as it has single economic function, so, it falls under a particular functional category, like as textiles.
- Structure dimension or building type – it simply reflects the structure types on land, like, residential building, commercial building, school building etc.

- Site development dimension – it refers to physical character of the land. Such classification identifies which land is developed and which is not, which land is occupied by building structures and which is not, etc.
- Ownership dimension – as it is named, it reflects the ownership of the land. This dimension of land-use classification shows either a land is owned publicly, privately, or non-profitably etc.

Thus using multi dimension classification techniques user can control the precision of land-use categories at different level. The LBCS supports planning applications at different geographical scales like neighborhood scale, city scale, regional scale or national scale.

Bangladesh followed a paradigm shift in the urban land-use classification during the Detail Area Plan (DAP) phase of Dhaka Metropolitan Development Plan (DMDP) project. It was one of the early approaches on GIS based urban planning in context of Bangladesh. The improved data acquisition technology and application of GIS tools allowed planners to adopt a wide and extensive level of land-use classification technique. Recently, the planning authority, Rajdhani Unnoyon Kartipakkha (RAJUK), area trying to make further improvement of existing land-use classification system. Some Planner Consultants of RAJUK proposed a three level land-use classification system. The first level is the general land-use classes. They proposed 20 general land-use categories. Under these general categories they proposed more detail land-use classes at 2nd level and most detail land-uses at the 3rd level, which is under 2nd level land classes. In their proposed classification system, they tried to address the issues they faced during the implementation of DAP. Such land-uses will help the planners during the plan preparation as well as plan administration.

4.3 Criteria for Urban Land-use Planning

There are no unique factors and criteria for urban land-use planning. Dai, Lee and Zhang (2001) applied comparisons of topography, ground conditions, grandwater and geologic hzards for land-use planning of Lanzhou city, where, they made geo-environmental evaluation. Dong, J. *et al.* (2008) claimed an integrated evaluation of urban development suitability in their study. They considered 11 paparameters under the factors of environmental backgrounds, water/land resources and socio-economic development. But their parameters don’t look as complete for an integrated evaluation. They neighter considered community services like schools, hospitals etc. nor they imposed utility services like water supply, electricity supply etc. in their evaluation. Tudes and Yigiter (2010) proposed land-use planning for high storey buildings, multi storey buildings, low storey buldings, industrial sites, waste disposal sites and green lands in their study in Adana-Turkey. They used varying conditions of environmental criteria, which are slope, elevation, surface geology, depth of ground water, bearing capacity, agricutural suitability, land-use, earthquake susceptability and flooding area. Their selcetion of criteria was rather complete according to their proposed types of land-use. So, from the selected literatures it was found that there is unified rule for urban land-use planning. Researchers identified their own criteria of land-use planning according to their subjective judgment, theoretical knowledge as well as local *in-situ* knowledge.

4.4 Multi-Criteria Decision Making Model (MCDM) and GIS

Several MCDM techniques have been evolved to solve complexity in human decisions. MCD techniques help decision makers to consider wide level of information and assist to deal with complexity of information in a convenient way. Using MCDM techniques decision makers can combine a lot of information, can make comparative analysis and can choose best alternative from a number of options. MCDM techniques guide decision makers to think consistently, especially, when they become puzzled with the elements of decisions.

There are many MCDM techniques and their number is still rising. The variations in MCDM approaches occur due to several reasons like, types of decision, time availability, amount or nature of data, the analytical skills of those supporting the decision, administrative culture and requirements of organizations etc. (Department for Communities and Local Government: London 2009). However, from literature reviews two basic types of MCDM techniques can be distinguished – multiple attribute decision making (MADM) and multiple objective decision making (MODM) (Kahraman 2008). MADM identifies best alternative from a set of finite number of alternative solutions, while, MODM deals with infinitive number of alternatives.

Traditionally GIS based land suitability analysis was done using simple overlay method (Malczewski 2004). For the last two decades, integration of MCDM techniques with GIS has made considerable improvement in land suitability analysis. MCDM techniques allow to set decision making rules, criteria, intensity or level of given preferences as well as to set functional relationships among the rules and criteria by using their methodological operations. On the other hand, GIS has huge capabilities for spatial and non-spatial data acquisition, storage, retrieval, manipulation and analysis. So, MCDM techniques embedded with GIS can be used fruitfully for land suitability analysis as well as for land-use planning as such planning approaches need involvement of different decision rules, analysis of wide level of spatial and non-spatial data and need combining all the decision making factors to get the results. GIS provides an output map of land suitability analysis by combining all the decision inputs in the realm of a particular MCDM technique.

A number of MCDM techniques embedded with GIS have been applied for land suitability analysis (Malczewski 2004). Some of them are MODM techniques and some are MADM techniques. MODM techniques, like heuristic approaches, AI techniques, require mathematical programming algorithms which are much complicated. While, there are several MADM techniques, which are easy to understand and much useful for land suitability analysis, especially, in raster environment. Such techniques are Weighted Linear Combinations (WLC) (or simple additive weighting), ideal point methods, concordance analysis, Analytical Hierarchy Process (AHP), Fuzzy Logic, Ordered Weighted Averaging (OWA) etc. Among those techniques, from the literature survey it was found AHP is most widely used technique for urban land-use planning (Dai, Lee and Zhang 2001; Zhang, Li and Fung 2012; Tudes and Yigiter 2010; Dong, J. *et al.* 2008).

There are several problems in applying MCDM techniques in GIS environment (Malczewski 2004). First, the input data may have property of inaccuracy, imprecision, and ambiguity. Some MCDM techniques need more accurate data to make judgment more objectively, while, some MCDM techniques can deal with less accurate data by making subjective judgment. Second, the problem associates with standardization of criteria. Different methods standardize criteria in different ways that shows different land-use suitability. Standardizations of criteria in some techniques are complicated and for some techniques it is simple. All standardization methods are not suitable for a particular study. For example, for the soil fertility analysis Fuzzy Logic can be appropriate, as the merits and demerits of the properties of soil should be determined in many-values but the Boolean values. Third, the problem is finding a proper justification on which method is more suitable. This problem associates with the first and second problems. An MCDM technique for a particular study can be supported in consideration of second problem, but, cannot be supported for the first problem. So, to minimize such problems, specific MCDM techniques should be selected based on data availability, technical expertise, time availability etc.

4.5 The Analytical Hierarchy Process (AHP)

AHP is one of the most popular MCDM techniques developed by Saaty (1980). It is used to identify the best one from a set of alternatives with respect to several criteria. The basic principle of AHP is to solve a problem by forming hierarchies. At first, a hierarchy tree is drawn to segregate each criterion into lower sub-criteria at two or more levels. At the top of hierarchy tree, the goal is set, and then, major criteria and sub-criteria are fixed. Thus AHP helps to make assessment from lower criteria; each criteria and sub-criteria have individual performance to achieve the goal. Following are the steps performed for GIS-AHP based land suitability analysis (Ullah and Hafiz 2014) -

(i) Making pair-wise comparison among criteria,

(ii) Preparing comparison matrices,

(iii) Standardization of matrix values,

(iv) Checking consistency ration and finalizing the relative weight values,

(v) Transforming the weight values into spatial database,

(vi) Overlay operations and preparing composite map,

(vii) Classifying the composite map into highly suitable, moderately suitable and marginally suitable area.

The detail steps of AHP have been described in the following chapter (Chapter 5).

4.6 Why AHP has been used for this study

Different social, economic, environmental and physical factors and criteria influence the land-use planning decision. It is a complex job to categorize the criteria because of conflicts among criteria and for their degree of effects on land-use planning. For example, both agricultural land and parks can be defined under open space category. But, in that case, agriculture can be treated suitable for recreational development that may have negative impacts due to scarcity of agricultural land and for food deficit. So, it is necessary to categorize the criteria very sensitively. But, it becomes hazy to categorize the criteria in a structured way. AHP allow to set factors and criteria in a structured way. Features under this criteria and sub-criteria may exist in separate locations or can coexist in a single location. So, each criterion needs to evaluate individually and it needs to sum up all the criteria on a given location for estimating its level of preference. AHP embedded with GIS can easily handle the matter with their measurement and overlay techniques. For land-use planning, some decision rules are necessary to be applied. Sometimes those decision rules can be fixed objectively by using quantitative measurements and sometimes it is necessary to apply subjective judgment to set the decision making rules. AHP can handle both the objective and subjective judgment as well. For imposing subjective judgments, decision-makers sometimes fail to maintain consistency. AHP guides to make consistent judgment. It helps to minimize contradictions among a set of criteria. For sustainable land-use planning, there are necessary to include different experts' opinions as well as that of non-expert stakeholders. Then, it becomes a tricky job to emphasize whose opinions are more viable. AHP make space for all individuals or groups from different backgrounds. For a larger area land-use suitability should be ranked in priority order. For example, an area, which is in highland and is well connected by civic facilities, should have high priority for residential development. AHP embedded with GIS can rank the suitable areas in different order like highly suitable, moderately suitable, low suitable or not suitable areas.

Chapter 5: Designing Geodatabase and Evaluation of Land Suitability using AHP

This chapter focuses major methodological operations of the thesis works. Through literature reviews and by sharing experts' opinions, the requirement analysis was done; the geodatabase was designed as well as the criteria influencing urban land-use planning were selected. After processing the collected data, land suitability was evaluated using AHP. For this entire methodological operation, it was kept in mind that the results would be used for urban land-use planning and its administration at a regional scale in view to promote sustainable urban development. It would not be a detail land-use plan but would be useful for a strategic planning like DMDP Structure Plan and would minimize the time and resources used for preparing DAP.

In context of Dhaka city, the priority area of urban development should be residential development, industrial and commercial development, recreational development and at the same time protecting the agricultural land. As a one of the fastest growing megacities in the world, the immediate necessity of Dhaka city is providing adequate shelters in the form of residential development. As a growing economy the primate city of the country, Dhaka needs room for commercial and industrial development. The current unplanned development of Dhaka city is limiting the parks, open spaces and agricultural land. So, it is also important to create parks, open spaces and other outdoor recreational facilities, and protecting the agricultural land for food sustainability. In this view, the evaluation process of land suitability of this thesis selected the criteria that affect those development issues. The priority of the criteria was set in a way so that higher suitable area could be proposed for hard urban development like residential, commercial and industrial development and lower suitable area could be reserved for agriculture, park, open spaces and other recreational facilities. In the next chapter, more discussion was made to highlight how priority orders of the study area were analyzed for proposing different land-uses.

5.1 Modeling Geodatabase using UML

The UML-Geoframe concept, described in chapter 3, was applied for designing geodatabase model of urban land-use planning. Two objectives were set for this conceptual modeling –

- Fixing data requirements and database structure to prepare land-use plan for DMDP (Dhaka Metropolitan Development Plan) area.

- Handover the datasets to the authority (RAJUK, the capital improvement authority, who is mainly responsible for planning, managing and controlling of land-use within DMDP area) to administer the land-use plan.

The broad themes for land-use planning and management under DMDP area are shown as in Figure 12:

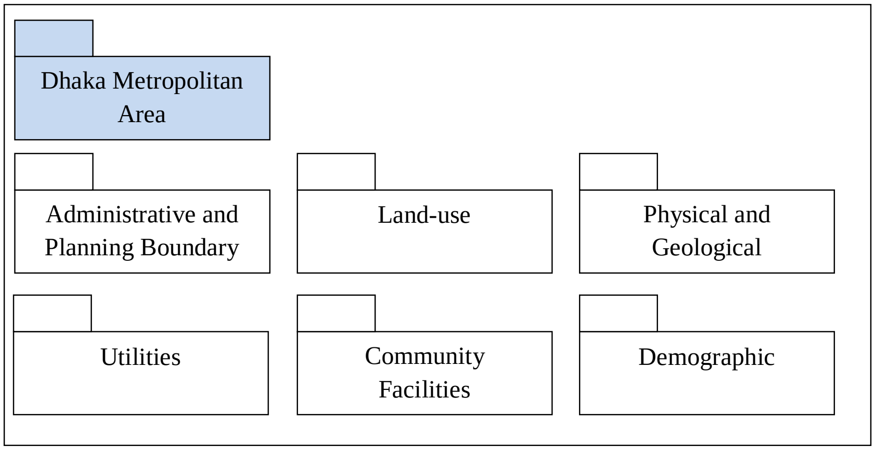


Figure 12: Broad themes of land-use planning

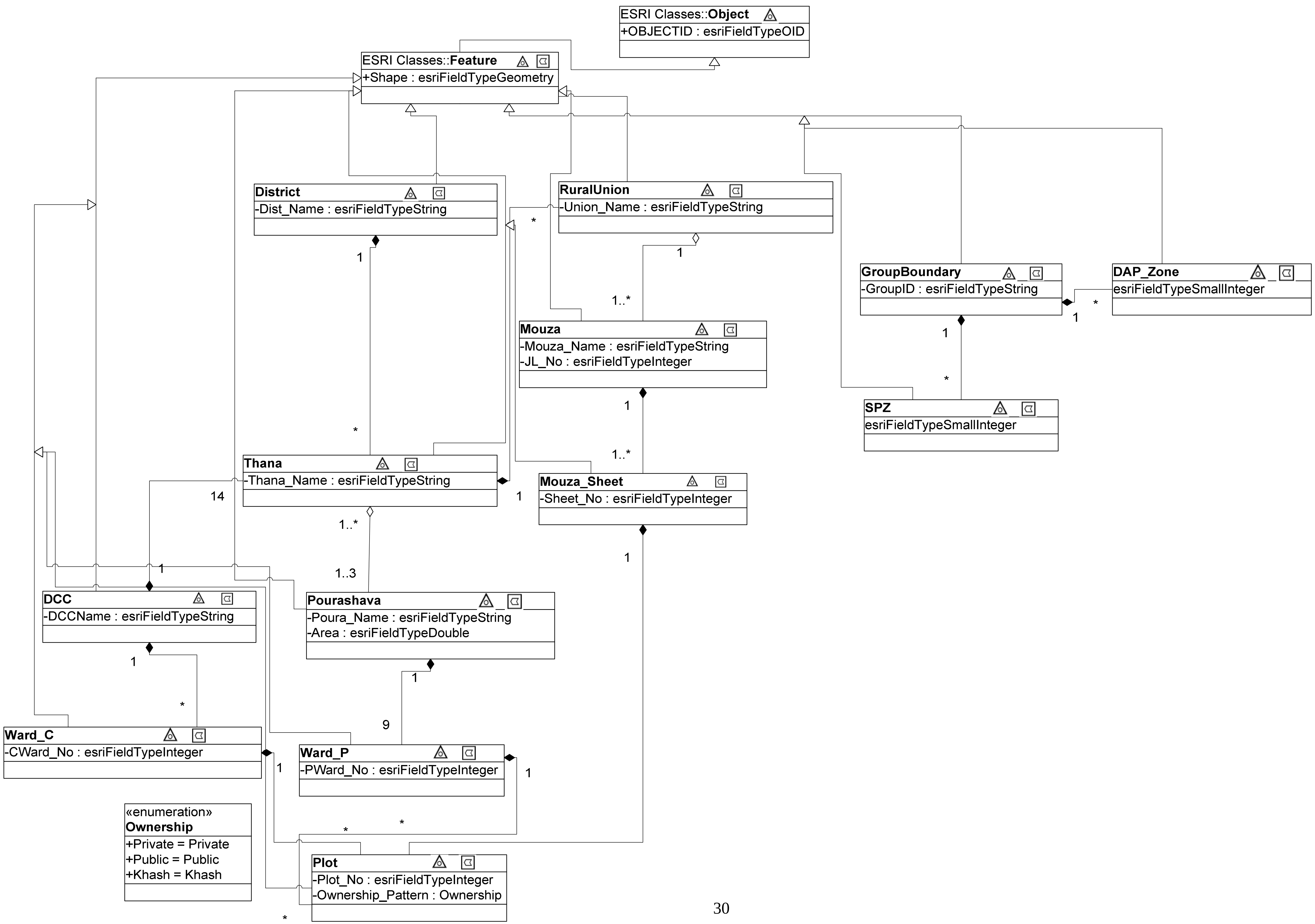
5.1.1. Administrative and Planning Boundary

This theme will mainly require for RAJUK for administrative and management purposes after finishing the land-use plan. The land-use plan will set guidelines for administration of land-use. Following information was step-by-step followed for preparing class diagram under this theme (Figure – 13)–

- DMDP area consists of several districts (fully or partly). Total Bangladesh is divided by 64 districts.
- Each district comprises number of Thana (sub-district).
- The major built-up portion of DMDP area is Dhaka City Corporation, which consists of 14 Thana. Recently, Dhaka City Corporation has been divided by two parts – Dhaka City Corporation North and Dhaka City Corporation South. So, name field has been added.
- Dhaka City Corporation is divided by around 100 wards. The name of the ward class of Dhaka City Corporation has been termed as Ward_C.
- There are other Pourashava towns (municipalities) in DMDP. Generally, a Pourashava exists within a single Thana. But in some cases, a purashava can overlap to another Thana. So, here aggregation relationship was used.

- Each Pourashava is divided by 9 wards. The name of ward class of Pourashava is termed as Ward_P.
- Besides Pourashava area, other areas of a Thana belong to Union Parishad (the rural local government institute). There are number of unions under each Thana.
- Each union contains 9 wards. But, the ward boundaries under union are not properly delineated in spatially. However, it will not make any problem to identify a parcel of land without considering the ward boundary for union areas, which are predominantly rural. In those areas, it will be better to use *Mouza* name. So, ward boundary in union areas were not considered for database.
- *Mouza* is the unit for keeping land record and is administered by Land Record office as well as by Land Ministry. Alternatively, it can be said as cadastral unit.
- Each union consists of one or more mouza, but, there may have overlapping. One mouza can be extended between two or more unions. So, aggregation relationship was used between union and mouza.
- Each mouza contains one or more blocks, which are delineated by Mouza Sheet.
- Each Mouza sheet has number of plots, that is, the ultimate parcel of land.
- It is very much important to know the plot ownership pattern for planners and authority. So, an enumeration class of plot ownership pattern has been added.
- Ward boundary of City Corporation and Pourashavas can be properly delineated by plot no. So, here composition relationship was used.
- The total DMDP area was divided into several group boundaries to prepare the detail land-use plan.
- Each groups were again divided by several number of SPZ (special planning zone) boundaries.
- During the plan preparation, planners divided each group into several DAP (Detail Area Planning) zone.
- Such grouping and zoning measures are taken during the planning phase. After finishing the plan, the land-use is administered by identifying plot no., ward no. etc. Such group or zoning boundary is not necessary for day to day work of authority. So, the group boundaries were presented in separate class diagram without making any link with land parcel and other administrative information.

Figure 13: Class Diagram - Administrative and Planning Boundary theme



5.1.2 Land-use

During designing class diagram for land-use theme following points were considered (Figure - 14) -

- Planners suggested preparing land-use in three hierarchy/categories: General land-use, Intermediate land-use and Detailed land-use.
- The primary data is procured from detailed land-use.
- The structure data is also used for preparing detailed land-use. For example, a building is a high school. So, a land-use of school is derived from that building.
- Structure may be one storied or multi-storied. So, it is necessary to know the no. of floor.
- Structures are in three type – Pucca (Hard brick, cement or similar structure), Katcha (soft straw, tin or similar structure) and Semi-pucca (Brick/Cement with tin/straw etc.).
- Land-use type can be existing or proposed in similar manner. So, Land-use_type attribute was added under Land-use_Detailed.
- Some environmental laws (like wet land act) control certain land-uses for particular areas.

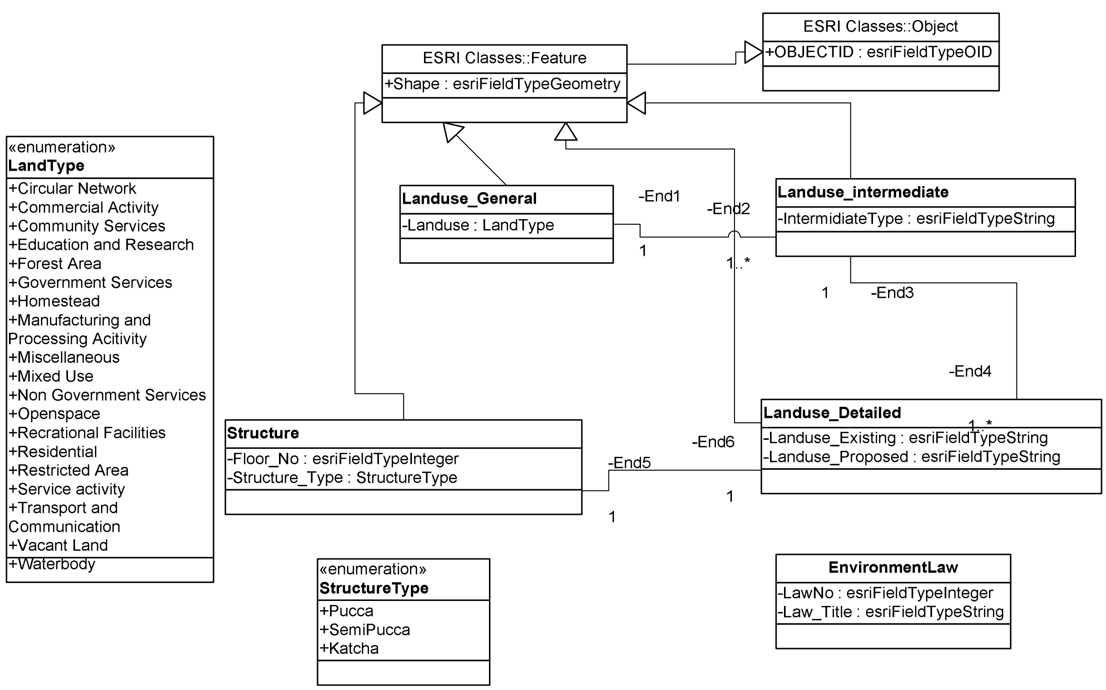


Figure 14: Class Diagram – Land-use theme

5.1.3 Physical and Geological

The main considerations for Physical and Geological theme were as follows (Figure 15) –

- Elevation, soil quality and distance to fault line are the datasets require under physical and geological theme. Because such features help to study the feasibility of construction sites, landing built-up areas, evaluation of earthquake risks and other geo-environmental phenomenon.
- Ground water condition was not considered as already experts are suggesting for collecting water from subsurface source for Dhaka city.

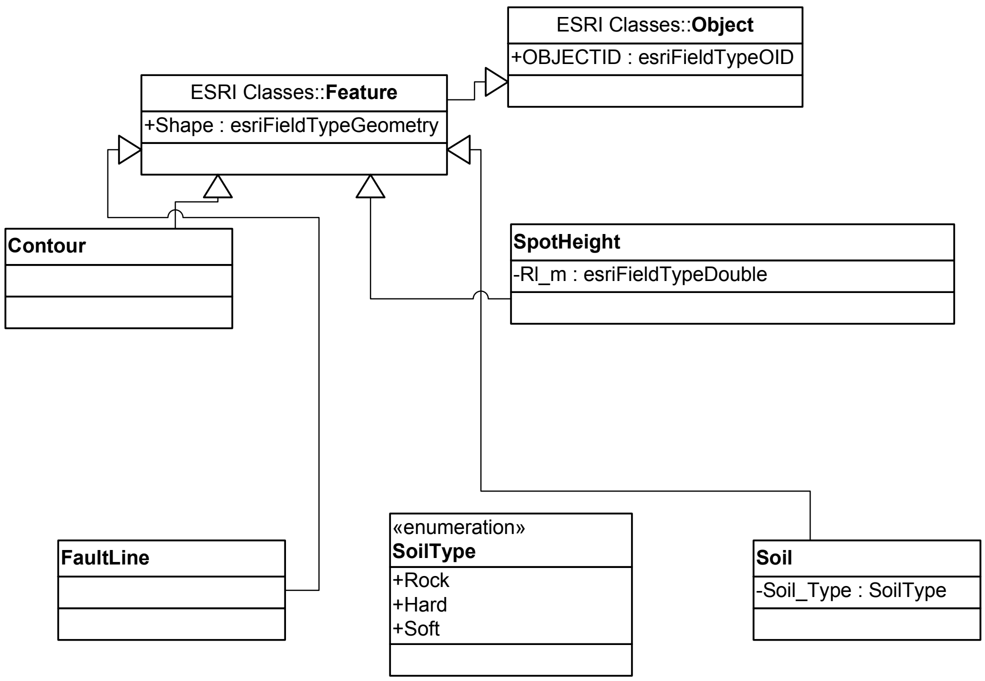


Figure 15: Class Diagram – Physical and Geological theme

5.1.4 Utilities

The principle considerations of Utilities theme are (Figure-16) –

- The major utilities services that have influences on land-use planning are road, drain, water supply, gas supply, electric supply and sewerage facilities.
- Road types are an important factor. Road types may be highway, pucca (metal road/carpeting road), semi-pucca (brick-built road), katcha (mud road), footpath, embankment and railway. The context of road hierarchy, like primary road, secondary road etc., is not usually applicable in perspective of Bangladesh. Specially, in the study area such hierarchy could not be maintained.

- Waterway has not been considered. Because, waterways have little impact over land-use of Dhaka city and a waterbus service project along the city failed. The feasibility of waterway services should be studied under transportation planning.

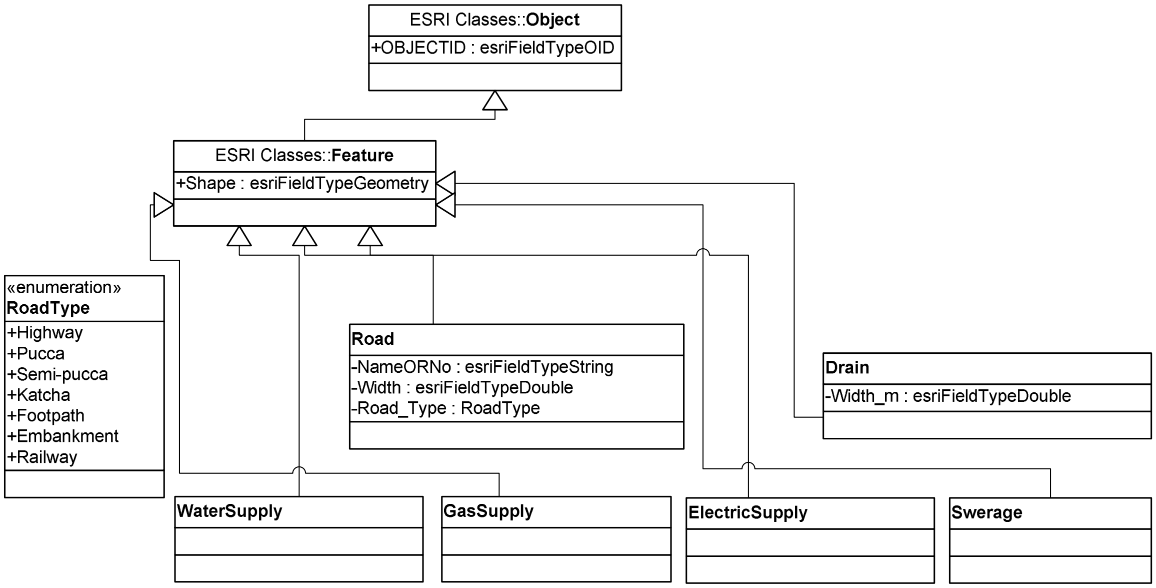


Figure 16: Class Diagram – Utilities theme

5.1.5 Community Facilities

Designing class diagram for community facilities was very simple as only point data of certain objects, like school, healthcare center, park, bus stop and market/bazar, were major considerations (Figure-17).

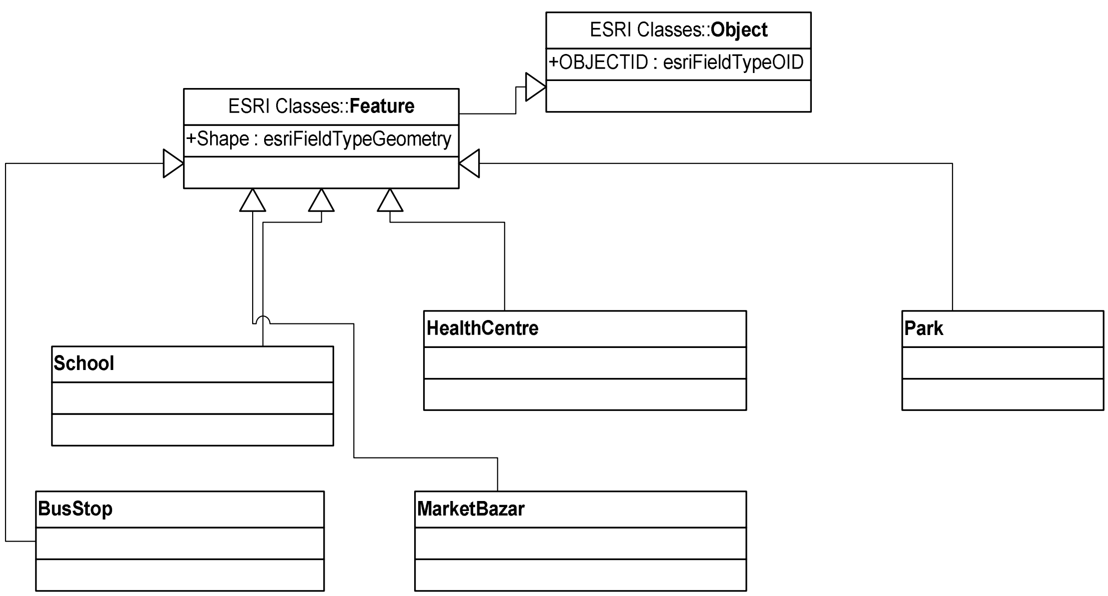


Figure 17: Class Diagram – Community Facilities theme

5.2 Data Processing

Different sets of secondary data were collected for this study (see section – 2.2). Data on administrative theme were not collected for this study. Because, this theme has no influence on proposed land-use planning. However, the requirements of the theme were designed in UML as this theme is important for planning authority to manage a land-use plan. Most of the data were collected from the source of RAKUK Detail Area Plan survey. In the study area, there is no service of Water Supply Authority, which is also responsible for providing drainage and sewerage facilities. So, no datasets were collected for those facilities. Data were also unavailable for soil types, which is much significant to analyze earthquake risks. But, the fault lines passing through the major rivers were used to determine the zones of earthquake risk (see section – 2.5).

All the data collected was in Esri Shape file format except data on Gas Supply. Gas Supply data was in paper map format which was digitized to store in GIS platform. The entire shape files were exported into an Esri Geodatabase.

An important task should be to process features in geodatabase so that the features maintain accurate topological relationships. There should not have overlapping in features, sliver polygons and associated problems. That is, efforts are necessary to ensure quality database. In this thesis, such jobs were avoided as that would be huge time consuming. Moreover, such job would be just a technical work rather than making something new inventory for research.

5.3 Selection of Criteria

In AHP process selection of criteria and their sub-criteria is a crucial stage. Because, selection of criteria influence the judgment by segregating one criteria from other and at the same time, by giving more importance to one criteria over other. By synthesizing numbers of literature reviews, local contexts and expert opinions a number of factor and criteria have been selected for this study. The criteria were further divided into several factor ratings (*Classes*) depending on their importance or preferences at different levels. Except the land-use criteria, all the criteria were classified into different factor ratings based on distances. Land-use is not a point or line feature, rather an area feature. Here, classification based on distances is not applicable. So, no classification was made for land-use criteria. The factors, criteria and their ratings can be shown in the following Table-6 –

Table 6: Factors and Criteria of Land-use

Factors	**Criteria**	**Unit**	**Factor Rating**				
			Class-1	*Class-2*	*Class-3*		*Not suit.*
Land-use	Agricultural	Type	Agricultural				
	Homestead	Type	Homestead				
	Residential	Type	Residential				
	Vacant Land	Type	Vacant Land				
Utilities	Proximity to Road	Meter	250	500	750		>750
	Proximity to Gas Supply	Meter	250	500	750		>750
	Proximity to Electricity line	Meter	250	500	750		>750
Physical & Geological	Elevation	Meter	3-6	6-9	9-13		
	Distance from Fault Line	Meter	>250				<250
Community Facilities	Distance from School	Meter	250	500	750		>750
	Proximity to Healthcare centre	Meter	500	1000	2000		>2000
	Proximity to Bus Stop	Meter	250	500	750		>750
	Proximity to Market/Bazar	Meter	250	500	750		>750
	Proximity to Park*	Kilometer	2	5	10		>10

*Reserved Open space has been considered as Park as there is no Park services data. This open space supposed to can be used as park.

5.4 Preparing Comparison Matrix

A useful step of AHP is making Comparison Matrix. The comparison matrix is prepared from Pair-wise Comparison. A Pair-wise Comparison, suppose comparison on how important is the *A* than the *B*, is performed in 9 degree preferences scale as suggested by Saaty (1980). At each higher level of scale shows higher importance than the previous lower level (Table-7).

Although Saaty (1980) suggested his 9 degree preferences scale for qualitative judgment based on experiments but at the same time his stance was flexible. Other suitable scale can be followed. Many authors criticized Saaty's numeric scale and several authors tried to improve that scale in alternative ways, but still no unique scale has been suggested other than Saaty's scale (Harker and Vergas 1987; Saaty 1990; Lootsma 1993; Dong, Y. *et al.* 2008). On the other hand, Saaty's ratio scale is easy to understand for decision makers and researchers from wide level of backgrounds are using this scale successfully to ease conflict decision making process.

Table 7: Fundamental scale used in Pair-wise Comparison (Saaty and Vargas 2001)

Intensity of Importance	Qualitative Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak	
3	Moderate importance	Experience and judgments slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another and dominance is demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

To make the pair-wise comparison between two factors or criteria under 9 degree preferences scale following Figure-18 was used –

Land-use	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Physical/Geological

Figure 18: Diagram to choose preference level between Land-use and Physical/Geological.

Using Figure-18, at first an expert fixes his stance, either both criteria are equally important or not. If they are equally important, then the value is 1. If they are not, then the expert takes his position where he prefers. For example in Figure-18, an expert prefers Land-use to Physical/Geological. So, he takes left side positions of 1. Finally, according to 9 degree preferences scale (Table-3) he marks his actual value of preference. In this diagram, the land-use got a weak favor over the factor of physical/geological. So, the value of 2 at the left side of 1 was highlighted. Thus pair-wise comparisons were made for all the factors. The number of pair-wise comparison can be calculated using the following formula (Saaty and Vargas 2001) –

$$\frac{n(n-1)}{2} \quad \text{------------------------------} \quad \text{Equation (1)}$$

Where, n is number of total criteria or factors. Suppose, we have 4 factors in our study. So, the numbers of pair-wise comparison were 6 at the first level.

After making pair-wise comparison, Comparison Matrix is prepared. For example, a 4 by 4 matrix was prepared for the 4 factors. The diagonal values of the matrix are always 1. We fill up the upper triangular matrix at first. If the values are at the left side of 1 (like Figure-18), we put actual judgment. If it is at the right side of 1 then we put reciprocal value.

After filling the upper triangle we fill the lower triangle with the reciprocal values. The formula is simple. If $\mathbf{a_{ij}}$ is the element of row $\mathbf{i}$ column $\mathbf{j}$ of the matrix, then the lower diagonal is

$$\mathbf{a_{ij}} = \frac{1}{\mathbf{a_{ji}}} \quad \text{------------------------------} \quad \text{Equation (2)}$$

So, we get one factor matrix and four criteria matrices from each expert (see Appendix - 1).

5.5 Estimating Weight for Factors and Criteria

For estimating weight for factors and criteria, at first level and second level, following steps were followed (Saaty and Vargas 2001) –

- Summing each column of comparison matrixes prepared in previous section (section – 5.4). For the example, at first level, we get from an expert –

	Land-use	Physical/ Geological	Utilities	Community Facilities
Land-use	1	2	7	8
Physical/Geological	1/2	1	6	7
Utilities	1/7	1/6	1	2
Community Facilities	1/8	1/7	1/2	1
Sum	1.77	3.31	14.5	18

- Dividing each element of matrixes with the sum of their columns. Here we get normalized relative weight, where, the sum of each column is 1.

	Land-use	Physical/ Geological	Utilities	Community Facilities
Land-use	0.56	0.60	0.48	0.44
Physical/Geological	0.28	0.30	0.41	0.39
Utilities	0.08	0.05	0.06	0.11
Community Facilities	0.07	0.04	0.03	0.55
Sum	1	1	1	1

- The Normalized Principal Eigen Vector was obtained by averaging across the rows –

$$W = 1/4 \begin{bmatrix} 0.56 + 0.60 + 0.48 + 0.44 \\ 0.28 + 0.30 + 0.41 + 0.39 \\ 0.08 + 0.05 + 0.06 + 0.11 \\ 0.07 + 0.04 + 0.03 + 0.55 \end{bmatrix} = \begin{bmatrix} 0.52 \\ 0.35 \\ 0.08 \\ 0.05 \end{bmatrix}$$

The normalized principle Eigen Vector is also called Priority Vector. As this is normalized, so, the sum of elements of priority vector is 1. Each element of priority vector shows the relative weight of its corresponding criteria. For example, the relative weight of land-use is 52%. But, before finalizing this relative weight, consistency of preferences was checked. The consistency is checked by following some steps of set formulas.

- To check the consistency, at first Principle Eigen Value was calculated. The calculation was obtained from the summation of products between each element of Priority vector and the sum of columns of the comparison matrix.

$$\lambda max = 1.77(0.52) + 3.31(0.35) + 14.50(0.08) + 18(0.05) = 4.12$$

Then Consistency Index (CI) was calculated using Equation-3. The CI is used to find the deviation or degree of consistency. But, this equation is not final. To do the final check Saaty(1980) proposed Consistency Ratio (CR), which is a comparison between CI and Random Consistency Index (RI), the appropriate one (Equation-4). Saaty (1980) determined standard RI against different number of criteria from 500 sample matrices. For example, RI is 0.9 for 4 numbers of criteria. From Equation – 3 & 4, we get CI = 0.04 & CR = 0.04 for this four factors example. Saaty (1980) suggested if the CR is less than or equal to 10%, then, the inconsistency is acceptable. In our all cases of study (both at the first level and second level), the CR values were remained below 10%.

$$CI = \frac{\lambda max - n}{n - 1} \quad \text{Equation (3)}$$

$$CR = \frac{CI}{RI} \quad \text{Equation (4)}$$

To do the whole weight estimation job, the calculation formulas were designed in MS Excel program. During sharing with expert opinion, experts were asked to give their preferences values on a 9 degree scale (like Figure-18). Based upon their judgment, if the values of CR were shown as greater than 10%, then experts were asked to repeat their task with different preferences. Thus, the weight assessments from individual experts have been shown in Appendix - 2.

A major challenge here was to aggregate different preferences values of experts into a single rating value. It was not possible to call all the experts for a group discussion and finalize the single ratings by them. In this connection, a number of literatures were reviewed. Several approaches have been suggested to aggregate individual judgments or priorities (Ramanathan and Ganesh 1994; Ernest and Kirti 1998; Dong *et al.* 2010; Aczel and Satty 1983). The main objective of those approaches is to reach at the *Pareto (unanimity, agreement) Principle*. In this study the Geometric Mean of individual priority was considered. That is, the geometric mean of all individual experts' Principle Eigen Vectors of a particular criterion was calculated. Then, the geometric means of all criteria were normalized by dividing with their sum so that disparity can be minimized (see Appendix-2).

Thus we get final weight of all the factors and criteria at the first and second level. At the end of this stage, we get the overall weight by multiplying the weight gotten in level one with that in level two (Table – 8).

Table 8: Weight values of factors, criteria and factor ratings

Level 1		**Level 2**		**Overall Weight**	**Rating (Level 3)**			
Factor	**W1**	**Criteria**	**W2**	**(Wi=W1xW2)**	**Class-1**	**Class-2**	**Class-3**	**Not Suit.**
Land-use	0.50	Agriculture	0.10	0.049	-	-	-	-
		Homestead	0.39	0.195	-	-	-	-
		Residential	0.07	0.036	-	-	-	-
		Vacant land	0.44	0.219	-	-	-	-
Physical Geological	0.34	Elevation	0.40	0.135	0.125	0.313	0.563	0
		Fault line	0.60	0.205	1	-	-	0
Utilities	0.10	Road	0.67	0.067	0.562	0.312	0.125	0
		Gas Supply	0.07	0.007	0.562	0.312	0.125	0
		Electricity	0.26	0.026	0.562	0.312	0.125	0
Community Characteristics	0.05	School	0.52	0.026	0.562	0.312	0.125	0
		Healthcare Centre	0.22	0.011	0.562	0.312	0.125	0
		Bus Stop	0.09	0.004	0.562	0.312	0.125	0
		Market/Bazar	0.12	0.006	0.562	0.312	0.125	0
		Park	0.05	0.003	0.562	0.312	0.125	0

At the third level, there is no overlapping condition. So, here comparison matrices are not necessary. But at different unit of intervals different level of scores were assigned. The scores were determined by the researcher's own judgment as he already have perceived idea about each criteria during the literature reviews and sharing experts' opinion survey. The score values were fixed according to AHP 9 degree scale. As this scale was already used in first and second level, so, it seemed convenient to use the same scale at the third level. Then, the score values were normalized to minimize disparity among the values. At an interval unit where a particular criterion is not suit, there zero value was assigned. In case of land-use criteria, there is no overlapping condition in the second level. So, for these criteria no score values were assigned rather the overall weights gotten from first and second level were used (Table - 8).

5.6 Evaluation of Land Suitability in GIS

To evaluate land suitability in GIS, the spatial database was prepared with data layers. Each data layer represents a particular criterion. The data layers were constructed from buffer analysis at the given distance units for each criteria. The attribute of these data layers were determined by multiplying the normalized score values at third level with the overall weights.

Then, each data layers were converted to raster format where the attribute values were used. That is, each criterion values are represented by a particular raster data layer. The raster operations were performed on 300m grid cells.

But, it was not necessary to buffering the land-use criteria as those criteria were already in polygon and there was no need of multiplication. On the other hand, elevation data was taken by creating Digital Elevation Model (DEM), which is also already in raster format. DEM was generated in Inverse Distance Weight (IDW) method as there was low resolution spot height data. DEM values were reclassified to prepare criterion map in raster format.

After creating all the required raster data layers, they were overlaid or aggregated in raster calculator. Thus a composite map was produced. The values of composite map show the land-use suitability index. The entire calculation at this stage can be shown by the following equation –

$$S = \sum_{i=1}^{n} Wi * Xi \qquad \text{Equation (5)}$$

Where, S is the land-use suitability index. Wi are the overall weights which were gotten previously by multiplying the weights of first level and second level criteria. Xi scores are normalized value of lowest level factors.

But, still one thing should be considered for evaluating suitability index. Some areas are restricted for existing university campus, army camps and for other reasons. These areas should be excluded from land-use planning. To do that job a Boolean raster should be multiplied with the suitability index, where the value of restricted areas in Boolean raster is 0 and other areas are 1. This can be simplified by the following equation –

$$S = \sum_{i=1}^{n} Wi * Xi * \pi \qquad \text{Equation (6)}$$

Where, π is the Boolean value.

Finally, the suitability index was classified into four classes to rank the study area into highly suitable, moderately suitable, low suitable and not suitable locations (Figure-19). As most of the criteria were rated under four classes so the final composite map were also classified into four categories. This suitability map was thereafter used for land-use planning.

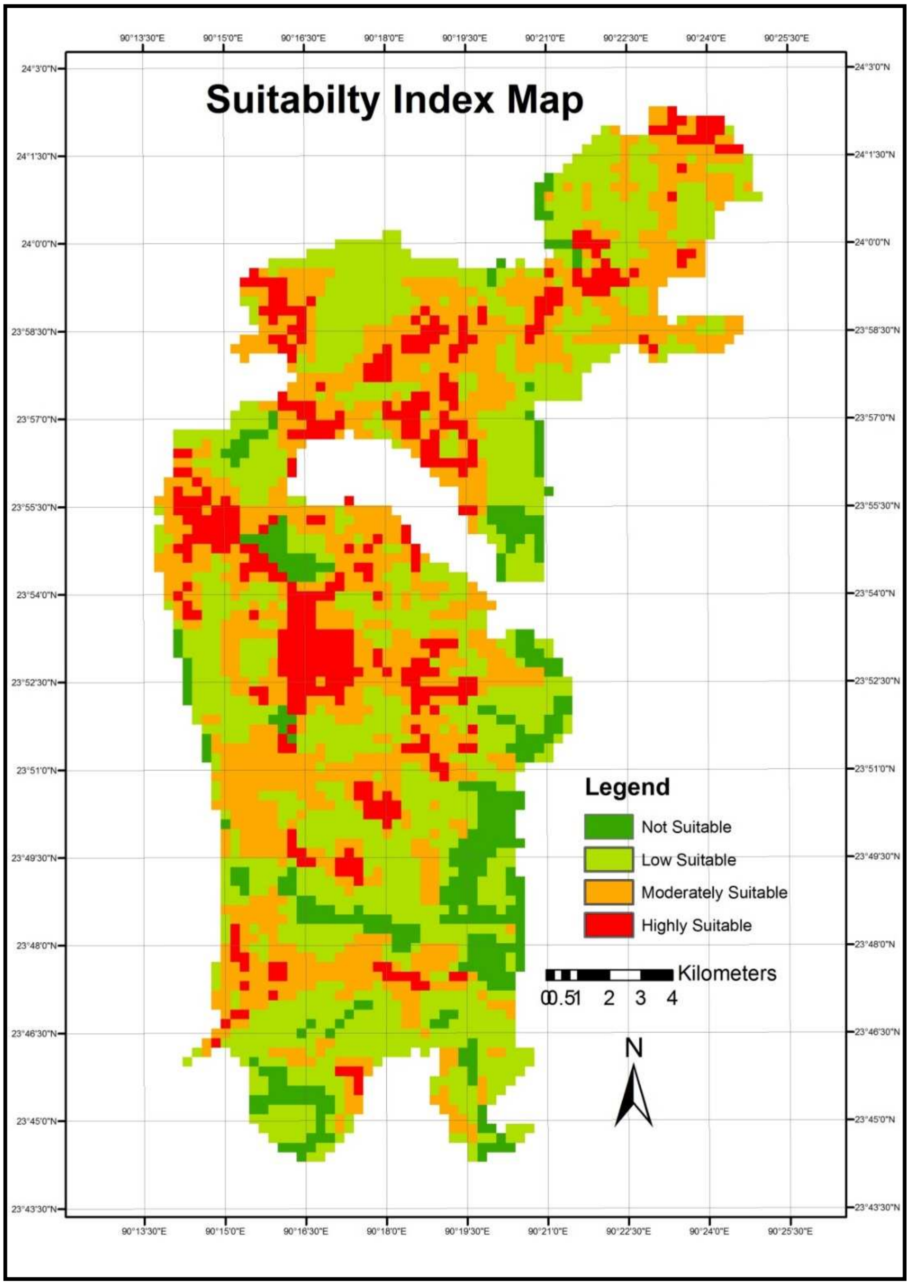


Figure 19: Land-use Suitability Index map

Chapter 6: Result, Discussion and Conclusion

6.1 Result and Discussions

6.1.1. The Land-use Suitability Indexes

As stated in the previous chapter, the suitability indexes were classified into four classes – highly suitable, moderately suitable, low suitable and not suitable.

Table 9: Area of different suitability types

Suitability Type	No. of Grid Cells	Area (in sq. km)	Proportion of Area
Highly Suitable	436	39.24	13%
Moderately Suitable	1186	106.74	35%
Low Suitable	1438	129.42	42%
Not Suitable	346	31.14	10%
Total	**3406**	**306.54**	**100%**

Table-9 shows that only 39.24 sq. km area is highly suitable (13%) followed by 106.74 sq. km is moderately (35%) and 129.42 sq. km (42%) is low suitable area. If we overlay each criterion map on this suitability index map, then, we get following findings –

6.1.1.1 Land-uses

Table 10: Land-use classes under each suitability types

Land-use Type / Suitability Type	Agriculture		Homestead		Residential		Vacant Land	
	Area	(%)	Area	(%)	Area	(%)	Area	(%)
Highly Suitable	0	0%	0	0%	0.27	9%	38.97	37%
Moderately Suitable	22.77	16%	37.26	61%	2.43	82%	44.28	42%
Low Suitable	90.27	65%	20.52	34%	0.09	3%	18.54	18%
Not Suitable	25.38	18%	3.15	5%	0.18	6%	2.43	2%
Total	**138.42**	**100%**	**60.93**	**100%**	**2.97**	**100%**	**104.22**	**100%**

Table-10 shows that most of the agricultural land falls into low suitable and not suitable area (65% & 18%). Around 16% of total agricultural land belongs to moderately suitable area, while, no agricultural land was found in highly suitable area. This happened, because, experts preferred to avoid agricultural land from residential, commercial and similar hard urban development. A substantial portion of homestead, residential and vacant land (61%, 82% &

42%) falls into the category of moderately suitable land. These types of land-uses are suitable for such hard urban development. Some 9% of residential land and 37% of vacant land are located within highly suitable area. This two types of land can get priority for urban residential development, because - The residential land-uses are already in residential. So, the existing residential land-uses could be promoted into planned residential area to facilitate more housing. Then, new housing development also can be promoted in the vacant lands.

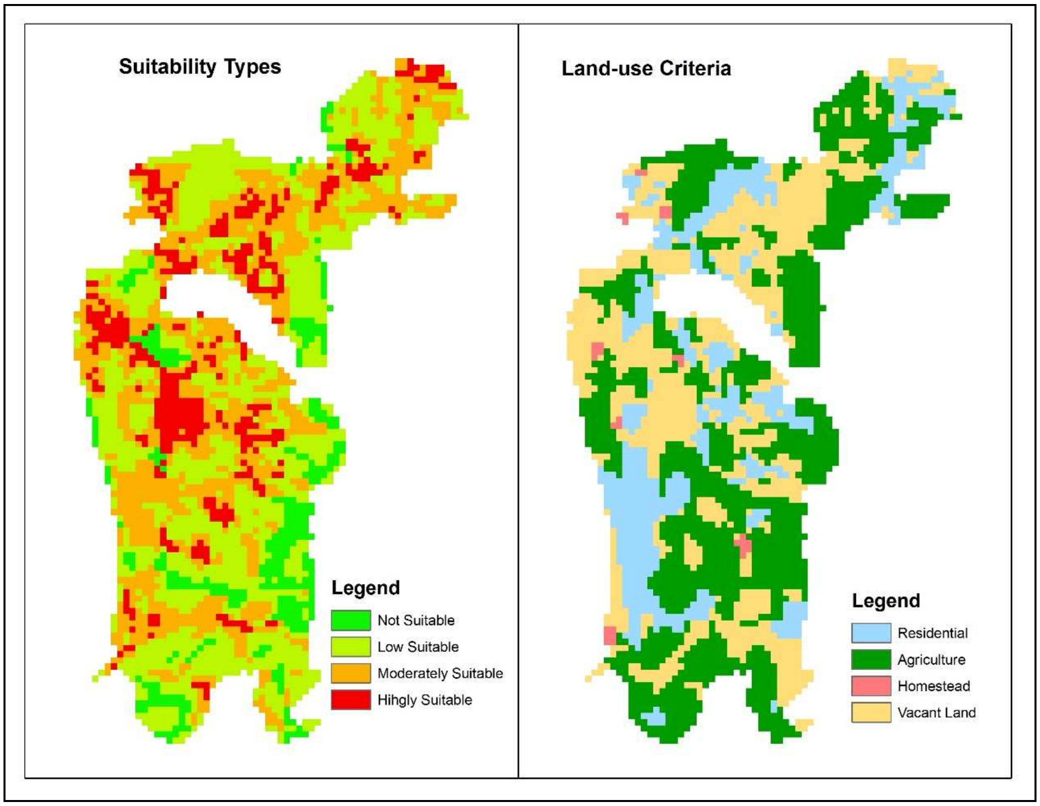


Figure 20: Comparison between suitability types and land-use criteria

6.1.1.2 Physical and Geological

Table 11: Elevation classes under each suitability types

Elevation / Suitability Type	3 to 6 m		6 to 9 m		9 to 13 m	
	Area	(%)	Area	(%)	Area	(%)
Highly Suitable	2.07	2%	12.24	10%	16.83	20%
Moderately Suitable	36.63	41%	48.06	40%	44.73	52%
Low Suitable	34.38	39%	52.47	44%	19.89	23%
Not Suitable	15.75	18%	19.44	16%	4.05	5%
Total	**86.76**	**100%**	**119.97**	**100%**	**85.5**	**100%**

Table-11 illustrates that 16.83 sq.km (20%) of 9 to 13 meter elevated areas falls into highly suitable area. This portion of area is comparatively higher than the portions of lower elevated area (2% and 10%) in the same suitability category. Such figure justify that more than 50% of highly suitable land fall into high land (9 to 13 meter), which is free from flood and favorable for residential development. Most of the significant portion of all types of elevation go under moderately and low suitable area. The facts for this significance is that the sizes of the moderately suitable and low suitable area are also significantly higher (35% and 42%, see Table -9) and there are little variation of elevation in the study area, meaning that the study area is primarily a plain land.

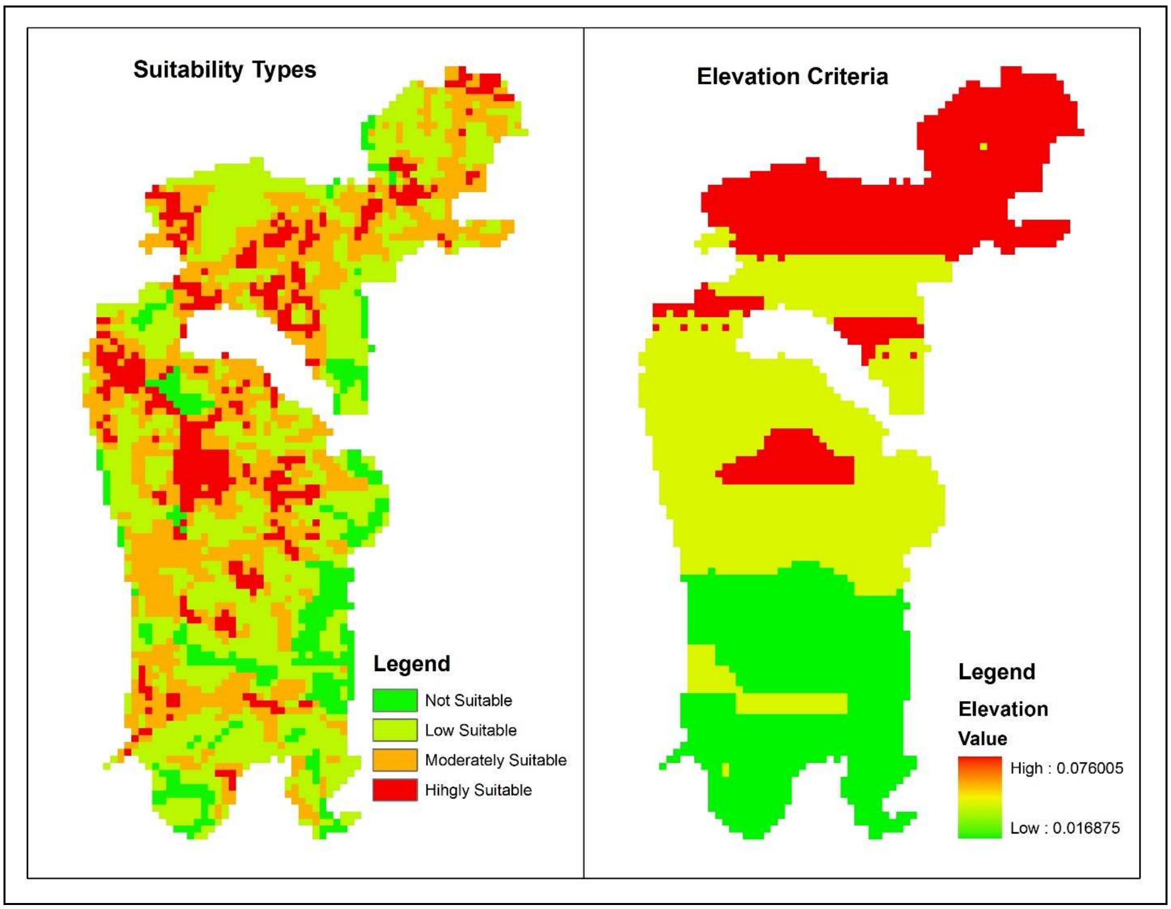


Figure 21: Comparison between suitability types and elevation criteria

Table 12: Earthquake risk area under each suitability types

Fault line / Suitability Type	Within Risk		Not in Risk	
	Area	(%)	Area	(%)
Highly Suitable	0	0%	39.24	16%
Moderately Suitable	4.41	8%	102.33	41%
Low Suitable	22.68	41%	106.74	42%
Not Suitable	28.35	51%	2.79	1%
Total	**55.44**	**100%**	**251.1**	**100%**

Table-12 depicts that highly suitable area has no risk of earthquake. So, residential land-use can be proposed in this area as people usually stay at their resident at night. Only 8% of risky area is under moderately suitable area. This marginal portion of land could be used for urban development other than residential, commercial and industrial development. Around 92% of risky area falls within low suitable and not suitable area. So, the result validates that low suitable and not suitable area should be protected from hard urban development.

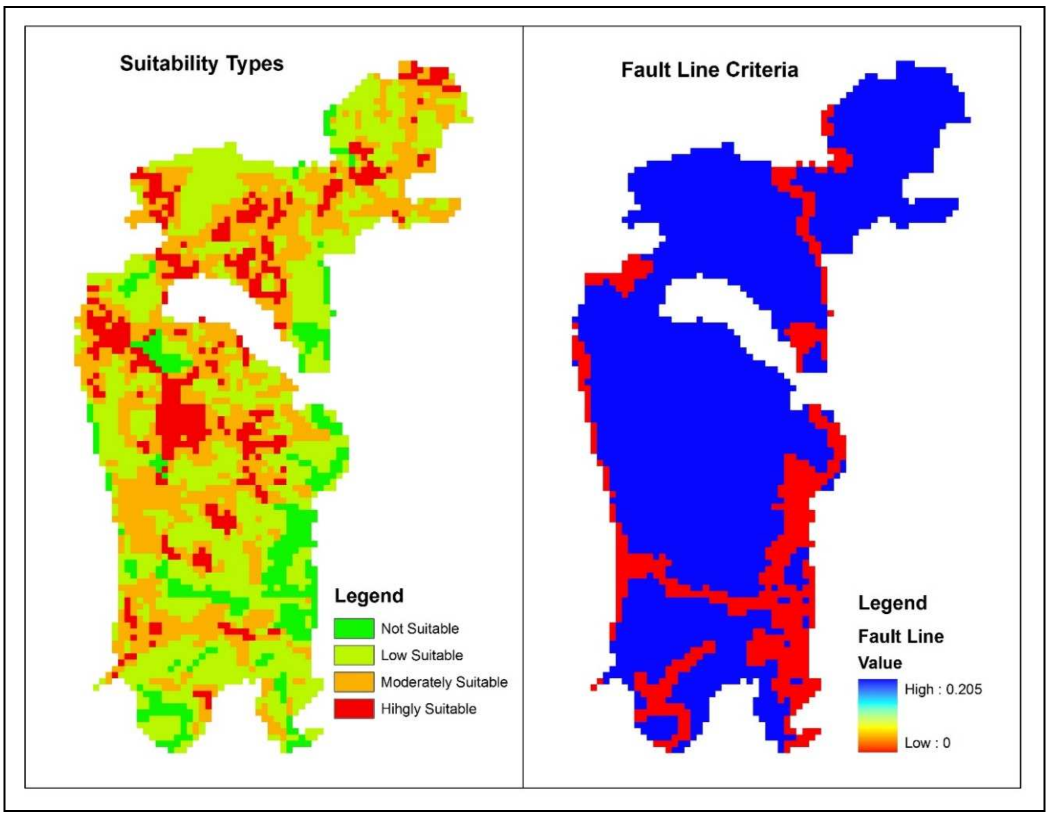


Figure 22: Comparison between suitability types and fault line criteria

6.1.1.3 Utilities

Table 13: Road classes under each suitability types

Proximity to Road / Suitability Type	Within 250 m		Within 500 m		Within 750 m	
	Area	(%)	Area	(%)	Area	(%)
Highly Suitable	39.24	36%	0	0%	0	0%
Moderately Suitable	64.44	59%	30.15	27%	12.15	14%
Low Suitable	4.05	4%	71.91	65%	53.46	62%
Not Suitable	1.26	1%	9	8%	20.88	24%
Total	**69.75**	**100%**	**111.06**	**100%**	**86.49**	**100%**

According to Table- 13 and Table-9, all the highly suitable area (39.24 sq. km) lies within the 250 meter buffer zone of road networks, that is, highly suitable are is well connected by road networks. Similarly, moderately suitable area is also close to the road network as 59% of the area within the 250m distance of roads fall under moderately suitable area. On the other hand, low suitable area and not suitable area located at the far distances from the roads. So, it can be inferred that land-uses, like residential, commercial and industrial developments, can be proposed in highly and moderately suitable areas. An almost similar result (with almost a similar figures) is also found in case of electricity (Table-14), because, electricity lines passes through the road networks. So, similar urban developments also can be proposed in consideration of electricity. Although the figures for gas line (Table- 15) are different, but the summary of the result is same – highly and moderately suitable areas are close to gas line, while, the low suitable and not suitable areas are in far distances. So, the land-use proposal in connection to the criteria of gas line should be similar to other utility services like road networks and electricity.

Table 14: Electricity classes under each suitability types

Proximity to Electricity / Suitability Type	Within 250 m		Within 500 m		Within 750 m		Above 750 m (not Suit.)	
	Area	(%)	Area	(%)	Area	(%)	Area	(%)
Highly Suitable	39.24	36%						
Moderately Suitable	64.44	59%	20.61	31%	9.54	21%	12.15	14%
Low Suitable	4.05	4%	41.22	62%	30.7	69%	53.46	62%
Not Suitable	1.26	1%	4.68	7%	4.32	10%	20.88	24%
Total	**69.75**	**100%**	**66.51**	**100%**	**44.6**	**100%**	**86.49**	**100%**

Table 15: Gas line classes under each suitability types

Proximity to Gasline / Suitability Type	Within 250 m		Within 500 m		Within 750 m		Above 750 m (not Suit.)	
	Area	(%)	Area	(%)	Area	(%)	Area	(%)
Highly Suitable	15.3	42%	4.68	15%	3.15	12%	16.11	8%
Moderately Suitable	18.72	51%	15.03	49%	11.8	44%	61.2	29%
Low Suitable	1.44	4%	8.82	29%	10.8	40%	108.36	51%
Not Suitable	1.08	3%	1.89	6%	1.35	5%	26.82	13%
Total	**21.24**	**100%**	**25.74**	**100%**	**27.1**	**100%**	**212.49**	**100%**

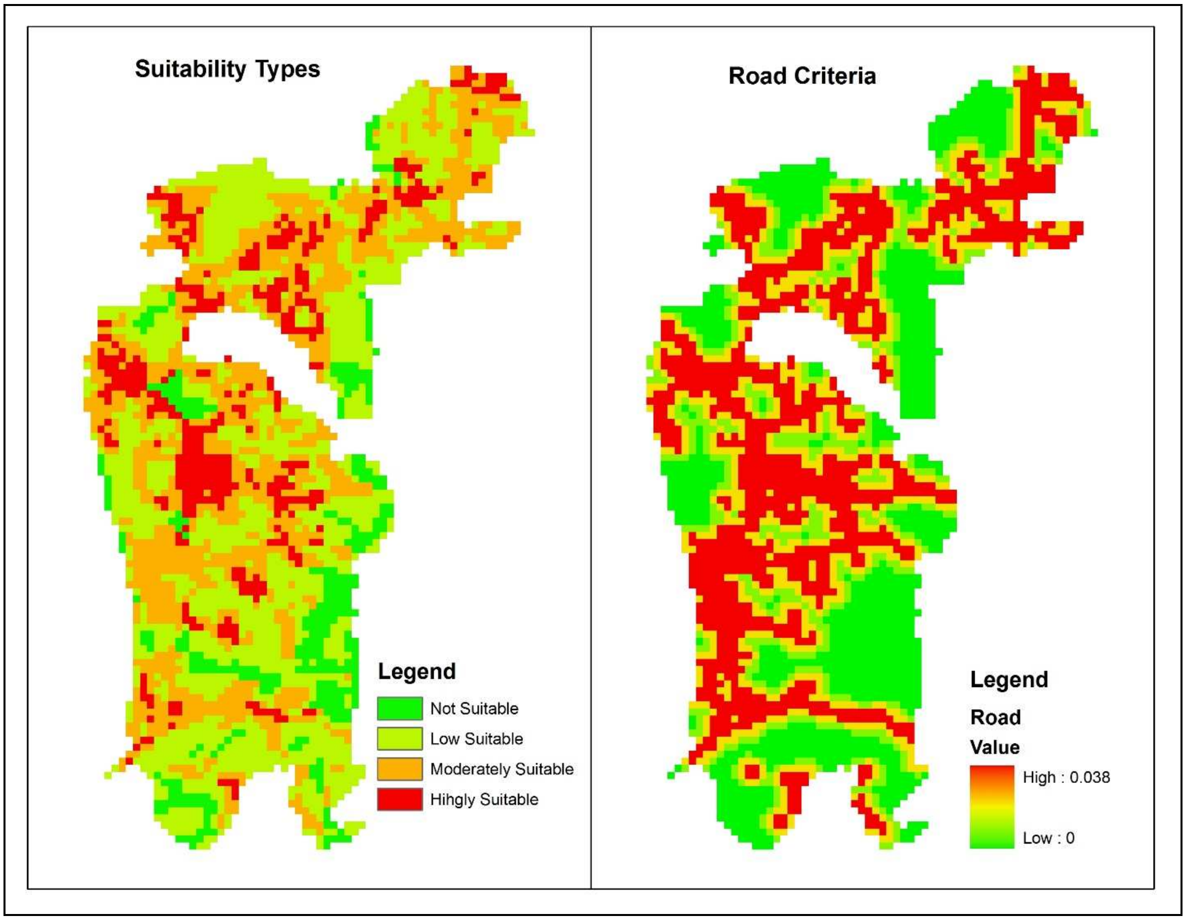


Figure 23: Comparison between suitability types and road criteria

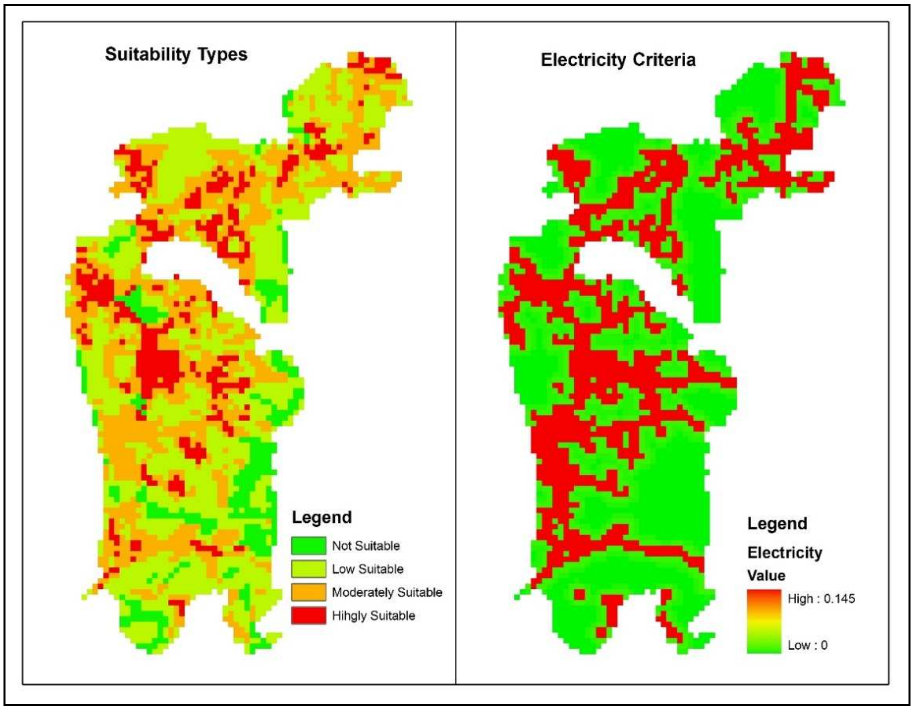


Figure 24: Comparison between suitability types and electricity criteria

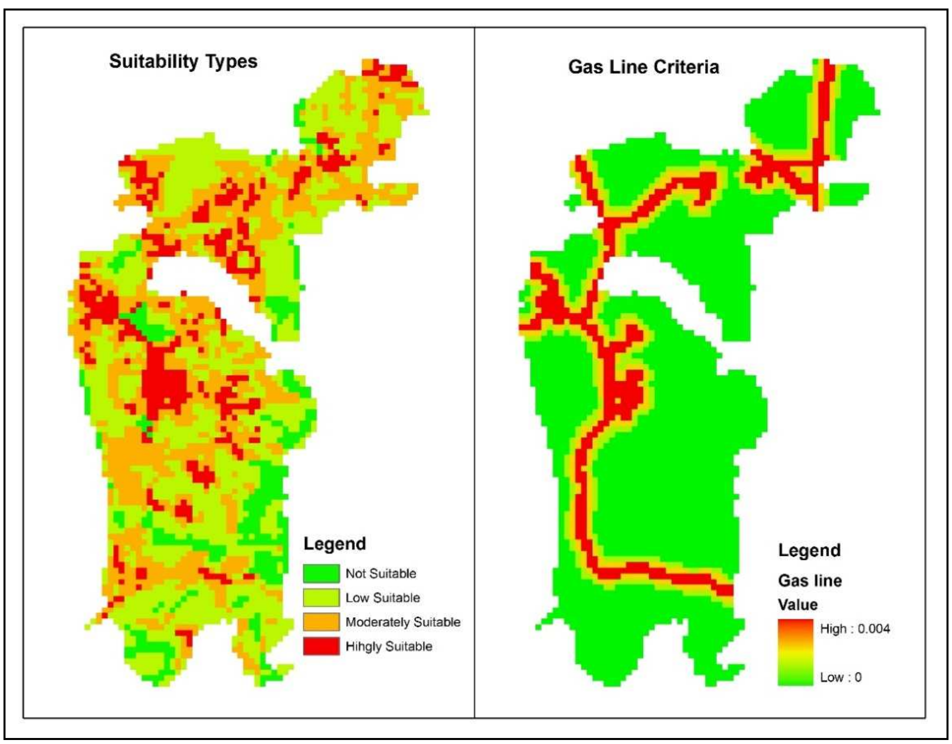


Figure 25: Comparison between suitability types and gas line criteria

6.1.1.4 Community Characteristics

Table 16: Proximity to school under each suitability types

Proximity to School / Suitability Type	Within 250 m		Within 500 m		Within 750 m		Above 750 m (not Suit.)	
	Area	(%)	Area	(%)	Area	(%)	Area	(%)
Highly Suitable	12.69	15%	7.2	14%	10.53	15%	8.82	9%
Moderately Suitable	32.4	39%	27.18	54%	22.77	32%	24.39	24%
Low Suitable	33.66	40%	14.31	28%	31.05	43%	50.4	50%
Not Suitable	5.22	6%	2.07	4%	7.38	10%	16.47	16%
Total	**71.28**	**100%**	**43.56**	**100%**	**71.73**	**100%**	**100.08**	**100%**

According to Table-16, the area coverage of schools at different distances is considerably higher in moderately suitable and low suitable areas. Actually, schools are distributed all over the study area to facilitate the education services to all. So, the area coverage of schools is higher in those two suitable areas, because, those two suitable areas cover major portion (77%) of the study area. However, within this scope of study, it could not be concluded that number of schools or their capacities are enough. Rather, it can be said, for example, highly suitable area has access to schooling facilities, so, residential land-use could be proposed there. Although the figures in number are somehow different, but similar discussions are also applicable for the criteria of healthcare services (Table-17).

Table 17: Proximity to healthcare services under each suitability types

Proximity to Healthcare / Suitability Type	Within 250 m		Within 500 m		Within 750 m		Above 750 m (not Suit.)	
	Area	(%)	Area	(%)	Area	(%)	Area	(%)
Highly Suitable	2.97	11%	5.94	10%	17.01	13%	13.32	15%
Moderately Suitable	15.3	56%	21.51	38%	42.12	32%	27.81	30%
Low Suitable	7.92	29%	26.55	46%	58.05	44%	36.9	40%
Not Suitable	0.9	3%	3.15	6%	13.68	10%	13.41	15%
Total	**24.12**	**100%**	**51.21**	**100%**	**130.9**	**100%**	**91.44**	**100%**

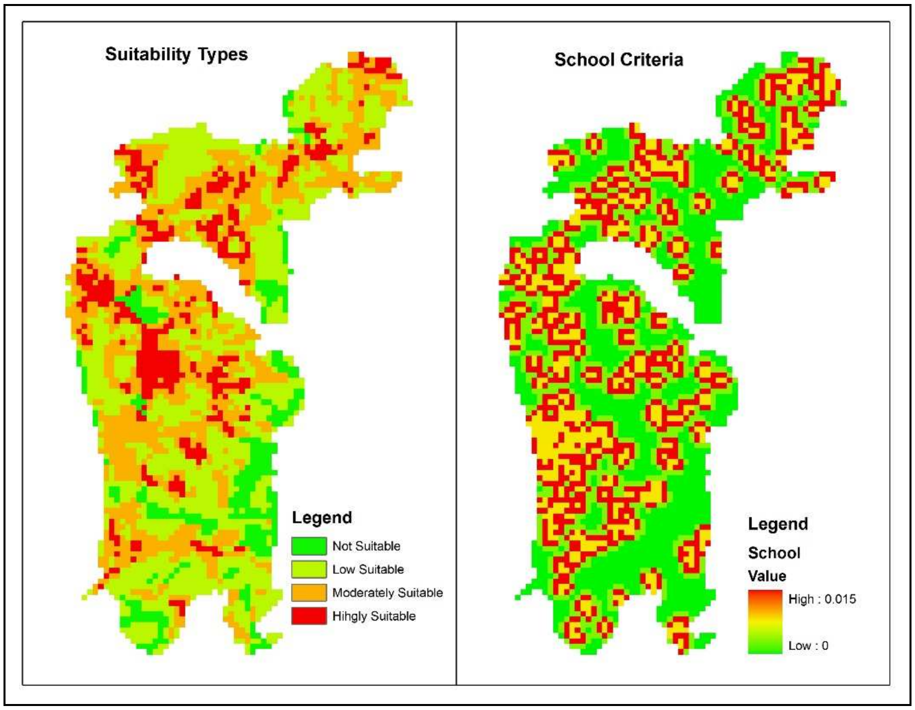


Figure 26: Comparison between suitability types and school criteria

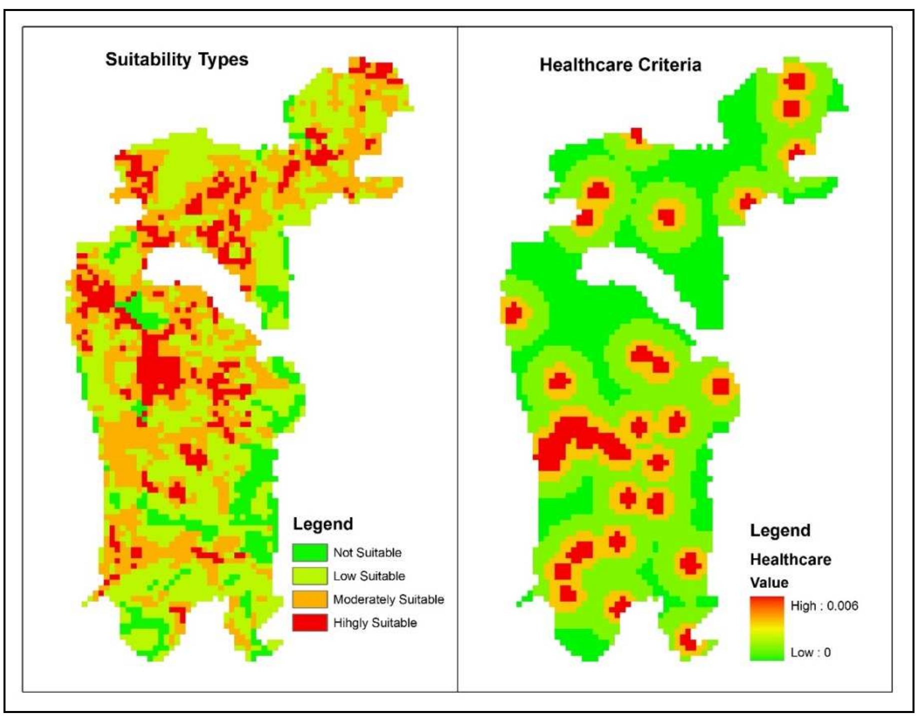


Figure 27: Comparison between suitability types and healthcare criteria

Table 18: Proximity to bus stop under each suitability types

Suitability Type \ Proximity to Bus Stop	Within 250 m		Within 500 m		Insignificant or Not Suit.	
	Area	(%)	Area	(%)	Area	(%)
Highly Suitable	0.9	29%	4.95	23%	33.39	12%
Moderately Suitable	1.62	53%	11.34	53%	93.78	33%
Low Suitable	0.45	15%	3.51	16%	125.5	44%
Not Suitable	0.09	3%	1.71	8%	29.34	10%
Total	**2.16**	**100%**	**16.56**	**100%**	**282**	**100%**

According to Table-18, areas that cover upper than 500 meter distances from bus tops are not significant. So, these areas have been added with *Not Suit.* areas. Those areas are insignificant and were added with *Not Suit.* as their weightage value is close to zero. Within 250 meter distance, area coverage is highest in moderately suitable area (53%) followed by highly suitable area (29%) which are also almost similar for areas within 500 meter distance. So, it can be inferred that highly and moderately suitable areas have greater accessibility to bus stops that is an advantage for residential, commercial and industrial development.

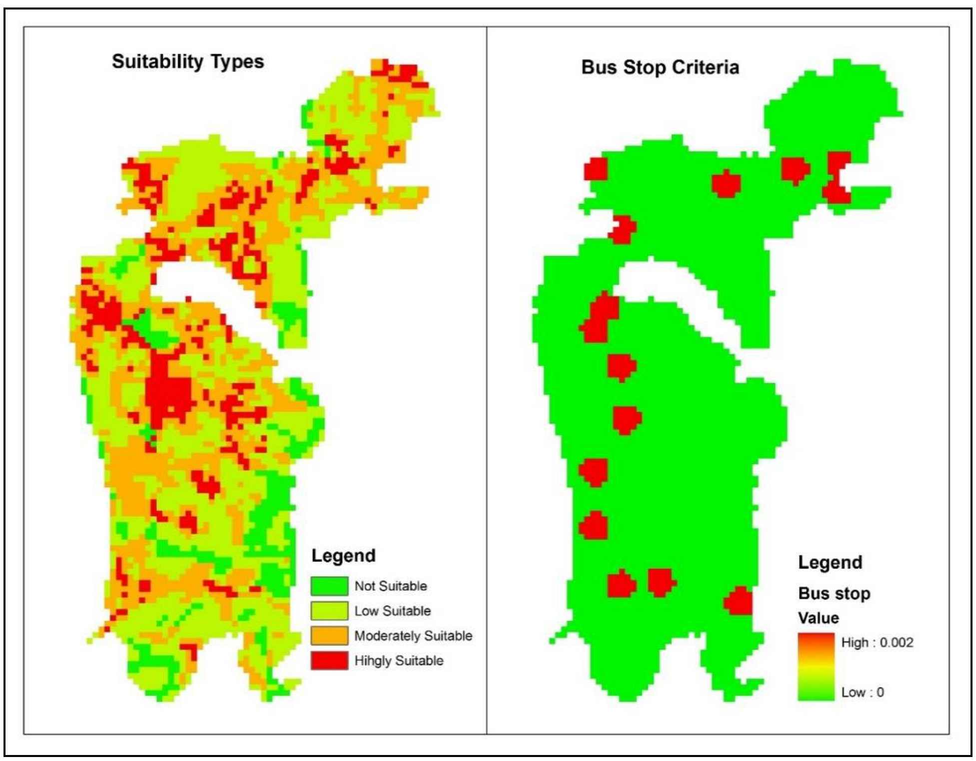


Figure 28: Comparison between suitability types and bus stop criteria

Table 19: Proximity to market/bazar under each suitability types

Proximity to Market/ Bazar / Suitability Type	Within 250 m		Within 500 m		Within 750 m		Above 750 m (not Suit.)	
	Area	(%)	Area	(%)	Area	(%)	Area	(%)
Highly Suitable	4.59	21%	5.76	18%	5.85	16%	23.04	11%
Moderately Suitable	11.61	54%	13.77	44%	15.21	42%	66.15	30%
Low Suitable	4.41	21%	10.35	33%	12.42	35%	102.24	47%
Not Suitable	0.9	4%	1.71	5%	2.52	7%	26.01	12%
Total	**16.92**	**100%**	**25.83**	**100%**	**36**	**100%**	**217.44**	**100%**

As Table-19 shows, some 217 sq. km of the study area is *Not Suit.* for access to market places. In fact, these market places are considerably big. People, who stay in long distances from these market places, don't come here in daily basis. They come in these market places one or two times in a week. They buy their daily necessary products from local shops or local small markets or temporary Bazars. This criterion has value on overall weight of suitability, but, as an individual criterion nothing could be inferred for land-use planning.

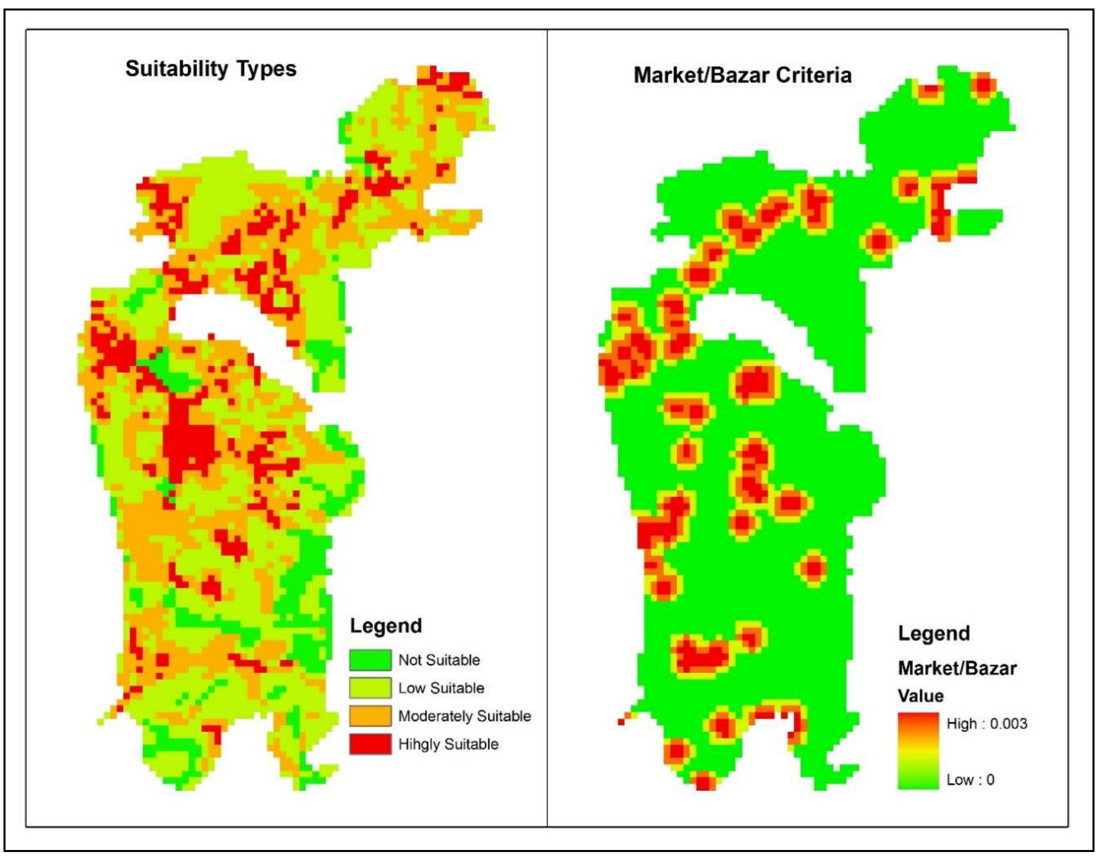


Figure 29: Comparison between suitability types and market/bazar criteria

Table 20: Proximity to park under each suitability types

Proximity to Park / Suitability Type	Within 250 m		Within 500 m		Insignificant or Not Suit.	
	Area	(%)	Area	(%)	Area	(%)
Highly Suitable	0.54	3%	5.94	6%	32.76	17%
Moderately Suitable	4.32	20%	30.87	33%	71.55	37%
Low Suitable	13.32	62%	40.77	43%	75.33	39%
Not Suitable	3.24	15%	16.29	17%	11.61	6%
Total	**20.88**	**100%**	**87.93**	**100%**	**191.25**	**100%**

According to Table-20, similar to bus stop, proximity to park got little preferences over other criteria. So, areas within 500 to 750 distances from park showed as insignificant as their weight value is close to zero. 62% area within 250 meter and 43% area within 250 to 500 meter fall under the category of low suitable land, that is, most significant areas close to park lie on low suitable areas. Actually, within the whole study area, no data of park was found. The study area has no planned development that can be a reason for not having any area designated for park. As stated in previous chapter, some reserved open spaces have been treated as park in this study, in a sense, these areas could be used for park in future. The result in the table validates that intention. Low suitable area, which is not useful for hard urban development as discussed previously, should be used for soft development, like creating recreational facilities. Parks along with other recreational facilities could be developed in the reserved open spaces, which belong to the low suitable area.

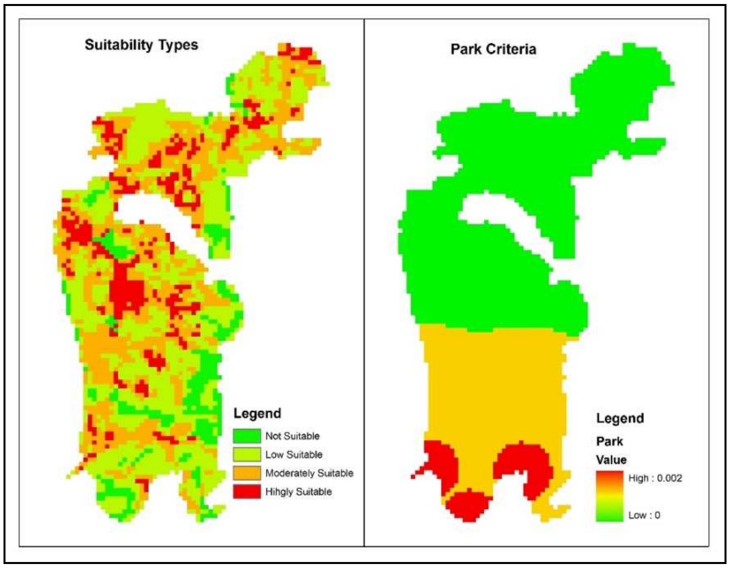


Figure 30: Comparison between suitability types and park criteria

6.1.2 Land-use Proposal

According to the above discussions, the dominant features under each suitability type can be shown like as following Table-21 –

Table 21: Dominant features under each suitability types

Suitability Type	Dominant Features
Highly Suitable	Vacant Land, High Elevation, No earthquake risk, Close to utility services, close to bus stops
Moderately Suitable	Homestead, Vacant Land, residential, High Elevation, Minimum earthquake risk, close to utility services, close to bus stops, close to market places
Low Suitable	Agriculture, homestead, earthquake risk, close to parks
Not Suitable	Agriculture, earthquake risk

Considering the above dominant features in Table-21, according to each suitability type we can prepare the following land-use proposal –

6.1.2.1 Land-use in Highly Suitable Area

The highly suitable areas are featured by vacant land, high elevation, connected with utilities and community services. Hard urban development can be promoted in these areas. These areas should be used for urban residential areas to facilitate new housing development.

6.1.2.2 Land-use in Moderately Suitable Area

Moderately suitable areas are featured by homestead, vacant land, existing residential use, high elevation, minimum earthquake risk, close to market places and connected with utilities and community services. Within this scope of study, these areas can be proposed as mixed-use area. This mixed-use area has potentiality of housing, commercial and industrial development. Detail study is necessary to find out which part of this area is preferable for industrial development. Other area could be used for both residential and commercial development as such mixed-use development is appreciated in Bangladesh. Any hard urban development should be protected in earthquake risk zone.

6.1.2.3 Land-use in Low Suitable Area

Low suitable areas are predominated by agricultural and low lying flood flow zones. These areas should be free from major development. The lands here are close to fault lines. So, the places are also prone to earth quack risk. Here development controlling mechanism is earnest necessary. Agricultural lands should be protected as Bangladesh is facing acute shortages of agricultural land. However, as these areas fall within the Greater Dhaka Metropolitan Area jurisdiction, so, some parcels of land in these areas could be used for sports grounds, parks and other recreational open spaces as a requirement of city's civic amenities.

6.1.2.4 Land-use in Not Suitable Area

The Not Suitable Area is featured by agricultural uses, restricted areas and high earthquake risk. Any type of use other than agriculture should be protected in this area.

6.1.3 Comparison with DAP

DAP was prepared by a number of experts with their supporting team, used huge technical and financial resources as well as time. So, it could be deemed as a hypothetical experiment to compare the DAP with this minor study. However, if we follow the DAP report, around 9.16% of total planning area of Group-E has been delineated for Urban Residential Zone. The highly suitable area, according to this study, is 13% of Group-E. Within this highly suitable area, some portion of land would be allocated for road networks and other civic facilities. In that sense, treating this 13% area as urban residential zone shows a considerable result comparing to DAP report. Again, it should be mentioned that according to DAP report, around 52% of Group-E planning area was proposed for reserving as agricultural and flood flow areas. In this study result, the low suitable area and not suitable areas are 52% of Group-E area in together. The study suggests using these areas as agricultural use with minor use of recreational services. Here, the result is similar to DAP's proposition. At least, this 52% area could be excluded from DAP preparation processes, thus, could minimize the resources use. Then, it could be followed more focused development plan to moderately suitable area and highly suitable area, where minor study could be enough for highly suitable area as it already have shown the suitability of residential use. So, with these thesis findings, it could be suggested that GIS-based AHP could be a useful tool for urban land-use planning, where the tool would assist the decision makers and planners for taking planning decision quickly, within limited resources and in a consistent and structured way. However, the thesis suggested the land-use plan at a regional scale that could be utilized successfully for structure plan or similar strategic planning.

6.2 Conclusion

In this study, a geodatabase has been conceptualized at first for urban land-use planning using UML model, where five broad themes; like administrative and planning boundary, land-use, physical and geological, utilities, community facilities and demography; were considered. Such conceptual model has specified data requirements and database structure to prepare land-use plan for DMDP that will enable the authority to administer the land-use plan.

Then, this study prepared an urban land-use plan using GIS and AHP at a regional scale, where data used was not in very detail. Such planning approach would be much helpful for the planners to make structure plan and to adopt other strategic planning. A regional planning becomes successful when it can be integrated well with the local level or detail level planning. This research tried to validate its regional urban planning approach with the Detail Area Plan and found success in some of the cases. This validation pronounces the suitability of GIS-based AHP application in land-use planning. Such regional approach will select the areas where more intensive development can be allowed and will identify the areas where development control should be imposed. In this manner, the specific areas could be chosen for detail level planning, like DAP of DMDP, using available data. As a result, entire works would be minimized by reducing detail physical and topographical survey for all over the city region; more focused development could be promoted; and finally, financial and technical resource uses could be minimized. However, further research is necessary for getting more justification in this regard.

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Appendix 1: Comparison Matrixes

Factor Matrixes

Expert 1:

	Land-use	Physical/Geological	Utilities	Community Facilities
Land-use	1.00	2.00	7.00	8.00
Physical/geological	0.50	1.00	6.00	7.00
Utilities	0.14	0.17	1.00	2.00
Community Facilities	0.13	0.14	0.50	1.00

Expert 2:

	Land-use	Physical/Geological	Utilities	Community Facilities
Land-use	1.00	2.00	5.00	7.00
Physical/geological	0.50	1.00	5.00	7.00
Utilities	0.20	0.20	1.00	2.00
Community Facilities	0.14	0.14	0.50	1.00

Expert 3:

	Land-use	Physical/Geological	Utilities	Community Facilities
Land-use	1.00	1.00	4.00	8.00
Physical/geological	1.00	1.00	4.00	8.00
Utilities	0.25	0.25	1.00	3.00
Community Facilities	0.13	0.13	0.33	1.00

Expert 4:

	Land-use	Physical/Geological	Utilities	Community Facilities
Land-use	1.00	2.00	4.00	8.00
Physical/geological	0.50	1.00	3.00	8.00
Utilities	0.25	0.33	1.00	3.00
Community Facilities	0.13	0.13	0.33	1.00

Expert 5:

	Land-use	Physical/Geological	Utilities	Community Facilities
Land-use	1.00	3.00	5.00	8.00
Physical/geological	0.33	1.00	3.00	7.00
Utilities	0.20	0.33	1.00	3.00
Community Facilities	0.13	0.14	0.33	1.00

Criteria Matrixes

Land-use

Expert 1:

	Agriculture	Homestead	Residential	Vacant Land
Agriculture	1.00	0.25	2.00	0.33
Homestead	4.00	1.00	4.00	3.00
Residential	0.50	0.25	1.00	0.20
Vacant land	3.00	0.33	5.00	1.00

Expert 2:

	Agriculture	Homestead	Residential	Vacant Land
Agriculture	1.00	0.20	2.00	0.17
Homestead	5.00	1.00	4.00	0.50
Residential	0.50	0.25	1.00	0.20
Vacant land	6.00	2.00	5.00	1.00

Expert 3:

	Agriculture	Homestead	Residential	Vacant Land
Agriculture	1.00	0.17	2.00	0.14
Homestead	6.00	1.00	4.00	0.50
Residential	0.50	0.25	1.00	0.17
Vacant land	7.00	2.00	6.00	1.00

Expert 4:

	Agriculture	Homestead	Residential	Vacant Land
Agriculture	1.00	0.20	3.00	0.20
Homestead	5.00	1.00	5.00	1.00
Residential	0.33	0.20	1.00	0.13
Vacant land	5.00	1.00	8.00	1.00

Expert 5:

	Agriculture	Homestead	Residential	Vacant Land
Agriculture	1.00	0.17	2.00	0.20
Homestead	6.00	1.00	5.00	2.00
Residential	0.50	0.20	1.00	0.13
Vacant land	5.00	0.50	8.00	1.00

Utilities

Expert 1:

	Road	Gas Supply	Electricity
Road	1.00	8.00	3.00
Gas Supply	0.13	1.00	0.25
Electricity	0.33	4.00	1.00

Expert 2:

	Road	Gas Supply	Electricity
Road	1.00	9.00	2.00
Gas Supply	0.11	1.00	0.25
Electricity	0.50	4.00	1.00

Expert 3:

	Road	Gas Supply	Electricity
Road	1.00	7.00	2.00
Gas Supply	0.14	1.00	0.20
Electricity	0.50	5.00	1.00

Expert 4:

	Road	Gas Supply	Electricity
Road	1.00	7.00	2.00
Gas Supply	0.14	1.00	0.20
Electricity	0.50	5.00	1.00

Expert 5:

	Road	Gas Supply	Electricity
Road	1.00	6.00	2.00
Gas Supply	0.17	1.00	0.20
Electricity	0.50	5.00	1.00

Physical-Geological

Expert 1:

	Elevation	Fault line
Elevation	1.00	2.00
Fault line	0.50	1.00

Expert 2:

	Elevation	Fault line
Elevation	1.00	0.50
Fault line	2.00	1.00

Expert 3:

	Elevation	Fault line
Elevation	1.00	0.50
Fault line	2.00	1.00

Expert 4:

	Elevation	Fault line
Elevation	1.00	0.50
Fault line	2.00	1.00

Expert 5:

	Elevation	Fault line
Elevation	1.00	0.50
Fault line	2.00	1.00

Community Facilities

Expert 1:

	School	Healthcare Centre	Bust Stop	Market/Bazar	Park
School	1.00	5.00	7.00	4.00	8.00
Healthcare Centre	0.20	1.00	3.00	0.50	5.00
Bus Stop	0.14	0.33	1.00	0.25	3.00
Market/Bazar	0.25	2.00	4.00	1.00	5.00
Park	0.13	0.20	0.33	0.20	1.00

Expert 2:

	School	Healthcare Centre	Bust Stop	Market/Bazar	Park
School	1.00	2.00	5.00	4.00	6.00
Healthcare Centre	0.50	1.00	3.00	3.00	4.00
Bus Stop	0.20	0.33	1.00	1.00	2.00
Market/Bazar	0.25	0.33	1.00	1.00	2.00
Park	0.17	0.25	0.50	0.50	1.00

Expert 3:

	School	Healthcare Centre	Bust Stop	Market/Bazar	Park
School	1.00	3.00	5.00	6.00	8.00
Healthcare Centre	0.33	1.00	3.00	4.00	6.00
Bus Stop	0.20	0.33	1.00	2.00	2.00
Market/Bazar	0.17	0.25	0.50	1.00	1.00
Park	0.13	0.17	0.50	1.00	1.00

Expert 4:

	School	**Healthcare Centre**	**Bust Stop**	**Market/Bazar**	**Park**
School	1.00	3.00	6.00	5.00	7.00
Healthcare Centre	0.33	1.00	3.00	2.00	6.00
Bus Stop	0.17	0.33	1.00	0.50	2.00
Market/Bazar	0.20	0.50	2.00	1.00	3.00
Park	0.14	0.17	0.50	0.33	1.00

Expert 5:

	School	**Healthcare Centre**	**Bust Stop**	**Market/Bazar**	**Park**
School	1.00	4.00	6.00	5.00	7.00
Healthcare Centre	0.25	1.00	2.00	2.00	6.00
Bus Stop	0.17	0.50	1.00	0.50	2.00
Market/Bazar	0.20	0.50	2.00	1.00	3.00
Park	0.14	0.17	0.50	0.33	1.00

Appendix 2: Factor and Criteria Weights

Factor Weight

Factor	Expert1	Expert2	Expert3	Expert4	Expert5	Geometric Mean	Normalized Value
Land-use	0.52	0.50	0.42	0.50	0.56	0.50	0.50
Physical/geological	0.35	0.35	0.42	0.33	0.28	0.34	0.34
Utilities	0.08	0.09	0.12	0.12	0.12	0.10	0.10
Community Facilities	0.05	0.06	0.05	0.05	0.05	0.05	0.05
					Sum	0.99	1.00

Criteria Weight

Land-use

Factor	Expert1	Expert2	Expert3	Expert4	Expert5	Geometric Mean	Normalized Value
Agriculture	0.12	0.10	0.09	0.09	0.09	0.10	0.10
Homestead	0.50	0.32	0.32	0.32	0.48	0.38	0.39
Residential	0.08	0.08	0.07	0.07	0.06	0.07	0.07
Vacant land	0.29	0.50	0.52	0.52	0.37	0.43	0.44
					Sum	0.98	1.00

Utilities

Factor	Exeprt1	Exeprt2	Exeprt3	Exeprt4	Exeprt5	Geometric Mean	Normalized Value
Road	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Gas Supply	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Electricity	0.26	0.26	0.26	0.26	0.26	0.26	0.26
					Sum	1.00	1.00

Physical-Geological

Factor	Expert1	Expert2	Expert3	Expert4	Expert5	Geometric Mean	Normalized Value
Elevation	0.67	0.33	0.33	0.33	0.33	0.38	0.40
Fault line	0.33	0.67	0.67	0.67	0.67	0.58	0.60
					Sum	0.96	1.00

Community Facilities

Factor	Member1	Member2	Member3	Member4	Member5	Geometric Mean	Normalized Value
School	0.53	0.46	0.51	0.51	0.53	0.51	0.52
Healthcare Centre	0.15	0.27	0.26	0.23	0.20	0.22	0.22
Bus Stop	0.07	0.10	0.11	0.08	0.08	0.09	0.09
Market/Bazar	0.21	0.11	0.06	0.13	0.13	0.12	0.12
Park	0.04	0.06	0.06	0.05	0.05	0.05	0.05
					Sum	0.98	1.00

Department of Physical Geography and Ecosystem Science

Master Thesis in Geographical Information Science (LUMA-GIS)

1. *Anthony Lawther:* The application of GIS-based binary logistic regression for slope failure susceptibility mapping in the Western Grampian Mountains, Scotland. (2008).

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