Improvement of The Management of Public Works Department (PWD) Through Geographic Information System

Project Thesis

by

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The project thesis has been submitted to the Department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology in partial fulfillment of the requirements for the degree of Master of Engineering in Advanced Engineering management.

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Candidate's Declaration

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma

Signature of the candidate

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(S.M. Zulkernine)

This Project thesis titled "***Improvement of The Management of Public Works Department (PWD) Through Geographic Information System***" submitted by S.M. Zulkernine, Roll No. 040008124P, Session April 2000 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Master of Engineering in Advanced Engineering Management.

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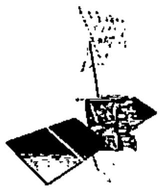

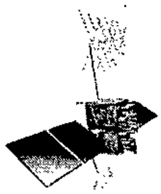

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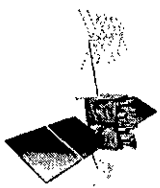

List of Abbreviations and Acronyms

ADP	: Annual Development Program
ACE	: Additional Chief Engineer
BNBC	: Bangladesh National Building Code
CAD	: Computer Aided Drafting
CBA	: Collective Bargaining Association
CE	: Chief Engineer
DOA	: Department of Architecture
DPEC	: Departmental Project Evaluation Committee
ECNEC	: Executive Committee of the National Economic Council
EIRR	: Economic Internal Rate of Return
ERD	: External Relations Division
FIRR	: Financial Internal Rate of Return
GIS	: Geographic Information System
GPS	: Global Positioning System
GOB	: Government of Bangladesh
IMED	: Implementation, Monitoring and Evaluation Department
MOHFP	: Ministry of Health and Family Planning
MOHPW	: Ministry of Housing and Public Works
PP	: Project Proforma
PCP	: Project Concept Paper
PWD	: Public Works Department
PDB	: Power Development Board
RHD	: Roads and High Ways Department
RAJUK	: Rajdhani Unnayan Kartipakhha
T & T	: Telephone and Telegraph
SE	: Superintending Engineer
SDE	: Sub-Divisional Engineer
SO	: Section Officer

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ABSTRACT

Public Works Department is a leading Government Department of the Peoples Republic of Bangladesh which is mainly responsible for the construction and maintenance of the Government buildings. The department is more than 150 years old and has a very good reputation in the field of construction. But in the recent days, this department is loosing credibility to its clients. There are many reasons behind this. But one obvious reason is that the department failed to adopt the new technologies in general and information technology in particular in its day to day operation. This has put a serious negative impact on the confidence of its clients. At the same time the efficiency of work could not be achieved at the desired level.

Under such circumstances, this study has been conducted to find out the problems of Public Works Department and to find out the areas where Geographic Information System (GIS) can be introduced to improve its management.

After an analysis with the help of cause and effect diagram, it is found that followings are the main problems lie with the Management of PWD. Such as improper organogram of the department at the Headquarter level, problem related to Human Resource development, traditional poor communication system, increase in time and cost in implementation of projects and complex departmental rules and regulations. After a detail analysis it was found out that GIS can effectively be introduced in planning of physical infrastructure, in design related aspects, in managing Government Khas Land under disposal of PWD, managing fund disbursement, managing human resource and in case of disaster management to improve the overall management of PWD.

A series of activities have been recommended to introduce GIS in PWD. Such as analysis of requirements, specification of requirements, evaluation of alternatives and finally implementation of the system.

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Chapter 1

Introduction

1.1 Introduction

Bangladesh was under the British rule for one hundred and ninety years. Initially the British rulers kept their public works limited to the construction of their offices and residences for officials, a few roads, military cantonments etc. only to meet their administrative and military need without caring for the benefit of the people and development of the country. For those purposes, Public Works Department (PWD) was created in 1849. Subsequently, construction of limited irrigation and flood control projects, construction of a few roads, construction of railway, ports and harbors etc. came under the scope of works of PWD. With the passage of time and due to phenomenal increase in the volume of works, some separate departments/agencies were created for some of the public works like Flood Control, Irrigation, Roads & Highways, Railway, Ports & Harbors etc.

Public sector has its glorious history in the field of infrastructure development of the country. Since Bangladesh Government undertook many development schemes to restore the infrastructure of the war ravaged country and to create new facilities, public sector played a vital role. Actually just after the blood shading war of 1971, the presence of private sector was insignificant and it was really the public sector who took the lead to rebuild the country. Public sector has a record of constructing a number of beautiful and important works in its book. The Government hospitals, schools, colleges, universities, cantonments, offices and residential complexes, dams, embankments, barrages, sluice gates, railway tracks, roads and high ways etc were constructed through the public sector.

Public Works Department under the Ministry of Housing and Public Works is mainly responsible for the construction and maintenance of Government buildings of all the ministries except a few. PWD, government's biggest construction agency, is a specialized building construction department. It is now mainly responsible for construction and maintenance of government buildings. PWD is headed by one Chief Engineer. Four Zonal Chief called "Additional Chief Engineer" are working in Dhaka, Chittagong, Rajshahi and Khulna. Each

Zone is divided into some Circles which are headed by the Superintending Engineers (S.E) while Executive Engineers work under S.Es in the district level. Now there are four Zones, thirty two Circles and one hundred and twenty eight Divisions.

1.2 Background of the study

Once PWD was the sole construction agency of the Government of Bangladesh. In fact during that time, public sector was the leading the construction of bridge culvert, hospitals, police stations, post offices and many more. Hence the Government departments enjoyed one kind of monopoly in their respective field . But after the independence of the country, the private sector gradually developed and became competitor of the Government departments specially in construction sector. On the other hand, demand of the construction increased many fold in the independent country which became very difficult to manage by PWD with their traditional system and technology. As a result, PWD (the then C & B) was divided into two departments like Building Directorate and Roads and Highways Department. Building Directorate was given the responsibility of construction and maintenance of Government buildings while roads and highways department was responsible for construction and maintenance of roads and culverts. Building directorate was later renamed as Public Works Department (PWD). But even with this divided work load, PWD was struggling to satisfy its clients. In the recent days, PWD is loosing its credibility to its clients significantly. There are many reasons behind it and all those are not within administrative control of the department. But at the same time it is also true that PWD has failed to organize itself in line with the recent technological development. The management of PWD is still dependent on the traditional British system and has seldom adapted new technologies specially the booming information technology. Another reason is the competition of PWD with the private sector. Different Ministries like Ministry of Health and Family Planning, Ministry of Education has began a culture of getting the work done through the consulting firms which gave them prompt services. As a result, several construction cell has been created in several Ministries which are commonly termed as “Mini PWD”. Despite the fact that PWD has two specialized Unit for planning purposes, planning is a very poor sector of PWD due to which many projects has to be revised at the middle of the implementation which increase cost of the project and also delay the completion. Introduction of Geographic Information System can strengthen the planning process and can help in some other area which would help PWD to survive under severe competition. Keeping eye on this, this study has been undertaken.

1.3 Objectives of the study

There are ample opportunities to improve the management of PWD by improving its decision making process with the help of information technology. Thus this project has been designed to explore the opportunities to improve the management of PWD by introducing Geographic Information System.

Under such circumstances the following objectives have been set for the present study. Such as

- To find out the problems of PWD from management point of view.
- To find out how GIS can be used in the department to help in decision making and thus improve the overall management of the department .

1.4 Methodology

To conduct the study at first the problem of Public Works Department was found out with the help of cause and effect diagram. Interview of officers and staffs of different level has been taken to facilitate the process. From Cause and Effect diagram, the areas where GIS can be introduced to improve the management of PWD has been found out. Then detail analysis has been made on how GIS can be used in those particular areas.

Emphasis has been given in finding out the areas where application of GIS can be helpful to improve the management of PWD. The process of application and the technical matters related to GIS software has been avoided as far as possible.

In some instances use of Arc Info and Arc View software have been made to show the use of GIS in a particular field. In such cases imaginary situations have been formulated such as planning of hospitals in town.

Chapter 2

Organizational Profile

2.1 Responsibilities and Functions of PWD:

At present PWD does the construction work of government offices, universities, schools, colleges, medical colleges & hospitals, parks, public halls, supreme court, district courts, residences for all categories of government employees of different ministries of the government. In addition PWD formulates 'Specifications for Construction' and prepares Schedule of Rates which are widely followed by other Govt. departments. In fact,, PWD acts as a Technical Adviser to the Government.

PWD has a team of highly experienced and qualified engineers, diploma engineers and other skilled technical people. The department has in-built Design and Planning Wing and a network of field offices throughout the country. Most of the government buildings in the country built since the British time are maintained by PWD. With architectural drawing prepared by the Department of Architecture and structural design made by the PWD engineers, all construction works are done through contractors.. Only in a few cases, consultants have been engaged for preparing architectural and structural design. PWD has the experience of implementation of challenging projects under difficult conditions. Union Seed Stores in far-flung, remotest and inaccessible areas of the country were built in the early sixties by PWD. In similar fashion, Cyclone Shelters in the coastal belt where there was no virtual communication for men and material were built in the mid seventies.

PWD has till date built government offices and residences totaling approximately 10.20 million sqm of plinth area. It has also built approximately 11,500-flats/houses/single-room accommodation in Dhaka city.

Major functions of PWD can be summarized as below:

- Design and construction of public buildings except those of RHD, T & T and Postal
- Repair and maintenance of Public Buildings
- Construction of National Monuments
- Maintenance of Public Parks

- Construction of Buildings of other agencies on deposit work basis
- Acquisition and requisition of land for construction work
- Valuation of land and property and fixation of standard rent
- Procurement of material and equipment required for construction work
- Preparation of book of specification for Public Buildings
- Preparation of book of schedule of rates and analysis of rates for construction and maintenance of Public Buildings

2.2 Client Ministries of PWD

At present PWD is working as construction agencies of as many as twenty ministries of the Government of Bangladesh. These are :

- Ministry of Agriculture
- Ministry of Establishment
- Ministry of Education
- Ministry of Finance
- Ministry of Food
- Ministry of Fisheries and live stock
- Ministry of Foreign Affairs
- Ministry of Forest and Environment
- Ministry of Health and Family Planning
- Ministry of Home
- Ministry of Information
- Ministry of Jute
- Ministry of Labour and Manpower
- Ministry of Land
- Ministry of Planning
- Ministry of Religious Affairs
- Ministry of Social Welfare
- Ministry of Housing and Public Works
- Ministry of Women Affairs
- Ministry of Law, Justice and Parliamentary Affairs

2.3 Organizational Set Up:`

PWD is headed by a Chief Engineer, supported at the Head Quarter level by 3 Additional Chief Engineer (Civil), 1 additional Chief Engineer (Elect./Mech.), 10 Superintending Engineer,18 Executive Engineers, 44 Assistant Engineers and 40 Sub-Assistant Engineers for planning and design, personnel and establishment, monitoring, organization and management, audit and accounts.

There is one legal adviser to advise the Chief Engineer in legal matters. PWD has field offices spread all over the country. Field offices are divided into civil working units and Electrical/ Mechanical(E/M) working units. In the field there are four zonal additional Chief Engineers in four Divisional Head Quarters under whom there are 22 Superintending Engineers, 107 Executive Engineers, 277 Sub-Divisional Enginers,168 Assistant Engineers and 1307 Sub-Assistant Engineers both for civil and E/M works. A summary of Manpower in PWD is shown in Table-1

TABLE -1 SUMMARY OF MANPOWER OF PWD

Chief Engineer		1
Additional Chief Engineer		8
Superintending Engineer		32
Executive Engineer		125
Sub-Divisional Engineer		255
Assistant Engineer		168
Sub-Assistant Engineer		1347
Legal Adviser		1
Executive Officer (Arboriculture)		6
Sub-Divisional Officer (Arboriculture)		6
Chief Accounts Officer		1
Administrative officer		5
Welfare officer		1
Other class III/ class IV staff		19345
	Total	**21480**

Chapter 3

Problem Analysis

PWD is an old organization of the People's Republic of Bangladesh. It has many good and prestigious work in its book. It has to deal with as many as twenty ministries of the Government. But in the recent days, PWD is loosing its acceptability to its clients and as a result different ministries has set up their own engineering cell. There are many reasons behind this. But it is true that PWD also has got some internal problems. Time has come to identify the limitations and weaknesses of PWD to reestablish its reputation. The Department needs self criticism and take necessary measures to rectify the pros and cons of the management.

In this study, cause and Effect diagram has been used to identify and analyze the problems of PWD so that necessary recommendations can be made to overcome some of those problems by introducing Geographic Information System (GIS).

3.1 Major Problem Area

In cause and effect diagram (Fig-1) , six major areas of problem have been identified. These are :

- Problem related to Organogram of the department
- Problem related to Human Resource development
- Problem related to Communication system
- Problem of increase in time and cost of the projects
- Problem related to Implementation of work
- Legal problem

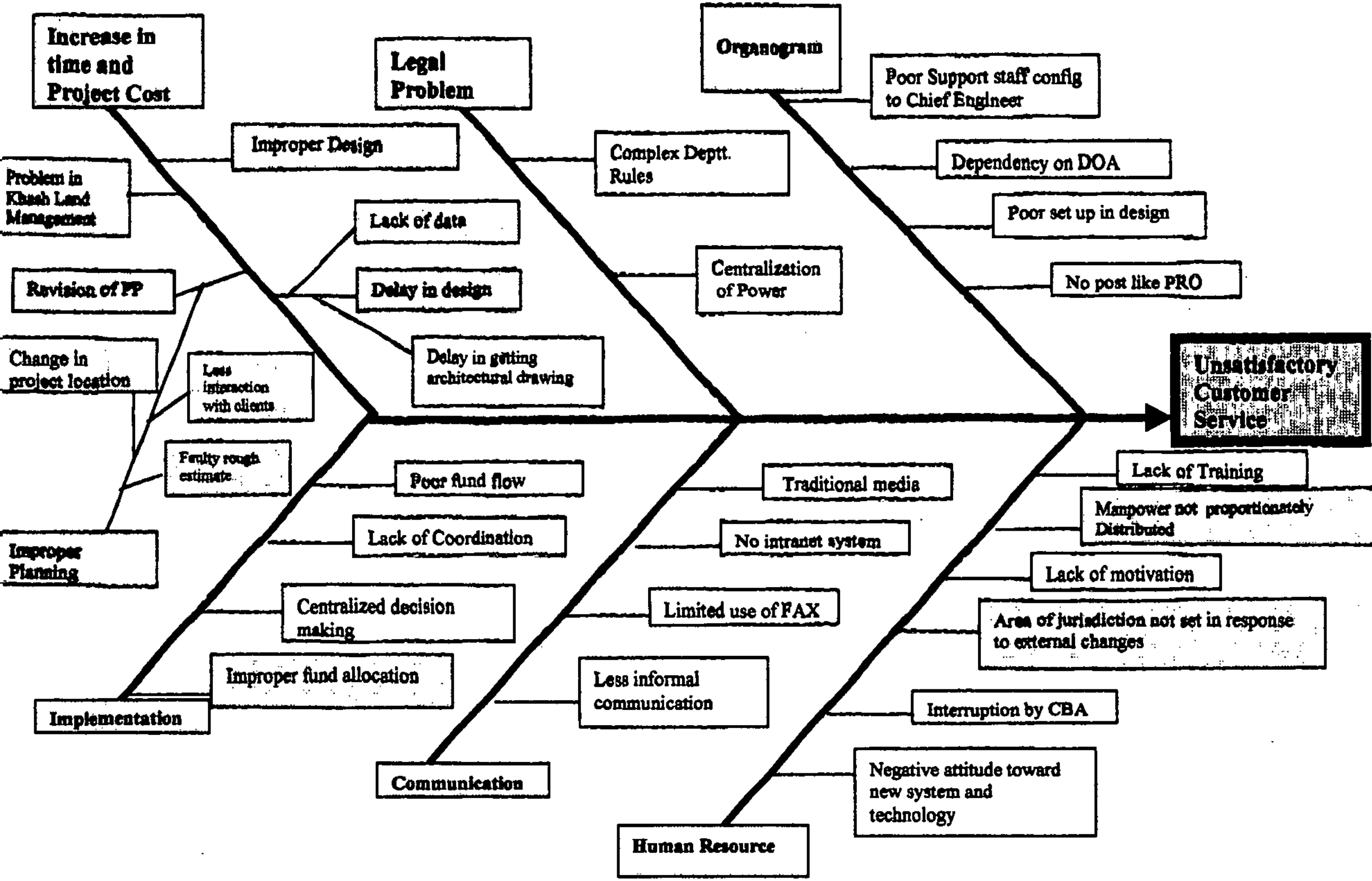

Fig-1 Cause and Effect Diagram

3.2 Problems identified with each major area

3.2.1 Problem related to Organogram

Poor Support Staff to Chief Engineer at Head Quarter level set up :

PWD is responsible for construction and maintenance of more than twenty ministries of the Government of Bangladesh. So the department has to maintain close relationship with its client ministries, has to keep accounts and allocate funds in separate head to the field offices of all these ministries. There are two Superintending Engineers called Superintending Engineer (Development) and Superintending Engineer (Coordination) to help the Chief Engineer in this regard. It is not at all an easy task to do and only two superintending engineer is there to do this job on behalf of Chief Engineer without being supported by any Executive Engineer or Assistant Engineer. Some time it happens that two or three meetings at different ministries is scheduled at the same date and time and it becomes impossible to attend all meetings for one Superintending Engineer (Development) or one Superintending Engineer(Co-ordination). On the other hand, Superintending Engineer (Establishment) has to handle the establishment related work of this huge manpower spread all over the country without being supported by any Executive Engineer or any Assistant Engineer. There is one Health Wing headed by one Additional Chief Engineer (Health) which looks after the works of Ministry of Health and Family Planning. This kind of Ministry Specific Wings for large clients would be helpful to meet customer demand.

Dependency on Department of Architecture:

PWD is dependant on Department of Architecture for the architectural design and drawings. While rough estimate cannot be prepared without the layout plan, detail structural design is also not possible without detailed architectural drawing. It is a common complain that Department of Architecture takes a lot of time in supplying requisite drawings. As the employee of Department of Architecture are not under the administrative control of PWD, the chief Engineer PWD has virtually no control over them. On the other hand, normally DOA does not face the clients directly as PWD does. Hence all the responsibilities and liabilities go to PWD.

Poor set up in Design

Although there are two individual circles headed by two superintending engineers for the design of the infrastructures, there are inherent problem in the human resource set up of these two circles. Each Design circle consists of two divisions headed by executive engineers. But it is actually the assistant engineers who prepare the design. The assistant engineers are most junior officers having very little experiences in many occasions. The main draw backs of this design divisions is that there are no post of Sub-Divisional engineers which is the next tire of the entry level post. The experienced Assistant engineers are promoted into the post of Sub-Divisional Engineers. As there are no post of SDE in the design divisions, the department does not get the service of these SDEs which makes the thing difficult for both the Junior and Senior officers.

No Post of Public Relation Officer

The present age is the age of publicity. One has to have a good marketing policy to sell his product in the market. Although PWD is a Government Department, there are many competitors of it. The client ministries are procuring the service of the consultants and some are creating their own construction agencies. While the external environment is such competitive, PWD does not have any Public Relation Officer who can really help the department by t disseminating the success stories of the department to its clients, to the press and to other stakeholders.

3.2.2 Problems Related to Human Resource

Lack of Training :

Technology changes very rapidly in the present days and it is almost imperative to update the knowledge of the officers after every regular interval. But unfortunately training has been neglected in PWD for long time. The department is almost 150 years old it is a matter of great regret that it does not have any training institute of its own.

Improper Distribution of Staff

The external world is changing very rapidly and every organization has to keep pace with these changes. The scope of work of the Divisions are changing, new administrative units are emerging and nature of work is also changing. The staff deployment should be according to the practical need and scope of work. But in case of PWD, this is a very static process. A dynamic , need based distribution Proper distribution of manpower would not only increase the efficiency of the department but also increase its credibility.

Negative Attitude Toward New Technology

In the present days, there is no alternative to adoption of new technologies. If any organization fails to incorporate this adaptation, the fate would be eventually tragic. The lower and middle class subordinates of the department have a negative attitude toward the introduction of new technologies. There is a fear that they may loose their job if new technologies like computer can make its road into the department. Some time the higher officials also show such kind of attitude which goes against the modernization of the department. As a result, while in all the consulting firms, AutoCAD is being used for drafting, PWD is still using the traditional manual drawing methods.

Lack of motivation among the staff

There is a huge number of officers in PWD who are really deprived of the promotion opportunity. There are various reasons behind this. One of the reasons is that a big number of officers were recruited at a time in the past and most of them are not getting promotion while the batch mate may have been promoted. This has brought in an enormous frustration among them which has become a problem to the Department.

Interruption by CBA

Some time it is very difficult to take administrative action in the Department because of the interference by the CBA. While CBA is to look after the interest of the employees, in many instances, it is being abused for the vested interest of the leaders and some other opportunists. This is also an acute problem for the Department.

3.2.3 Problem Related to Communication System

PWD is still dependant on the traditional communication system. The District Offices are not connected by internet or intranet. Even the use of Fax is limited. Because of the question of responsibility, informal communication seldom takes place. This has been found as one of the bottlenecks of the department.

3.2.4 Increase in time and cost of the project

Delay in Design Divisions

There are only six design divisions in PWD to perform design of the whole country and it is a common complain from the field level officers of the department that they do not get design from the design divisions in time and have to pursue the matter time and again. On the other hand the design engineer often complain about lack of design data both from the field and from Department of Architecture.

Improper Design

Some time design divisions make improper design which leads to change in design during the implementation of the project. This is mainly due to the lack of data specially about the soil condition of the particular site.

Improper Planning

Planning is one of the area which needs sufficient field data and good analytical tools. Good planning a lot of data like subsoil exploration data, data on client availability of different utility services and many more. PWD very often helps the ministries in selecting the site location and prepare the Project Concept Paper and Project Proforma. One of the very important aspect of planning is to prepare a rough estimate of the scheme under consideration. This is the time when a planner not only has to consider the location of the infrastructure but also has to take decisions on the type of foundation and type of superstructure along with other specification. The procedure of getting an scheme approved is that the client ministry requests PWD that they want to establish some police stations or some livestock hospitals throughout the country and seeks help in this regard. PWD then select the locations of those infrastructure in collaboration with the client Ministry and prepares a rough estimate. The rough estimate is sent to the client Ministry who gives administrative approval on the basis of this rough estimate. Then Project Concept Paper id prepared on the basis of the rough estimate which is sent to Planning Commission to be approved by ECNEC. Once the PCP is approved, Project Proforma (PP) has to be prepared within 45days of the approval of the PCP within the same estimated amount. Any change in the estimated amount that is reflected in the PCP/PP needs approval and revision of PP accordingly. This is why preparation of the rough estimate is so important. But unfortunately there are ample example that PWD had to revise the PPs due to the lack of far sightedness . In many instances PP revision is done because of the faulty rough estimate. Some of the causes of revision of estimates are inadequate foundation design (i.e. normal foundation has been provided where a pile foundation was required), change of the location of the site, change in amount due to the cost of utility (i.e. there is no gas line close to the site or the electric line of PDB passes through a far distance which increase the cost in this respect), increase in plinth level of the building as the highest flood level is higher than one considered during the preparation of the rough estimate. As described earlier, this is a field where PWD is under question by every client. The revision of PP not only takes a long time but also put the client in an embarrassing situation.

PWD has two individual circle called project circles headed by two superintending engineers. But PWD does not use any GIS software in selecting the location of a particular site of a project. It has a operational set up in every District and has a huge data about the soil of a particular District Head Quarter. But these have not been used to create a unique GIS database. As a result, after approval from planning commission, site are being changed, foundation of the building are being changed which in tern is increasing the project time and cost and decreasing the credibility of the Department to its clients.

3.2.5 Problem related to Implementation of project

Insufficient and Improper Fund Flow :

The progress of work is very much dependent on the fund flow to the development projects. In most of the cases the client ministries can not ensure continuous fund flow to the projects. As a result the field officials can not pay the bill of the contractors and eventually the progress of work is hampered. It does not only increase the project duration and cost but also hamper the reputation of the department. On the other hand the fund for maintenance of the existing buildings is not properly distributed and as a result the buildings are not being maintained properly at the field level. In many instances no rationale is maintained by PWD in allocating maintenance fund. A GIS data base could be helpful in visualizing the districts where the plinth area is more. GIS could provide some other spatial information which would help the decision making easier.

Centralized Decision Making

Centralized decision making of the Department is also responsible for delay in implementation of the projects. If at any instance, it is felt by the field engineers that the design of the structure is not correct, or some modification is necessary, he is not allowed to do it by himself or by his designates at the field. This decision has to come from the central design division. This takes lots of time and as a result implementation of the project is delayed.

Lack of Co-ordination between PWD and Clients:

As mentioned earlier, there is lack of co-ordination between PWD and the client ministries. Some time there exist genuine causes which hamper the progress of the project. But as the client ministries are not informed of the problem in time, they cannot perceive the situation and this creates confusion and put the goodwill of the department at stake.

No Testing laboratory of the Department

Although PWD is a department of about 150 years old, it is a matter of great regret that the department does not have any testing laboratory of its own and has to rely on BUET , BITs and Polytechnic Institute for quality control. This is also a reason for inferior quality of work in some instances and delay in implementation of work.

Insufficient financial power of the PWD officials

The financial power of the PWD officials is very insignificant comparing to the present day need. For example, Sub-Divisional Engineers are the main grass root level officers of the department and he is responsible for all the petty maintenance of the building under his jurisdiction. But a SDE can approve Tk 100 only for a single voucher. It is well understood that the very insignificant work can be done with this financial capacity.

3.2.6 Legal Problem

Complex Departmental rules and procedures

PWD is an old department having its century long own rules and procedures. But the development perspective has changed many fold by this time. The old rules and procedures only make the things complicated and lengthy.

Chapter 4

Literature Review

4.1 Geographic Information System (GIS)

Historically, maps have been used for navigation through unfamiliar terrain and seas. Within this context, the preparation of maps accurately locating physical features is the primary focus of attention. More recently, however, analysis of mapped data for decision making has become an important part of resource planning. During the 1960s, manual analytical procedures for overlaying maps were popularized. These techniques mark an important turning point in the use of maps- from one emphasizing physical description of geographical space to another spatially prescribing appropriate management actions. This movement from descriptive to prescriptive mapping has set the stage for revolutionary concepts of maps structure, content and use. GIS provide the means for effecting such a transition. In one sense, this aspect of GIS is similar to conventional map processing involving map sheets and drafting aids such as pens, rub-on shading, rulers, plainmeters, dot grids and acetate sheets for light-table overlays. In another sense, these systems provide a vast array of analytical capabilities enabling managers to address complex issues in entirely new ways.

A GIS is a computer system capable of capturing, storing, analyzing and displaying geographically referenced information: that is , data identified according to location. Practitioners also define a GIS as including the procedures, operating personnel, and spatial data that go into the system. The Power of GIS comes from the ability to relate information in a spatial context and to reach a conclusion about this relationship. Most of the information we have about our world contains a location reference, placing that information at some point on the globe. When rainfall information is collected, it is important to know where the rainfall is located. This is done by using location reference system, such as longitude and latitude and perhaps elevation. Comparing the rainfall information with other information such as the location of the marshes across the landscape, may show that certain marshes receive little rainfall. This fact may indicate that these marshes are likely to dry up, and this interference can help us make the most appropriate decisions about how humans should interact with the marsh. A GIS, therefore, can reveal important new information that leads to better decision making.

The various ideas about GIS can be synthesized in the form of three distinct but overlapping views. These can be termed as the map, database and spatial analysis views.

The map view focuses on the cartographic aspects of GIS. Supporters of this view see GIS as map processing or display systems. In map processing, each data set is represented as a map (also called a layer or coverage). The maps are usually held in raster format and are manipulated by a function that might add, subtract or search for patterns. The output from these operations is another map. Topographic and thematic mapping agencies also support the map view and place great emphasis on the ability of GIS to produce high quality maps and charts usually in vector format.

The database view of GIS emphasizes the importance of well designed and implemented database (Frank 1988). A sophisticated database management system is seen as an integral part of a GIS. This views predominates among members of the GIS community who have a computer science background. Applications which record transactions and require the frequent use of simple queries are particularly suited to this approach. Complex analytical operations which require the use of many types of geographical data can be incorporated into this view only with difficulty.

The third view of GIS emphasizes the importance of spatial analysis. This view focuses on analysis and modeling in which GIS is seen more as a spatial information science than a technology (Goodchild 1990). Although current proprietary systems have limited functionality for spatial analysis, it is clear that this is a major development area. This view looks at likely to become the most widely accepted by the GIS community and already it can be used to differentiate between GIS and other information systems.

Although these views of GIS are widely held, few people see them as conflicting. A single system may be viewed in all three ways depending on the perspective of the user or application in hand. Nevertheless, this classification serves a useful function in highlighting the ways in which GIS are used by the GIS community. It also illustrates once again the widespread applicability of GIS and the heterogeneity of the GIS community.

4.2 Maps as DATA:

Spatial analysis often involves large volumes of data. These data are characterized by maps describing both 'where' (the location attribute) and the 'what' (the thematic attribute). Map scale and projection determine the form of coordinates locating landscape feature in geographical space. The features indicate the theme of the map, such as a soil map. Traditionally, this information is identified by lines and shadings carefully drawn on paper sheets. In a GIS, this information is computerized and stored as numbers. It is digital nature of maps that fuels the revolution in map analysis.

Manual cartographic techniques allow simple manipulation of maps, but are limited for the most part to qualitative, rather than numerical processing. Such procedures are severely handicapped and often do not provide the numerical input demanded by the modern decision making models. Traditional quantitative approaches, on the other hand, enable numerical analysis of the data but the sheer magnitude of mapped data becomes prohibitive for practical processing. Most often, decisions are made based on the 'average' slope or 'dominant' soil type occurring over large geographical areas. These simplifying values are easily manipulated with a calculator but gloss over the actual spatial complexity of a landscape. For example, a study area may have a gentle average slope most often containing very stable soil. Under these typical conditions, traditional analysis using the spatially aggregated averages would be free to allocate a lands use generating high surface water runoff. However, scattered throughout the area may be pockets of very steep slopes with highly erodible soils. In these instances, the results could be environmentally devastating- a condition missed by assuming that the average pertain everywhere.

The ability of GIS technology to retain detailed geographical information in characterizing space, termed locational specificity, is a major advantage over traditional numerical analysis, especially when allied to analytical procedures. For example, a set of maps indicating a town's suitability for residential development considering soil types, slopes, wetlands, farmland preservation, proximity to existing residential areas, schools, parks and numerous other factors could be drawn in various colours and subtle hues could be interpreted as a measure of overall suitability for development of all locations within the town (locational specificity). However, the manual approach does not allow for different weights being assigned to various factors (a very realistic decision making condition requiring thematic specificity), such as considering soil type as being twice as important as proximity to existing development and four times as important as the farmland classification. Even more frustrating is that the composites most often results in an unidentified deep magenta almost everywhere when more than a few maps are used.

4.3 Spatial Modeling

GIS system store information as numbers, rather than colours, shading, lines or discrete symbols. A GIS makes it possible to link, or integrate information that is difficult to associate through any other means. Thus a GIS can use combinations of mapped variables to build and analyze new variables .When overlaying a set of maps the values can be summed, averaged, weight averaged, minimized or any other appropriate statistical or mathematical options. The result is new number assigned to each location which is a numerical summary or mathematical function of the conditions occurring at that location on the 'input' maps. Such procedures greatly extend traditional map processing capabilities and provide a sort of 'map-ematics'. Figure-2 shows how over laying of different layers can generate new information and new maps.

As an example, the spatial relationship between roads and timber resources can be rigorously modelled. Traditional timber supply analysis generalizes resources accessibility into a few broad groupings, such as the proportion of trees near roads, set back, and distant. The timber supply is calculated from values describing the typical timber composition within each broad accessibility zones. A serious limitation in this approach is that all tress are assumed to be transported straight to the nearest road. This concept of distance as the 'shortest straight line between two points' is the result of our traditional tool, the ruler-not reality. A straight line may indicate distance 'as the crow flies' but offers little information about the complex pattern of spatial barriers in the real world: such a straight line from a stand of trees to the road might cross a pond or steep slopes (very realistic obstacles that must be circulated by the harvesting machinery), effectively making the distance much greater. In fact, the actual route may be so much further that the tress are economically inaccessible.

Advanced GIS procedures can consider obstacles in computing effective distance and express this distance in decision making terms, such as dollars or gallons of fuel, instead of static geographical unit of meters or miles. The result is a more useful map of effective distance, indicating harvesting cost at each location throughout a study area as a function of landscape characteristics and harvesting equipment capabilities. Such timber access

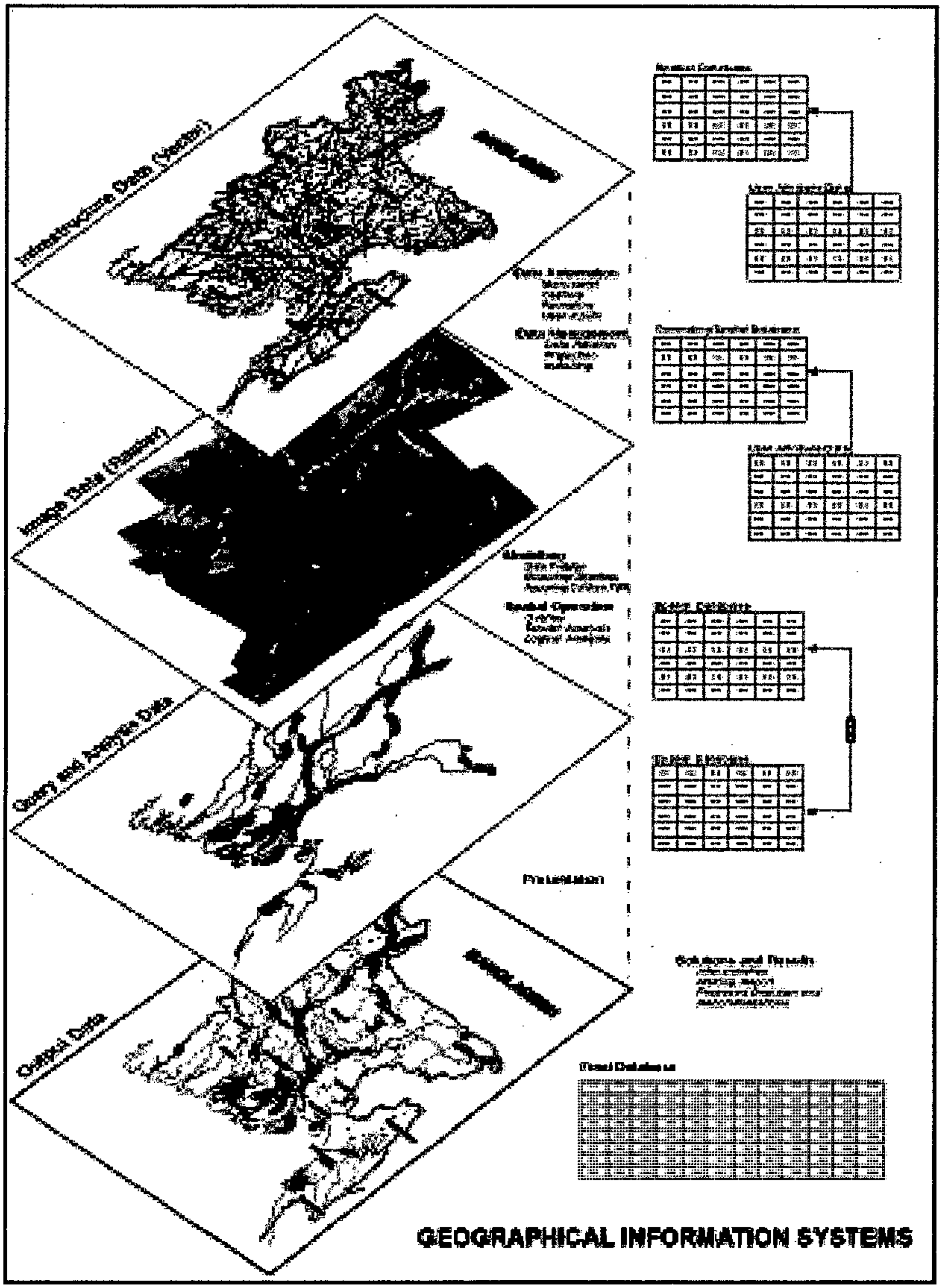

Fig-2: GIS Layers to generate new information

information can be combined with a map of forest cover for new map indicating forest the forest type and harvesting cost combinations throughout a study area- the principal input to traditional supply models, yet now spatially specific and realistic.

It is the combined factors of digital format, spatial and thematic specificity and advanced analytical procedures which form the foundation of computer assisted map analysis.

4.4 Data base development

Since 1970s, an ever-increasing quantity of mapped data are being collected and processed in digital format. Early use of GIS technology required users to become experts in the emerging field and develop their own systems and databases. Their efforts also required large mainframe computers costing hundreds of thousands of dollars, environmentally controlled buildings and a staff of computer technicians. These conditions made GIS non-viable for most potential users. More recently, GIS systems have become available for personal computers with a total investment of less than US $ 5000, with familiar office desktop as the computing environment.

GIS Data Capture Hardware and Software:

The progress in the commercial application of GIS technology is in practice more likely be limited in the foreseeable future by the rate at which GIS database can be populated rather than by shortcomings in the applications software. It is now widely accepted in the literature, and has been apparent for the same time to the practitioners, that the cost of data collection(or data capture) is by far the dominant component of overall GIS project costs. For example, Prof. G. Konecny in his keynote paper to the fourth European AM/FM Conference in 1988 (Konecny 1988) analyzed a range of mature Land Information System projects and concluded that acquisition of data for the database constituted the single largest expenditure element, between 34 and 84 percent of the total cost. The larger the project, the less the hardware and software costs mattered.

Data capture process can be split into two different operations. Such as :

- Primary data collection, for example from aerial photography or from remote sensed imagery.
- Secondary data collection, for example from conventional cartographic sources.

Primary Data Capture:

The introduction of remote sensing, particularly from the early 1970s with Landsat series of land resource satellites, produced a climate of expectation that generalized access to primary data source would be available together with automated techniques of land use and feature extraction. The evolution of hardware and software for primary data collection has been more rapid in the late 1980s. Direct surveying techniques employing in-the-field digital recording, GPS technology for precision positioning and vehicle location tracking are becoming routine tools. (Goodchild 1991). The use of remotely sensed data is gradually offering the theoretical benefits identified in the early 1970s. These benefits are only being achieved by introducing radical change of thinking in the user community.

Secondary Data Capture:

Despite the perceived benefits of primary data, for the immediate future the largest source for GIS data will continue to be existing maps. The most important source of analogue spatial data is the map. Since prehistory, maps have been produced with specific purpose of recording the spatial relationships observed and measured by the map's compiler. Maps are used to convey spatial knowledge to others and to store knowledge for the compiler's in future use (Robinson et al. 1984). Two primary methods of analogue to digital data conversion exist, namely automated scanning or manual digitizing. Manual digitizing requires the operator to generate a caricature of the line, not a precise representation (Douglas and Peucker 1973). This may lead to various complications. Computer –controlled photogrametric devices are another means of transferring analogue data into digital data. Contour lines, spot heights and planimetrically rectified locational data are now as easily delivered in digital form as in the traditional map form (Lillesand and Kiefer 1987). Such systems are usually still under the control of human operators, but research is advancing to remove this bottleneck in data collection (Dowman and Muller 1986)

Different kinds of data in map form can be entered into GIS. A GIS can also convert existing digital information which may not yet be in map form, into forms it can recognize and use. For example, satellite images can be analyzed to produce a map of digital information about land use and land cover. Fig-3 shows a satellite image of Dhaka City from where land use and other thematic maps can be produced. Likewise, census or hydrologic tabular data can be converted into a map form and serve as layers of thematic information in a GIS. A GIS can be used to emphasize the spatial relationships among the objects being mapped. While a computer-aided mapping system may represent a road as a line, a GIS may also recognize that road as the boundary between wetland and urban development between two census statistical areas.

Data Output

A critical component of GIS is its ability to produce graphics on the screen or on the paper to convey the results of analyses to the people who make decisions about resources. Wall maps, internet-ready maps, interactive maps, and other graphics can be generated, allowing the decision makers to visualize and thereby understand the results of analyses or simulations of potential events.

Fig 3: Satellite Image of Dhaka city

Chapter 5

GIS In PWD to Improve Management

5.1 Decision making and GIS in PWD

Decision making is very important for smooth functioning of any organization. The efficiency of the management highly depends on the capability to take the right decision at right moment. Formal analysis of decision making began with the development of operations research in response to demands for rational and analytical decision making during the Second World War (Moore, 1975). Today, decision analysis is treated in a wide range of disciplines, each with its own techniques and focus of study. Generally there are two types of decision making. Such as Prescriptive and Descriptive decision making.

Descriptive decision making have their roots in psychology and sociology and concentrate on the search for reasons for why decisions are made in the manner that they are. For example, one might be interested in why people buy a certain product, or vote for a particular political candidate.

On the other hand, the prescriptive decision making emphasizes the development, evaluation and application of techniques to facilitate decision making (Moore, 1975). This relies on the logic of mathematics and statistics and utilize the concepts of utility and probability to analyze decision problems. The concept of utility relates to the expression of preferences among alternative options while probability serves to evaluate the likelihood of these preferences being realized.

Geographic Information System has made it easier for prescriptive type of decision making. With the development of GIS, managers increasingly have at their disposal information system in which data are more readily accessible, more easily combined and more flexibly modified to meet the needs of decision making.

5.2 Application of GIS in PWD

It is apprehended that introduction of GIS in PWD would help the management to take proper decision and thus increase the efficiency of the Department. While it is not expected that every sector of the management of PWD would be benefited by introducing GIS, there are areas as shown in green colour in the cause and effect diagram (Fig-1) where GIS can contribute to improve the management of PWD which are described below.

a) Planning of Physical Infrastructure
b) Design related aspects
c) Management of Government Khas Land under disposal of PWD
d) Fund Management
e) Human Resource Management
f) Disaster Management

5.2.1 Planning of Physical Infrastructure:

Bangladesh, like many developing countries is a resource hungry country. Its needs are enormous but resources are limited. As such, judicious utilization of resource is of prime importance. The Government of Bangladesh seeks to mobilize scarce resources for obtaining the desired rate of growth through making a National Development Plan. The central Planning Commission makes economic projections, fixes priorities and sets out target for each sectoral activity. But since projects are the building blocks of the National Development Plan, the initial activity with regard to economic development projects and aggregating the same for sectoral output is done at the ministry and agency levels. Public Works Department is one of such agencies. Before discussing the role of GIS in planning new infrastructure undertaken by PWD, it is necessary to have an idea about the planning procedure followed by the department.

There are two major heads of accounts through which development works are undertaken. These are : Revenue Head and Development head. Normally, major works of development are not undertaken under revenue head, unless specially desired by the government. Normally, Planning Commission suggests those projects of value less than Tk. 1 crore should be undertaken in revenue budget. But some time exceptions are made under special circumstances. One special feature of revenue budget is that, the money cannot be carried over to the next year and whatever amount is allotted must be spent with the financial year. Otherwise the fund shall be lapsed and it cannot be utilized in the next year. Repair work under PWD is undertaken through Revenue Head.

Before undertaking a project planning, first comes the project idea, which can be generated from below or stimulated from above. Keeping in view the plan objectives, targets and strategy, a project may be conceived. Field units may come up with such ideas, but it is the job of the ministerial agency planning cell to throw project ideas. These ideas may be rendered into project profiles if they sound attractive and viable. As such the responsibility of preparing PCP, as per rule, lies with the planning cell of each ministry. PWD as an implementation agency of different ministries normally helps the ministries in the preparation of PCP. In other words PWD prepares PCP for other departments and ministries.

Projects under Annual Development Plans is undertaken through Development Head. There are two standard forms of Planning Commission for project planning.

1. Project Concept Paper (PCP)
2. Project Proforma (PP)

For any projects to be undertaken for implementation through ADP, approval of PCP & PP is a must, unless specially authorized by the government. Project Concept Paper was introduced in late eighties by the then government in order to eliminate delay in approval process. Based on preliminary drawings, rough estimate is prepared, which forms the basis for preparation of PCP. Rough estimate is prepared on the basis of PWD Schedule of Rates.

PCP is written in Bengali and has 16 Articles. The articles cover aims and objectives, description of the project, project cost, financing, major components of the project, effect of the project, financial return, employment opportunity, production, environmental impact, recurring expenditure, project implementation period etc.

For projects which are production oriented, or which are expected to give financial return, it is required to calculate Financial Rate of Return (FRR) and Economic Rate of Return (ERR). PWD normally undertakes projects which offer services like housing for government servants, offices, national monuments etc. whose benefits cannot be quantified. As such ERR and FRR is not required for this types of projects.

Approval Procedure:

When the project is approved or accepted for approval by the Planning Commission, the project is included in the ADP of the year and budget allocation is provided for the project. For projects under revenue head, no PCP is required to be prepared. Administrative approval is accorded by the client ministry on the basis of the rough estimate/detailed estimates prepared by PWD. The work can be started as soon as fund is placed in favor of PWD for the work. After approval of PCP, PP is prepared for approval by filling standard form. It is a much elaborate form of physical and financial phasing of each year of project life. Project proforma has as many as 50 Articles, through which an exhaustive and detail analysis of the physical and financial aspects of the project is done.

It is the responsibility of the implementation agency to prepare the PP after approval of the PCP and place it before Departmental Project Evaluation Committee (DPEC) (formation of DPEC is attached as Annex-1) of the client ministry represented by the Planning Commission, IMED, Ministry of Finance, Establishment Division, ERD, client department and the implementing agency. As a rule of the government, PP should be prepared and approval process of a project comes to an end and the project is ready for implementation provided fund is placed in favour of PWD.

If there is a cost over run of any project, revised PP shall have to be prepared and submitted again to the Planning Commission stating reasons for cost overrun and preparing a comparative estimate of the original and revised scheme.

Rough estimate is prepared mainly for taking administrative approval form the client ministry. At the same time it serves as the basis of the preparation of PCP. As the name suggest, rough estimate is not prepared on the basis of engineering tests and analysis but on the good engineering judgement. It is mainly done on the basis of the Plinth Area Rate as described in PWD schedule of rates. But one has to remember that this the cost which is included in the PCP and PP and approval is got on this cost. Any change of this cost needs a lengthy approval procedure which often put the client ministry and PWD in an embarrassing situation.

Normally the following information are required to prepare a rough estimate:

- Apparent soil condition
- Necessity of soil/sand filling.
- Source of water supply and distance of the source form the site.
- Source of power supply and its distance from the project site.
- Source of gas and its distance from the project site.
- Rain water and Sanitation/sewerage system .
- Highest flood level of the area.
- Distance/location of the site from the main road network etc.

Presently arsenic in the tube well water is major threat to health and this needs to be taken care of. Before finalizing a project, necessary information on arsenic contamination of ground water should be collected and necessary mitigation measures should be incorporated. A map showing the arsenic contaminated Upazila is shown in Fig-4.

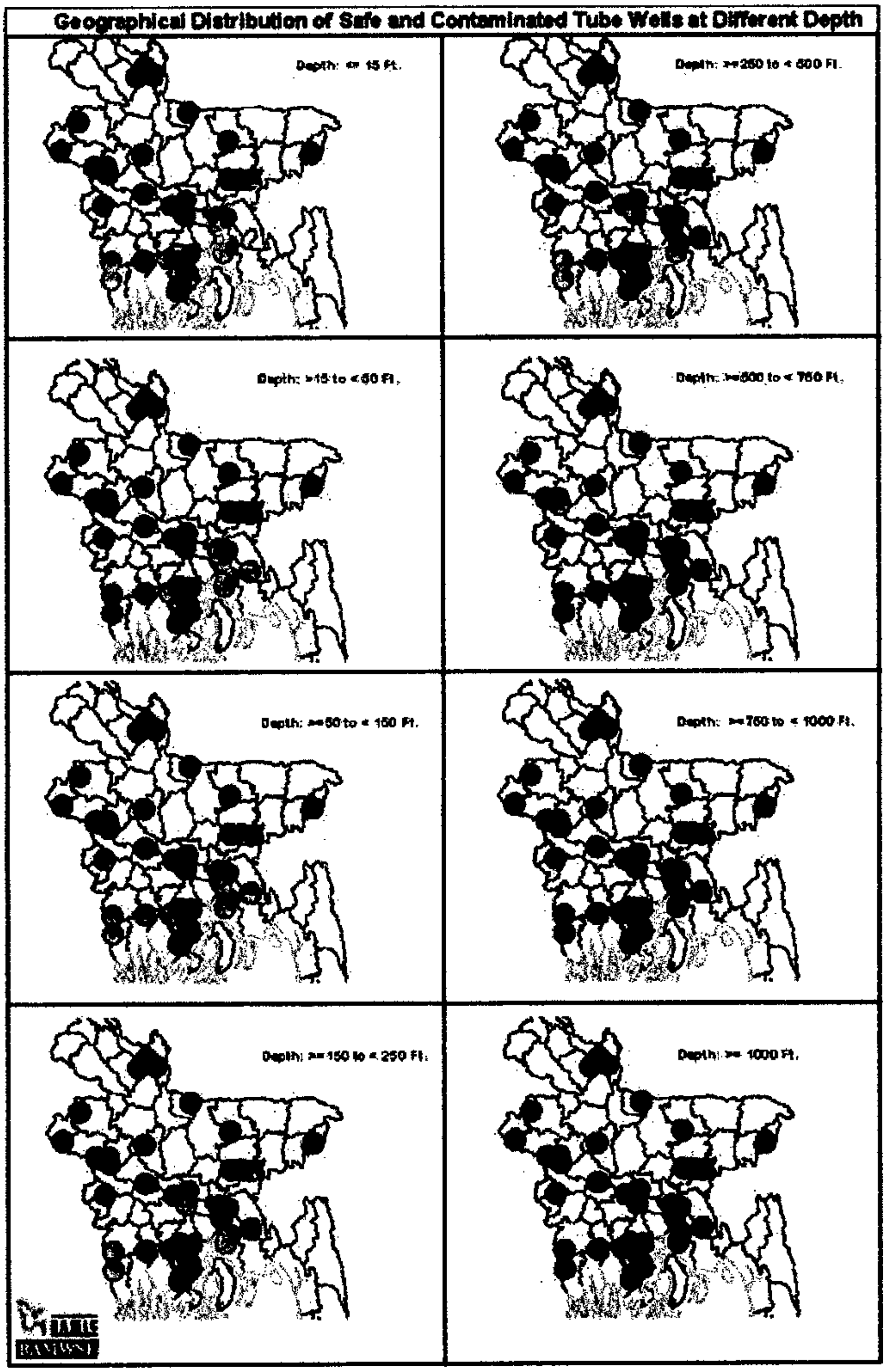

Fig-4: Arsenic Contamination in Ground Water

Source : Bangladesh Arsenic Mitigation and Water Supply Project

GIS can play a vital role in planning infrastructure and preparing a good rough estimate. PWD has two Circle for planning purposes called Project Circle-I & II. All the project proposals are prepared through these two circles. There are four Divisions working under these two Circles. These planning circles provide technical assistance to all the client ministries to undertake development activities throughout the country and prepare the project concept paper on their behalf. This is a field where GIS can be of great help.

Through GIS it is possible to find out a good piece of land for development by using the overlaying technique. Land already developed can be identified in the maps. Lands constrained for different reasons such as environmental reasons can also be identified. Flood areas, steep slopes, publicly owned lands, areas of endangered species, riparian habitats, transmission line easements, airport noise contours and land set aside for future freeways all limit the type and amount of land development which may occur in given area. Overlaying one map layer to another ultimately enables to find out the desired output.

PWD is responsible for construction of large hospitals, police stations, fire stations, Jails, Parks and lakes in the major city and many more. A brief description is presented here on how GIS can be used in planning these infrastructures.

Planning for a new Hospital :

Rapid population growth has lead to increasing demand for public services. One of the most significant of the public services is health care. The selection of a hospital location is a crucial decision to be made as the wrong location may mean that the hospital is not utilized to it's fullest potential. Such an occurrence would represent a tremendous financial loss to the government who funded the project as well as various costs to the public. Such costs to the public include not only service costs or market costs, but also 'accessibility' or 'convenience' costs that the individual incurs to obtain the service (Slobod & Sonenblum, 1971).

A simplified approach to planning public health has previously been lacking. GIS is one of the newest and most effective methods available to help analyze and organize all of the complex information needed to properly site a location. It is certainly not limited to health facilities, as it can be applied to various location applications. The use of GIS has accelerated in the past decade, moving from basic mapping to a more integrated analysis of land use types, human settlement patterns and human movement trends (Huber and Schneider 1999). GIS is most advantageous when dealing with multi-variables and the consideration of differing criteria as it has programs which allows for the weighing of value for criteria and thus allows the user to decide on the best location quickly and effectively. Previous methods such as surveying and air-photos, were quite time consuming, and were unable to process all of the varying factors together.

PWD is responsible for construction of large hospitals in the country specially in the capital city and District towns. But the planning process of the construction of a new hospital at a new location is still done without having much analysis. GIS can be used very effectively in such cases.

There are many variables in the selection process of the location of a health facility. These issues include the optimal location of hospitals and clinics, the relationship between existing locations and health care needs, and the assessment of facilities accessibility. The planning of any health care system should have answers to the following important questions: What are the population needs for health care and how should resources be allocated to the population they are designed to serve (Gatrell and Senior, 1999).

GIS can assist in finding comprehensive answers for the proceeding questions. For example, Jonhs and Bentham 1995 have used GIS to test for a relationship between health outcomes and accessibility. Forbers and Todd, 1995, have also used GIS to evaluate the potential locations for a new radiotherapy unit for cancer treatment in northwest England.

Finding the best location for a health care facility is considered as one of the health authority task in order to optimize resources. The best location for a facility can be identified using for example location - allocation models that are now been integrated to the modern GIS softwares such as Arc info Version 7.

Evaluating the accessibility of existing health facilities is also another task carried by health authorities. Hear the health planners determine the areas, which have poor accessibility for certain health facility and then prepare proposals for improving such low level of health care accessibility. One way of improving such accessibility is by increasing the capacity of the related health facility, but this can only be achieved after intensive analysis of the area that contain such a facility.

In order to evaluate the existing location of a health service or to prepare a new site location, health care planners have to collect large set of data that then can be used for the relevant Health care issue. There are several ways of classifying this type of data, but one method is based on the GIS data format types, i.e. dividing the health data into three main groups which are point, area and line data.

In a GIS, point data can be a model for the locations of residences, hospitals or ambulance stations. Each one of the point data can have different attribute information. For examples the locations of individuals might include attributes for the presence or absence of a disease, age, gender, occupation, and so on.

Population zones or census data on the other hand are examples of area data format which can be captured and stored in GIS and can be used for different health care studies. For instance census data can be used to analyze the socioeconomic status of certain patient locations. Finally, line data such as road network are used in GIS to study the travel journey to and from health facilities locations. They are also used to analyze the routes used by emergency vehicles and to identify how fast do ambulance vehicles reaches to patient locations.

Here we can site an hypothetical example on how GIS is used to analyze accessibility to hospitals in a City called "A". There are three important factors that affect the level of accessibility in any facility location. These are the capacity of the facility, the amount of demand for such facility, and the transportation network that communicate such demand to the relevant capacity. Let us take an example where all these three factors have been considered.

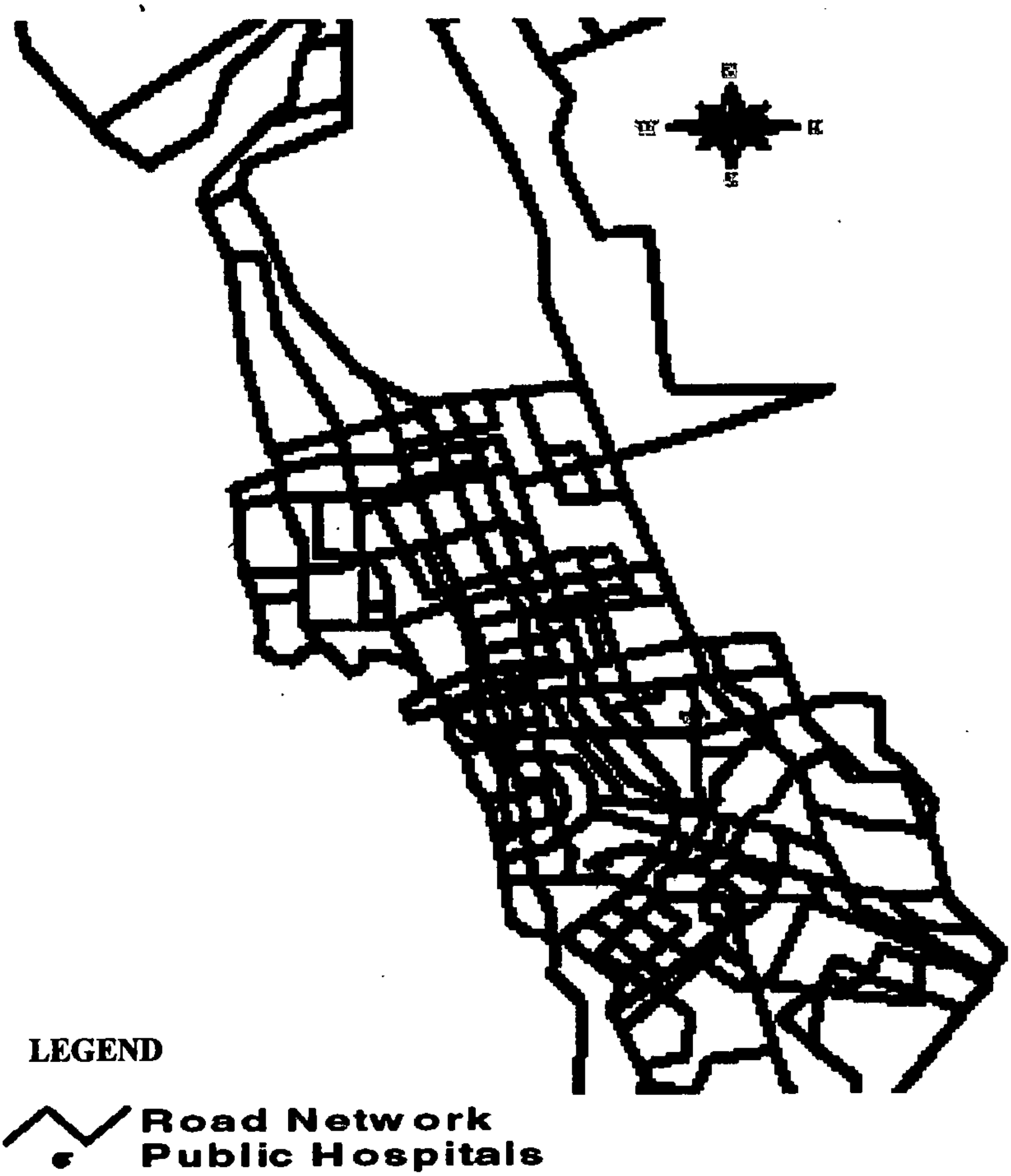

Fig-5 : Location of Public Hospital in the proposed city

In order to explain this application, large set of data has to be collected which are then to be entered into the GIS to form the database of this application. This means that all of the collected data may be in a paper format, i.e. they are not digital. Accordingly, all of the collected data have to be entered into the GIS using the digitizing method. Let us assume that three major maps (GIS Coverages) has been captured and then added to them their relevant attribute (non-spatial) data. These coverages are the road network, the hospital locations and the population coverage. (Figures 5 and 6). The nonspatial data which are linked to those coverages include the hospitals size (capacity), no of people lives in each ward of the city, and the population density of these wards. All of these data are then used for the modeling process of hospital accessibility.

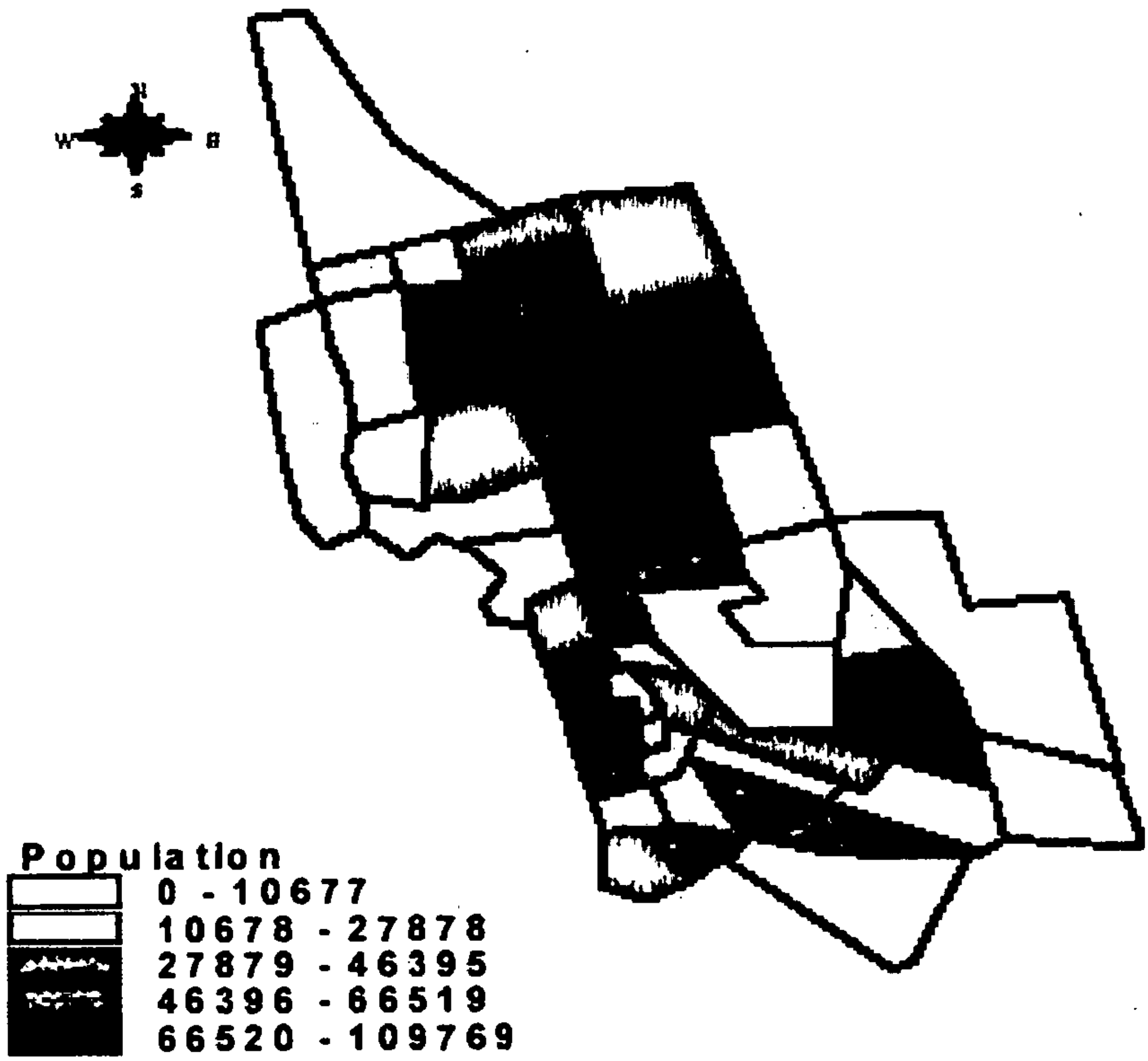

Fig-6 : Population Distribution of the proposed city

Once the required data have been captured into the GIS, then the following step is to decide about the relevant analysis methods that may be used for determining hospital accessibility. There are three main GIS spatial analysis functions that could be used for analyzing the accessibility of any selected facility location. The first one is known as buffer analysis which draw buffer around existing facilities proportional to the latter's size and capacity (Davis, 1996). The second method is related to the GIS network analysis module where population in a network is allocated to the nearest facility locations. Site suitability analysis is the third GIS function that identifies sites according to the suitability for the location of facility under a set of certain (ibid.). Looking at these three GIS functions, the present study has selected the second method that is the network analysis module as the analysis tool for determining hospital accessibility in the city A. The main reason for this selection is that hospital demand can be included in the network analysis functions while it is not possible to do so by using buffer or suitability analysis functions. In most GIS softwares, the network analysis module consists of several modeling functions including finding shortest path, service area model, allocate model, location - allocation model and spatial interaction model. Let us consider the service area model that is one of Arc view (a GIS software produce by ESRI, USA) network analysis functions for evaluating hospital accessibility. This function can find the accessible streets within certain distances of a site and accordingly the streets which are not selected by this function are representing the problem areas i.e. they have poor accessibility (ESRI, 1997).

Let us assume that Ministry of Health and Family Planning (MOHFP) has defined a set of criteria for the planning of hospital locations. These criteria are selected and applied on every hospital in the city under consideration in order to evaluate their locations and accessibility. Let us consider the Public (governmental) hospitals only as the main provider for hospital care in the city and also for the fact that private hospitals have different planning and management process that can be analyzed by separately.

Suppose MOHFP criteria for hospital planning indicates that each service should cover a 4 km catchment area with a population capacity of 60,000 or 2.5 beds per 1000 persons. These criteria are applied on every hospital using the service area function of Arc view software. The output of the function is a network coverage showing the parts of the city that are within 4 Km at catchment area (Figures 7 and eght).

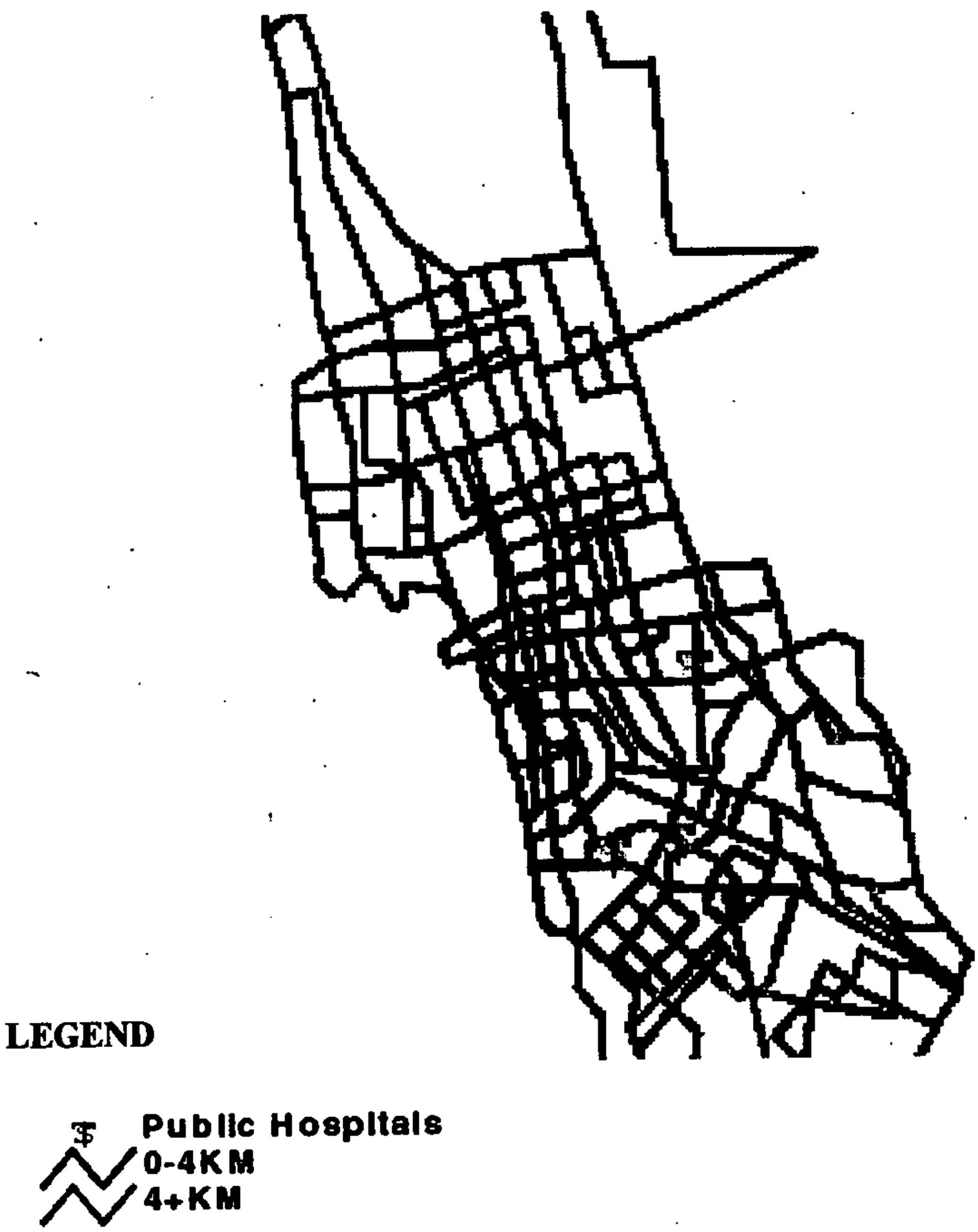

Fig-7 :Public Hospital Accessibility

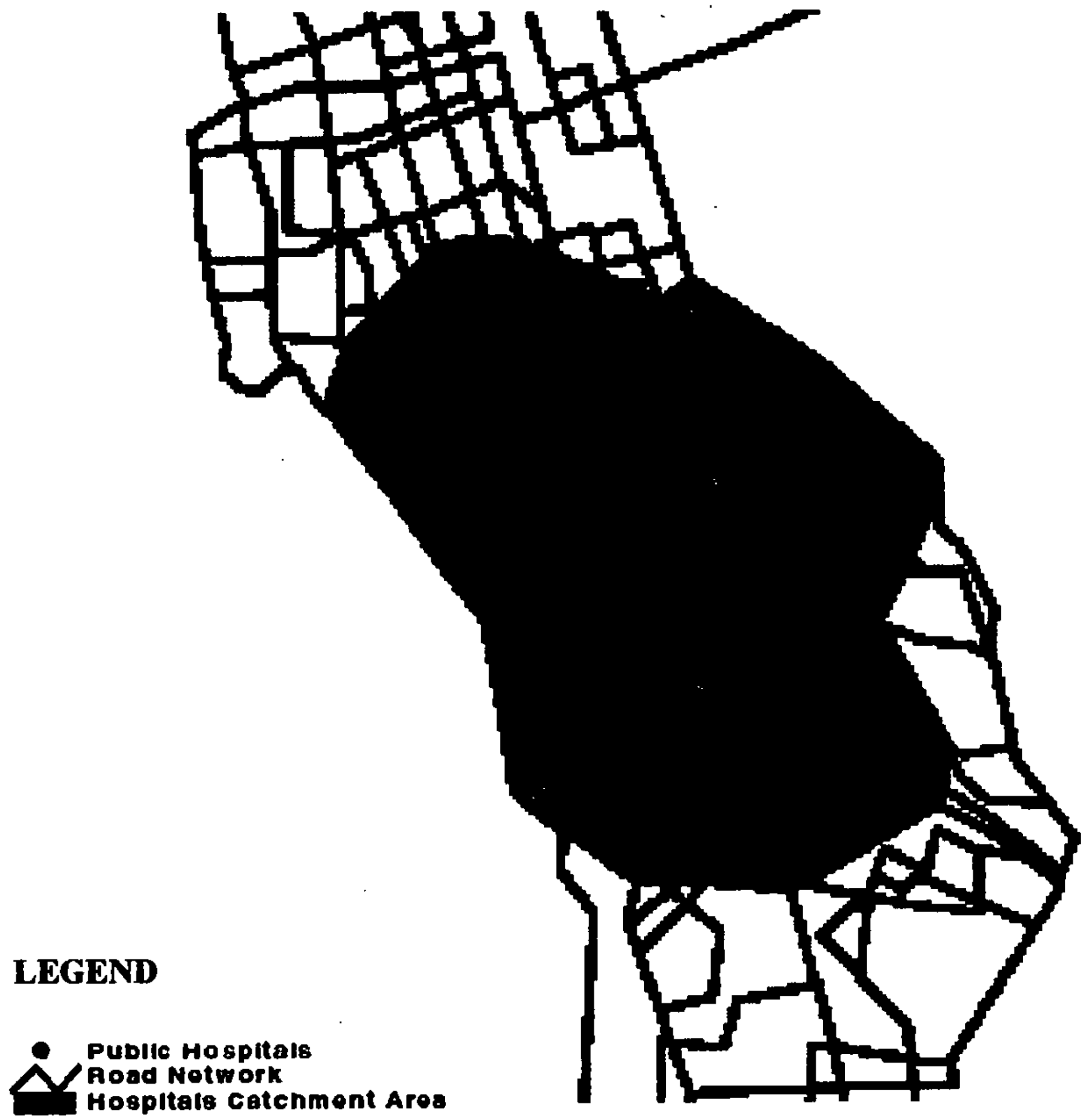

Fig-8 :Public Hospital Service Area

It is clear from this figure that the northern part of the city is located outside the hospital catchment area. This means that the existing hospitals are not serving the whole city, and there is a large part of the city, which is based on MOHFP criteria, is not within the hospital catchment areas.

The next step of the analysis is to define the size of demand within each hospital catchment area. This step will identify how many people be served by the existing hospitals, and the no. of beds that should be provided by each hospital. Relating hospitals demand (D) with hospital capacities is calculated using the following formula

$$D = P \times a$$

Where P = the total no. Of people living inside hospital catchment, and a = 2.5 / 1000 person

Table 2 *Results of 4Km Hospitals catchment areas.*

Hospital Name	Hospital capacity (Beds)	Population within catchment area, P (assumed)	Catchment area	Hospital Demand (Beds)
H1	1001	389800	4 Km2	974.5
H2	442	461520	4 Km2	1153.8
H3	143	669200	4 Km2	1673.0
H4	294	643160	4 Km2	1607.9
Total	1880		16 Km2	5410.2

Using Arc view select by them function, we can define the size of people that lives inside each hospital catchment area. Theoretically, all of the people living inside these catchment areas should have free access to hospital care, but practically this is judged by the capacity of each hospital. Accordingly, if the size of demand of any hospital catchment area is more than the hospital capacity then the problem of service shortage will appear. Table 1 shows the results of this application, which are mainly as following:

1. Existing hospitals capacity are greater than MOHFP criteria e.g. H1 Hospital is serving 389815 people where the criteria define hospital size by 60,000 people.

2. The size of demand within each hospital catchment area is more than hospital capacity. For example, H4 Hospital capacity is 294 beds while its demand is 1608 beds.

Accordingly, it can be said that there is a great need to increase existing hospital capacities in order to overcome their existing supply shortages. The resulting shortages also clarify, why private hospitals are distributed at all parts of the City.

Thus information technology in general and GIS in particular can help PWD and health authorities to make their required jobs in an efficient manner. For example GIS can be used to support health planners in reaching a decision regarding increasing hospitals capacities. The present example has illustrated how GIS has been used for health care facilities planning for the proposed city. This application has identified the parts of the city, which require more attention regarding their health care supply. Using this application, health planners can allocate areas of the city which having poor accessibility to hospitals and a decision regarding improving hospital accessibility can be easily and quickly reached.

One can have the Population map, the map of the existing hospitals with the area of influence and a map on the disease proneness of each of this districts. Then by analyzing these maps, one can get the most suitable location of setting up a new hospital. Similarly the location of a new trauma center can be found out by combining a road network map and the accident proneness of the locations. These type of analysis give the rational to planners and the policy makers and helps the nation as well.

Planning for a new fire station :

PWD is responsible for the construction of the fire stations throughout the country. It can make significant contribution in selecting the location of a the new fire stations and help Department of fire defense which is one of the big clients of PWD. A detailed study can be undertaken to analyze the location of the existing fire stations throughout the country and identify the needs of new fire station and select the suitable locations in this regard. The road network of all the major cities and upazillas will be necessary (most of which are available) for analysis. It will contain geographical coordinates defining the location of road segments including the street name, address etc. Attribute would contain maximum speed possible in each road and an impedance value showing the travel time in seconds for fire equipment to drive from one end to the other. If we have the map showing the population of each area and a map showing the number of fire occurred during the last five years and also have the street network of the area having the above mentioned information, we can very rationally select the location of a new fire station to be constructed on an urgent basis. A more detail analysis can be undertaken for the major cities like Dhaka, Chittagong, Khulna, Rajshahi, Barisal and Sylhet. In these cases, detail city map can be used to locate the important installation, population density and other parameters.

Planning for New Government Housing:

Out of approximately one hundred thousand government employees in Dhaka city, only 11% could be provided with government accommodation. Since the rent of private houses is very high compared to their income, rest 90% of the Government employees either somehow manage to rent private houses spending lion's share of their salary on house rent or keep their families away in the village homes for years together. Moreover, the rent hike of private houses does not keep pace with the salary increase of the government employees. So it is a foregone conclusion that more houses should be built for Government employees.

With vast experience of building residences for government employees and with a team of highly skilled engineers and technicians, in-built Design and Planning Wings etc. PWD can build houses on massive scale for all. Establishment of National Housing Authority is in the offing which will felicitate construction of housing for all. PWD can play a very active role as the construction agency of National Housing Authority for construction of houses.

The average cost of building a house is Tk. 8000.00 per sqm and considering average size of a flat 80 sqm the cost of building one flat come to Tk. 640,000.00. This means a huge investment in the housing for government employees or housing for all which the Government cannot afford. **However Article 5.7.6 of National Housing Policy-1993 (revised in 1999) , adopted by The Government of Bangladesh states that-** Government shall "Undertake construction of essential housing facilities for public servants *in locations where housing facilities in general are scare. Wherever available, houses/flats may be constructed in the vacant spaces of the plots/houses of the existing Government housing colonies and the abandoned properties (Reserve list) or by demolishing the old decaying houses thereon.* Special projects will be undertaken to provide houses to the government employees on hire purchase system. The Public

Servants who are not provided with government accommodation would be given reasonable house rent support. The existing house rent ceiling would continue with adjustment of price escalation factor from time to time".

Suitable location for such housing project can greatly be facilitated with the help of GIS as discussed at the top of this section.

Flats or high-rise residential buildings are essential for the residential purpose of a modern city. But there should be some regulations on the constructional activity of flats and zones of potential areas shall be delineated. GIS provides a very efficient tool for doing this delineation. An example is presented on identification of suitable sites/areas for constructing high-rise residential buildings in a hypothetical City. It is done by applying various conditions on different data sets of the city in the GIS environment of ARC/INFO. The suitable areas are again prioritized based on the residential density. The example demonstrates the use of GIS for the efficient and effective utilities development planning of a city.

The developmental process of a city with far-reaching physical, social and economic consequences has impact on the community. This definitely calls for a dynamic planning support system that ensures efficiency in data handling, processing and presentation. In fact GIS has provided a strong tool for preparation of a variety of thematic maps to support the development plan proposals as well as present such proposals in a visual form which is more comprehensible for people, planners and developers. The use of GIS and Remote Sensing techniques is now gradually picking up in all the sectors of human life.

The high rise residential buildings or flats are essential for residential purpose in most of the modern cities since the flats save the space of ground, cost of construction, cost of infrastructures and cost of utility services. The site selection of flats in a city is very crucial when economic activities can be related to the spatial location of residential flats in terms of money and vice versa.

The strategic locations of flats facilitate easy traffic of people from home to work places, avoiding wastage of time, money and energy and have minimum impact on the economic base (resource base) of the city. So there shall be some regulation on the constructional activity of high-rise residential buildings (flats). Zones of potential areas shall be delineated and GIS (Geoinformatics) provides a very efficient and fantastic tool for doing this delineation. The analysis capability of GIS can be streamlined for this purpose. "Narrowing Down the Area of Interest' by applying various conditions is a very relevant method in GIS for selection of suitable (potential) sites. GIS also provides a platform where various types of data and themes can be integrated together and get analyzed to derive the fruitful output.

Let us consider a city for an example for the suitability analysis based on multi-data. Suppose a Ward is taken as the basic spatial unit and existing high-rise residential buildings located in the city map serve as a database. This example would help to integrate statistical as well as graphic data from various sources (Water Authority, Census Departments) and to organize systematic GIS-based information system for the Master Plan of the City.

Suppose the city consists of 50 wards with a total population of 5,23,733 as per the 1991 Census. The area is primarily a service area with more than 30% of the total workers are office workers. Land use refers to the spatial distribution of city function. The predominant land use is residential. There are 4 zones for the present water supply system. The city underground drainage scheme is designed to serve the population with 5 blocks, namely, A, B, C, D and E. From these blocks the sewage is being drained into a pumping stations and then to the treatment area.

Let us consider that we want to identify the spatial distribution of existing high rise residential buildings (flats) and to identify suitable/potential sites for constructing high rise residential buildings in the city, optimizing the resources, infrastructure, networks thereby eliminating the imbalance in the future population distribution

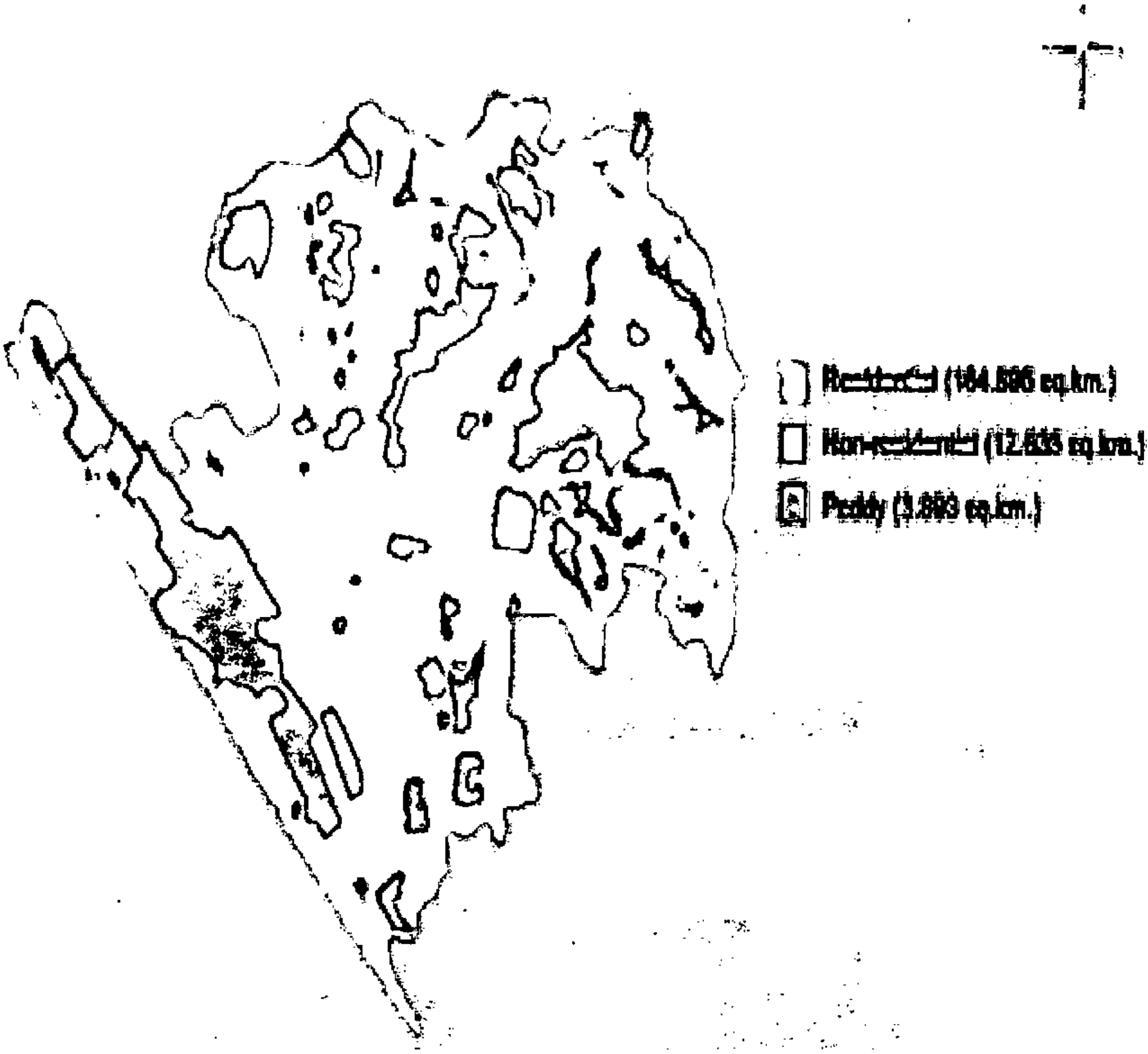

Fig-9: Land use map of the city under example

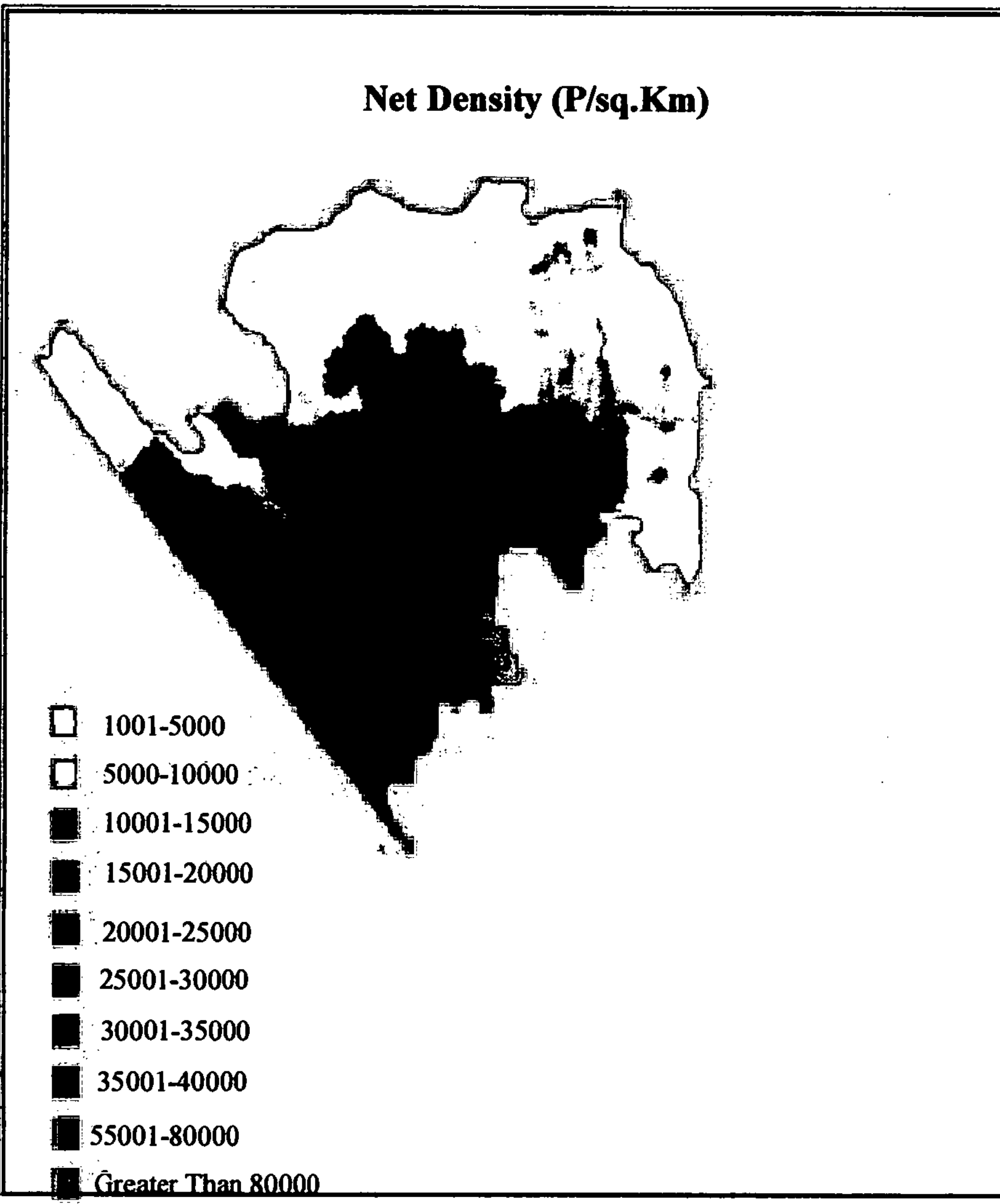

Fig-10 : Net Population Density of the city under example

For analysis purpose, we need data collection or acquisition, data preparation, data input, data editing and verification, storage and management, analysis and output presentation.

The analytical procedures in the GIS environment can be used to arrive at the objectives of the study. Various conditions are applied on the GIS database by executing various analytical tools in the software. The conditions set are.

1. Preferred land use in residential.
2. Sites having low net density.
3. Sites beyond 100 meters from rivers, 50 metres from canals.
4. Site within the areas partially covered by the existing sewerage system and within areas to be covered by the new sewerage system.
5. Sites within the areas covered by Water Supply Zone-1 and Water Supply Zone-2.
6. Sites beyond 250 metres from railway line .
7. Sites beyond 500 metres from City-Bypass,
8. Sites outside CBD
9. Sites beyond 500 metres from the seashore

To apply these conditions on the data, the analytical tools available in ARC/INFO can used. The tools are UNION, INTERSECT, ERASE, BUFFER and RESELECT. The analysis takes the criteria that the net density is a factor that determines the potential sites, since the net density of above 30,000 persons/sq.km creates over crowding.

Then an item called suit_class is added to the attribute table of the resultant coverage to prioritize suitable areas. Areas having net density>1000 and <7501, net density>7500 and <15001 and net density>15000 and <30001 are selected with adding suit_class values 1, 2 and 3 respectively (to represent 1st priority, 2nd priority, 3rd priority) using RESELECT to get the final map. Finally a reclassification of flats based on the number of floors is done.

The tabular Analysis commands such as 'RESELECT' 'ASELECT', 'STATISTICS' are used in TABLES to select features based on attribute values and command 'CALCULATE' is used to calculate new attribute values. The final layouts for printing are created in the ARCPLOT Module. Presentation can also be prepared in ArcView GIS as a project with different views, tables, charts, and layouts. The project also incorporates the real images of some of the existing flats using the tool 'HotLink.'

As a result of the analysis, the final suitable sites for the construction of flats are identified priority-wise based on the net density criteria. The resultant graphic data provides vast scope for applications in zonal regulations, planning, monitoring, area calculation and length calculations. As any information system, GIS gives provision for constant update of the data. The analytical output could be updated either by ground surveys or by aerial photographs in terms of graphic elements. The computerization of graphic data made the area calculation relatively accurate compared to the calculation being done manually. To arrive specific information such as cadastral information, property assessment, consolidation of land and redensification etc this analysis is much useful.

Disproportional development may cause rapid conversion of agricultural land/paddy fields/open spaces. To end this process this spatial analysis is to be used as a tool to establish a relationship between population, occupation and the location of activities with demand for space. The following policies can be adopted.

- Priority areas identified in accordance with their net density ranges shall be the centres of redensification.
- Within the priority areas, availability of land, costs of land etc have to be considered further to promote the construction of flats.
- High-rise residential buildings zone thus evolved shall have direct impact on urban sprawl.
- Control measures have to be enforced to control the growth of flats in high-density areas.

GIS will be able to take care the location of the commercial zones, location of hospitals and other facilities and find out a buffer zone for best suitable location for a new Government housing. First a map showing the location of the Government offices, hospitals, clinics, markets and educational institute would be necessary. Information regarding Government Khas land with all its attributes and characteristics will be in another layer. Then buffer zone around Government

Offices and other facilities can be drawn which can enable some one to see which Government khas land falls within the common zone i.e. within the influence area of all the above functional area.

Planning for a new police station:

Ministry of Homes is a big client of PWD. All the infrastructure of this ministry are constructed by PWD which include Police Stations spread over the whole country, police hospital, police head quarters, residence of the police officials and many others. Introduction of GIS can play a vital role in planning these infrastructure more rationally. For example, suppose Ministry of Homes want to construct some new Police stations. As the resource is scarce, it is not possible to construct police stations at every potential places. Then comes the question of priority. Here PWD with the help of GIS can guide its client. If we have a crime occurrence map, a population map and map of the existing police stations with their area of influence and if we superimpose all these maps, we will get the locations of the most suitable locations (it can be Upazila) where police stations should be constructed on an urgent basis.

Planning for a new jail:

Normally Jails are constructed on Government lands if available. GIS can give spatial information on the availability of such a piece of land as described earlier. Moreover the planner would have the option to perform spatial analysis on the location to combine it with other socio-economic data, communication system with other Districts, Area of influence etc. Jails should be constructed keeping eye on some demographic and socio-economic factors . Among others, the important ones are population of the influence area, frequency of occurrence of crime within the area of influence, existing road network, connectivity of the area with other Districts and Upazilas etc. If we have digital maps containing these information, we can analyze these maps with the help of GIS software to get a basis for the capacity of the jail, most suitable location of the jail and other desired information.

Planning for National Monuments:

PWD is responsible for construction of National Monuments on the Bodhhya Bhumies and other place of National importance. The national monuments at Savar, National Shaheed Minar, Rayer Bazar Bodhhya Bhumies are a few structures which were constructed by PWD and are being maintained by this Department. If we have maps showing the location of the Bodhhya Bhumies and can indicate the locations where a monument has already been constructed, we can easily find out the places where a monument is yet to be constructed. This type of information is very often sought by the concerned Ministries and still PWD has to rely on the traditional source of information.

Planning for new parks and lakes:

The city population is expected to rise to 17 million by 2020. Apart from the residential zones created by RAJUK (Uttara, Gulshan, Banani, Baridhara), PWD (Dhanmondi Residential Area) and Housing and Settlement Department (Lalmatia, Mohammadpur, Mirpur), most other parts of the city have gone through an unplanned urbanization with narrow lanes and utterly lacking in civic facilities such as parks, empty spaces, community centers etc. Those areas are becoming concrete jungles with high rise buildings. As per the Rules of Business of the Government of Bangladesh, PWD is responsible for the maintenance of public parks. The Ramna park, Sahrowardi Uddyan, Chandrima Uddan- all these large public parks are made and being maintained by PWD. PWD has the opportunity to give advise to the Government to increase the number of public parks and probable location of those which can make its proposal justified with the help of GIS. With GIS, one can see the location of the existing parks and also see the Government Khas lands still available in the cities and can also see the locations of the other features like road network, hotels, environment pollution sources etc. This not only would increase the credibility of the department but also would help the city dwellers to get parks at the right places. This would have contribution to the enhancement of the physical environment of the cities. The satellite imageries can be very effectively used in this respect (Fig –3). A land use map can be derived from this kind of imageries as shown in Fig-11.

Planning for Cyclone shelters:

In the past, PWD constructed a considerable number of cyclone shelters in the remote places of the country. But the location of those cyclone shelters were fixed without any analysis. It is now the demand of the time to fix the location of the cyclone shelters keeping eye on the existing utility services, the mode of communication available at every cyclone/flood prone areas and the number of people going to be affected in each area. Scarce resource can only then be spent rationally on propriety basis. All these can be done with the help of GIS. A project can be undertaken in this respect. An extensive survey will be necessary to collect data on flood/cyclone in each Upazila. Data like highest flood level, mode of transport available during flood and during normal season, available high land like dams, embankments etc. The Population data will

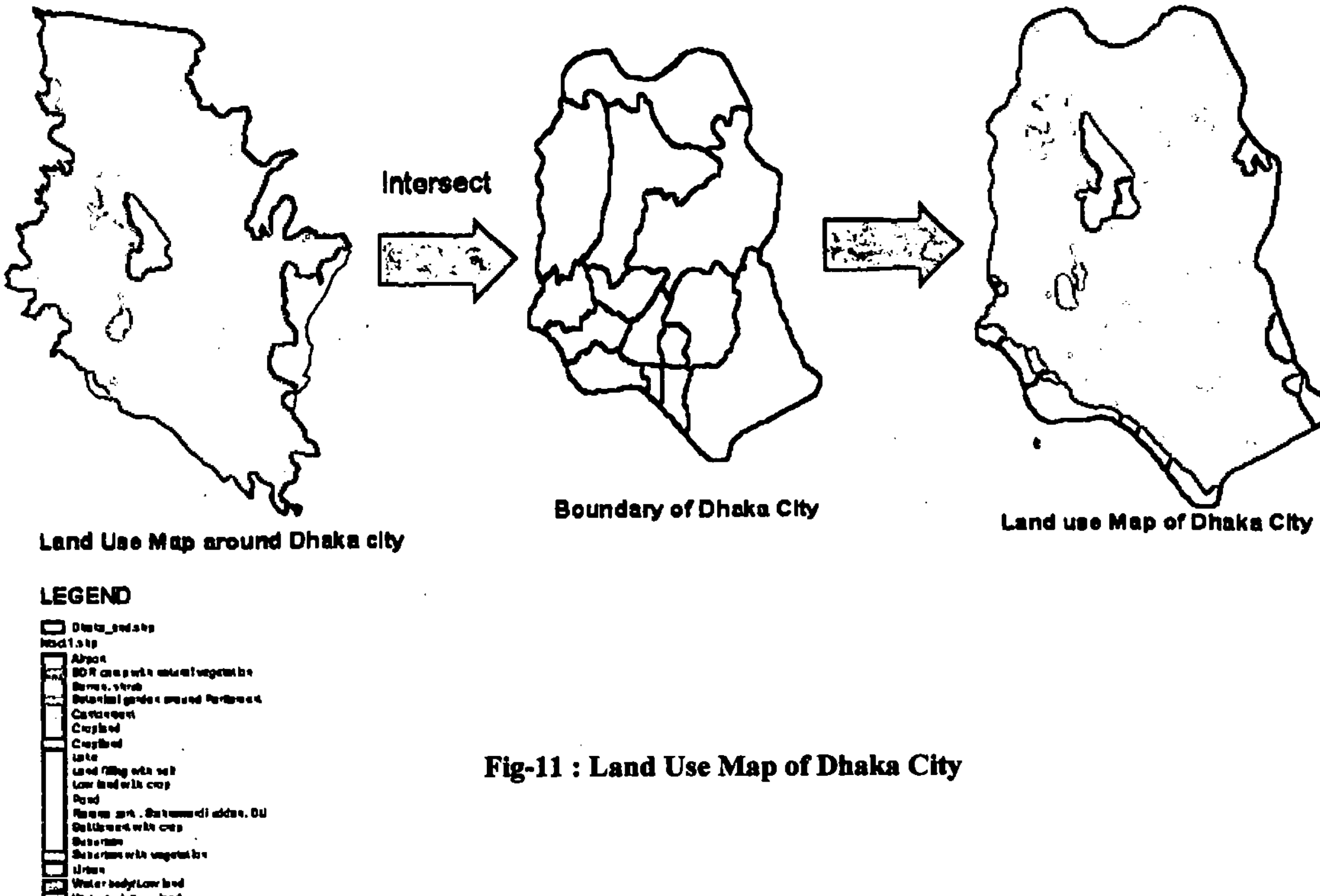

Fig-11 : Land Use Map of Dhaka City

be available from the census of BBS. These information can be linked with the maps of the Upazila and then it is possible to get a clear picture of the location where it would be wise to construct a new flood/cyclone shelter. Fig-12-14 shows maps which can be helpful in planning cyclone/flood shelters. This will give PWD a chance to get the confidence back of the Ministry of Relief and Rehabilitation and get back its old reputation again.

Planning for Deep Tube Wells

PWD installs deep tube wells at different locations. But it is very difficult to analyze the resultant effect of closely located tube wells. If a second tube well is installed within the influence area of another tube well, there is every possibility of lowering the water table of the area in a negative way. Buffer zone analysis of GIS software provides an unique solution to this problem. In this operation, if the locations of the tube wells are located with the help of GPS receiver, buffer zone around each tube well would enable some one to see that whether there are any over lapping in the draw down curves. An analysis of this kind is shown in Fig-15 .

Planning for Food Godown:

PWD does the construction work of infrastructure of Ministry Food. Construction of food godown is one of the major construction work under this Ministry. But in the past , there were no analysis behind the selection of the sites of the food godowns. Select by theme tool of Arc View software can be very effectively used in such kind of analysis. Depending on various advantages, the food godowns are normally constructed beside the river or canal. If we have a map of the Upazilas of Bangladesh and if we superimpose the river and canal polygon on this Upazila polygon, Arc View gives the opportunity to select the Upazilas which are within a certain distance of the rivers or canals. Fig-16 shows such an analysis.

5.2.2 GIS in Designing Infrastructure:

As mentioned earlier, one of the major tasks of PWD is to design different infrastructure which includes school, college, Government Offices, Residence of the Government Officials, Hospitals and many more. In the present days, delay in design and inappropriate design has become a bottleneck to the smooth operation of the department. In many cases, the designers are to design the structure without knowing the physical characteristics of the site. Physical characteristics include bearing capacity and other properties of soil of the site, salinity condition, information on

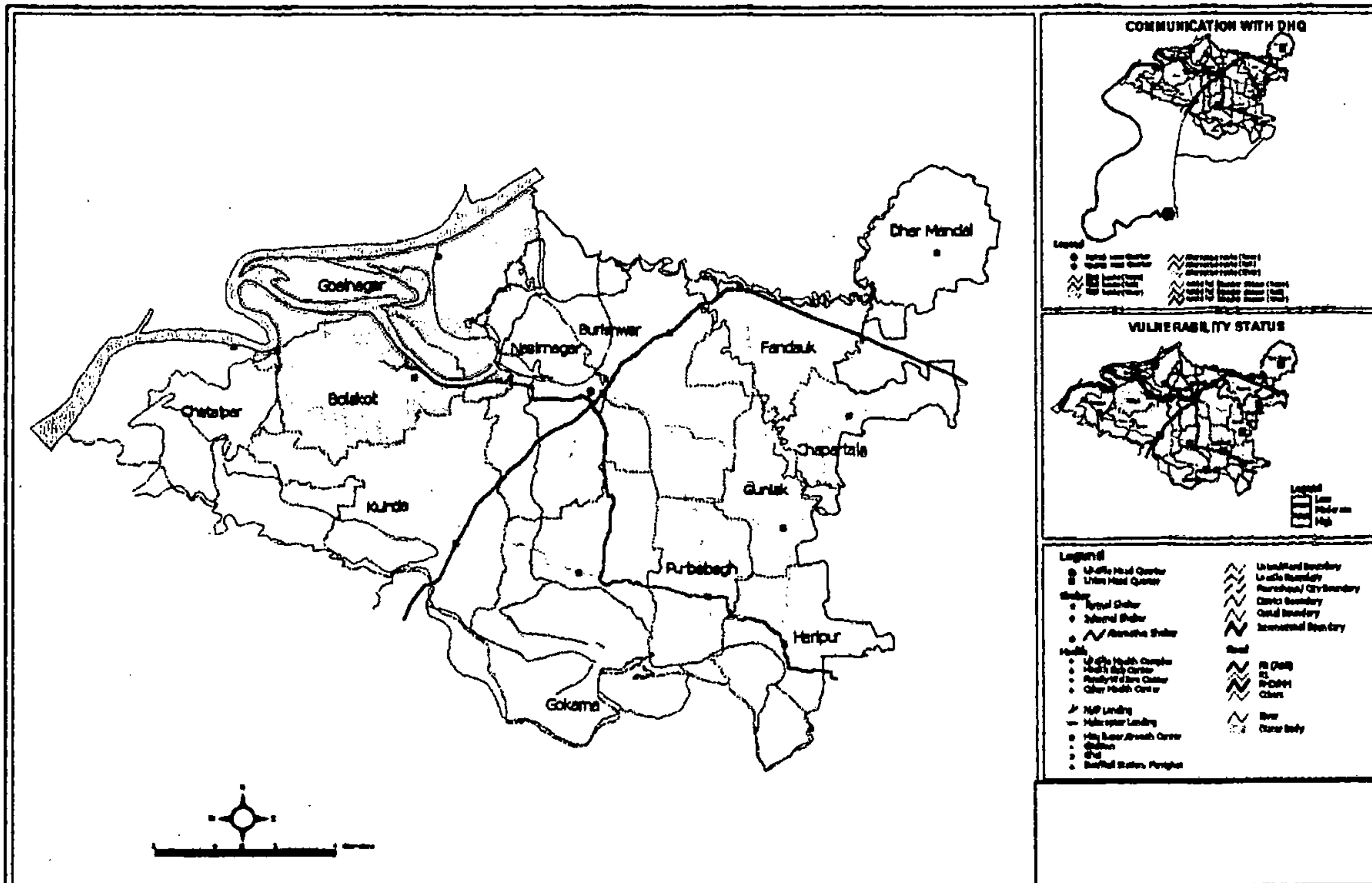

Fig- 12 : Disaster Vulnerability Map

Industrial & Production Engg. Deptt.
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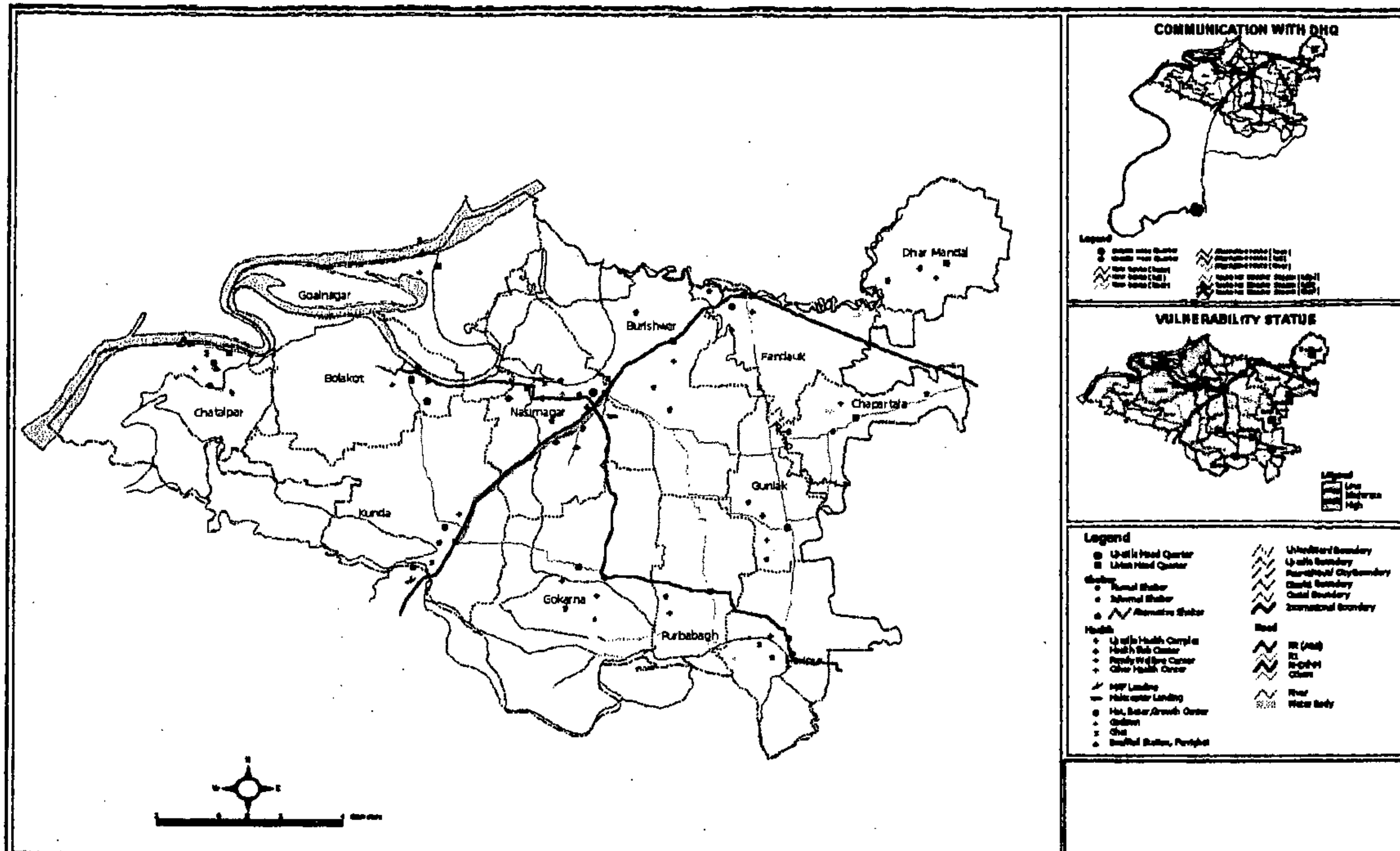

Fig 13 - Availability of Infrastructure during Disaster

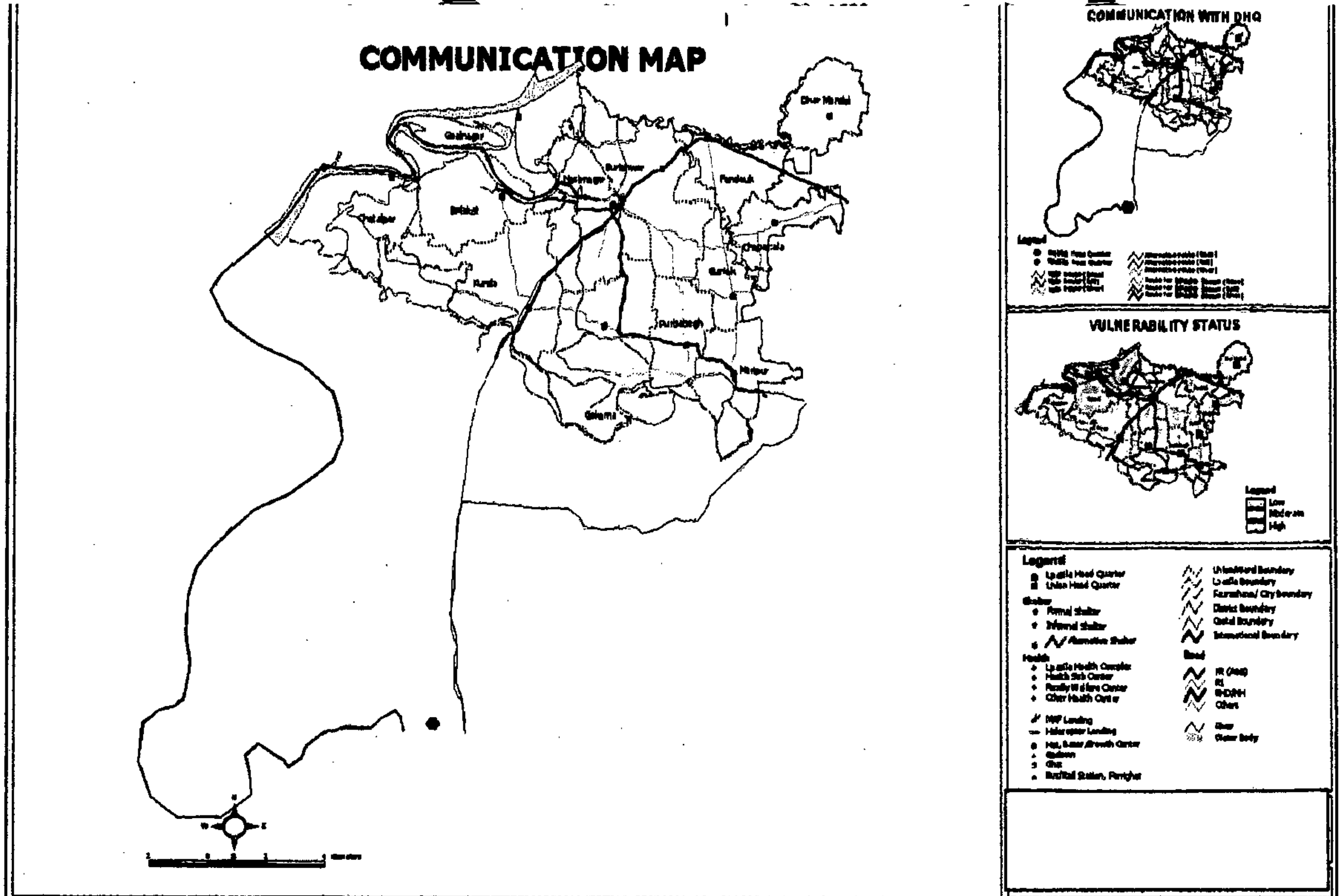

Fig- 14 Disaster Time Communication

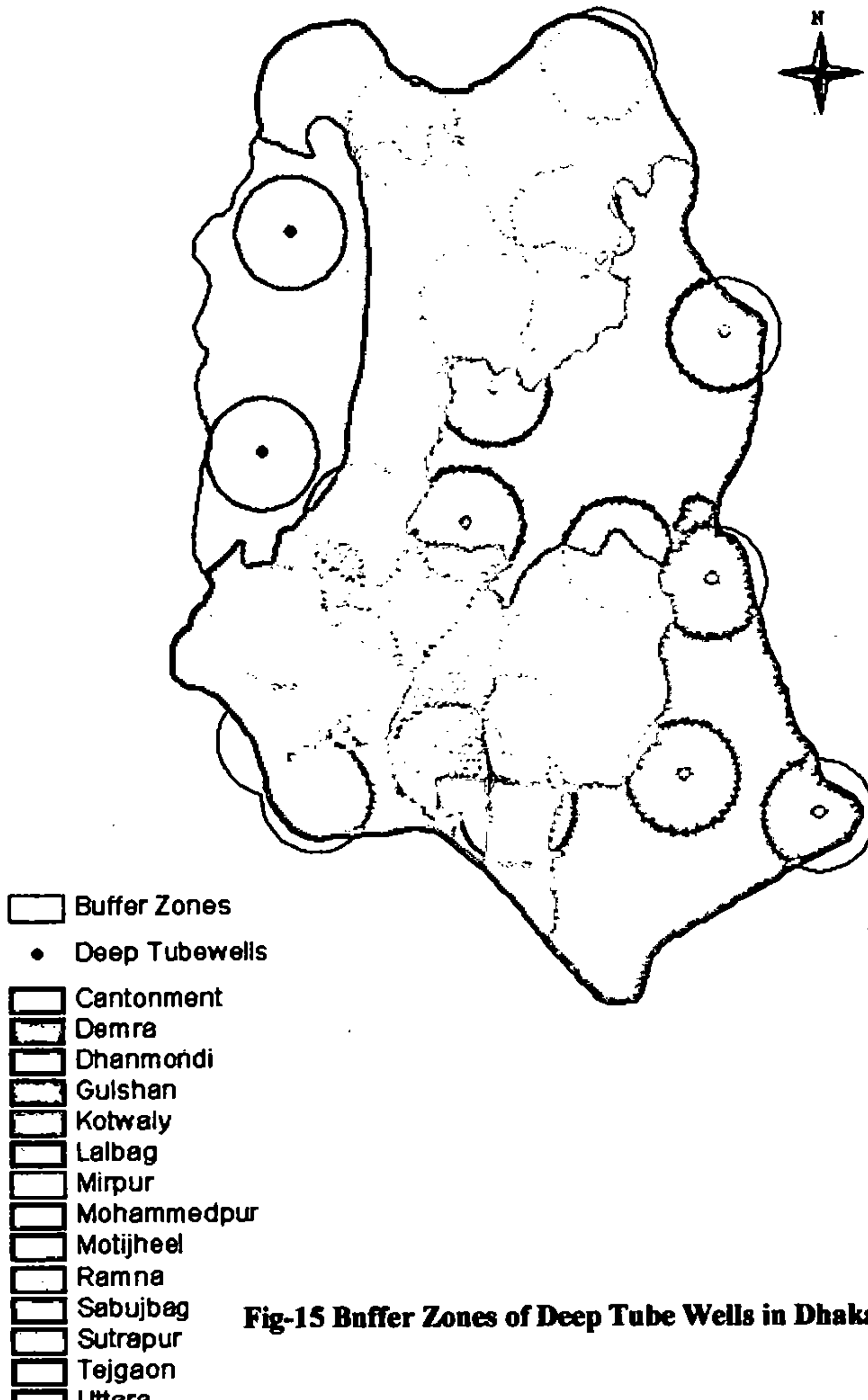

Fig-15 Bnffer Zones of Deep Tube Wells in Dhaka City

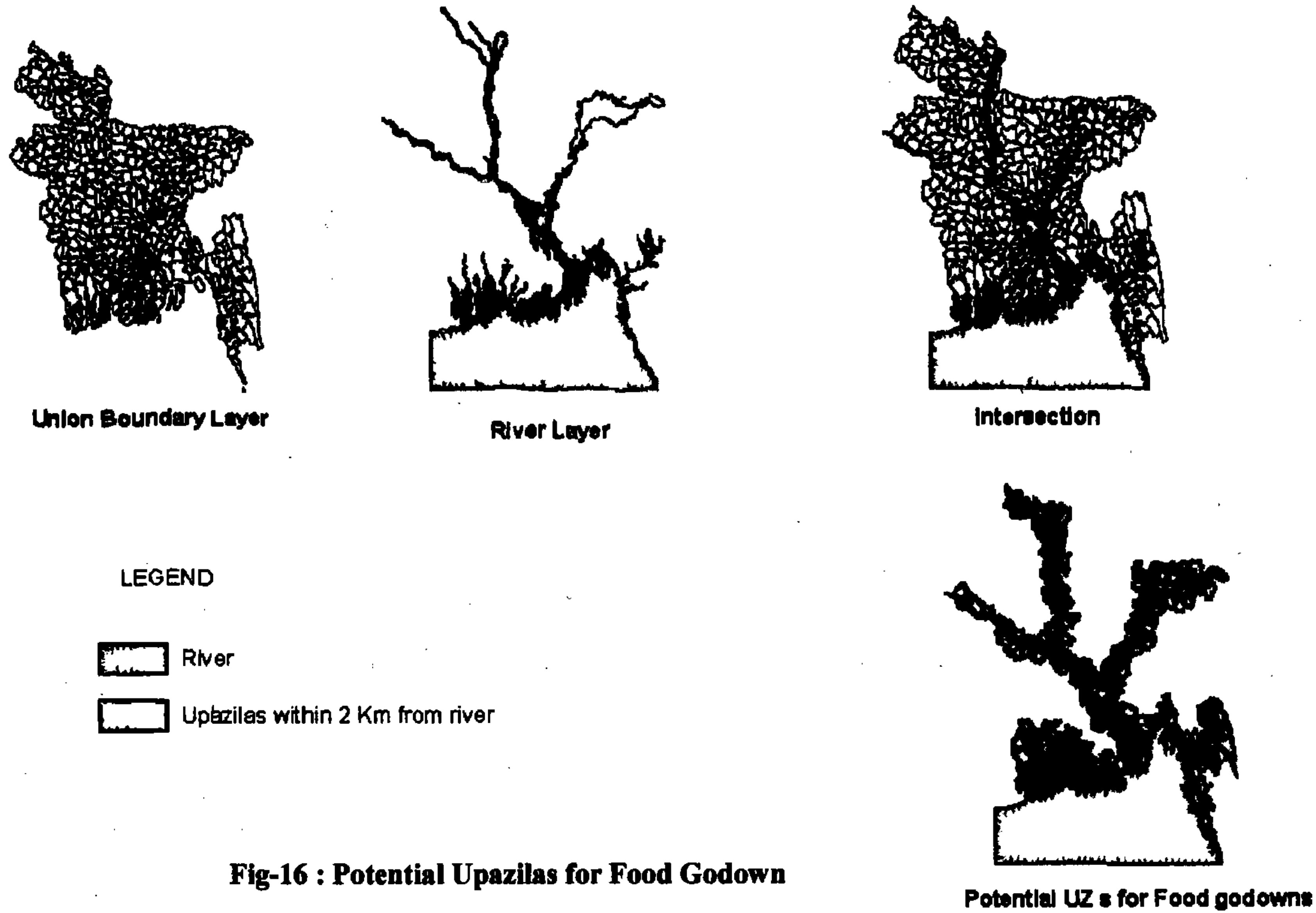

Fig-16 : Potential Upazilas for Food Godown

earthquake, wind speed contour map, topography of the site and adjacent areas, level of ground water with seasonal variation, average and highest flood levels etc. In each of these case, GIS can help PWD to take right decision as described below:

Information on Soil properties:

GIS can help us by providing data on soil properties. This can include bearing capacity of soil, unconfined compressive strength, colour and type of the soil etc. This needs a good database on the soil properties which would be linked with GIS software to visualize the spatial distribution of the parameters. PWD has a huge record on the subsoil exploration throughout the country specially in the District towns which can be organized to build a database in this regard. As PWD mainly works at the District level, the database can be built for the District Head Quarters at the preliminary level. The Engineers of PWD at District level can play a vital role in building the database and update it on a regular basis. Each District can be divided into several region depending of the physical characteristics of the area. Then soil test can be undertaken on sample basis if not already available. This information would help PWD engineers to prepare the rough estimate of the projects which is the basis of administrative approval of the project from the client ministry. The project concept paper (PCP) is built on the basis of this rough estimate. Because of lack of information, the rough estimate is not prepared properly. For example the type of foundation is often mistakenly put. A normal foundation is put in a place where pile foundation would have been appropriate. The consequence of this is a revision of the estimate at the time of execution of the project which put the management of PWD in an embarrassing situation and put the competency of the engineers in question. Application of GIS can help PWD to avoid such situation. In GIS one can see not only the soil type of the region where the site exists but also can see the soil type of the adjacent regions. Moreover, location of other physical infrastructure like rivers, water bodies etc can also give some one an idea about the soil type of the project site. Different layers of soil information can be overlaid to get an impression of the suitability of certain type of foundation for a specific structure. For example, the bearing capacity layer can be superimposed on the layer of water table to see impact of water table on the bearing capacity. This can serve as a cross check of the information on bearing capacity as we know that an area having a shallow depth of water table normally exhibits a lower bearing capacity. Fig-17 shows a sample soil classification map of Bangladesh.

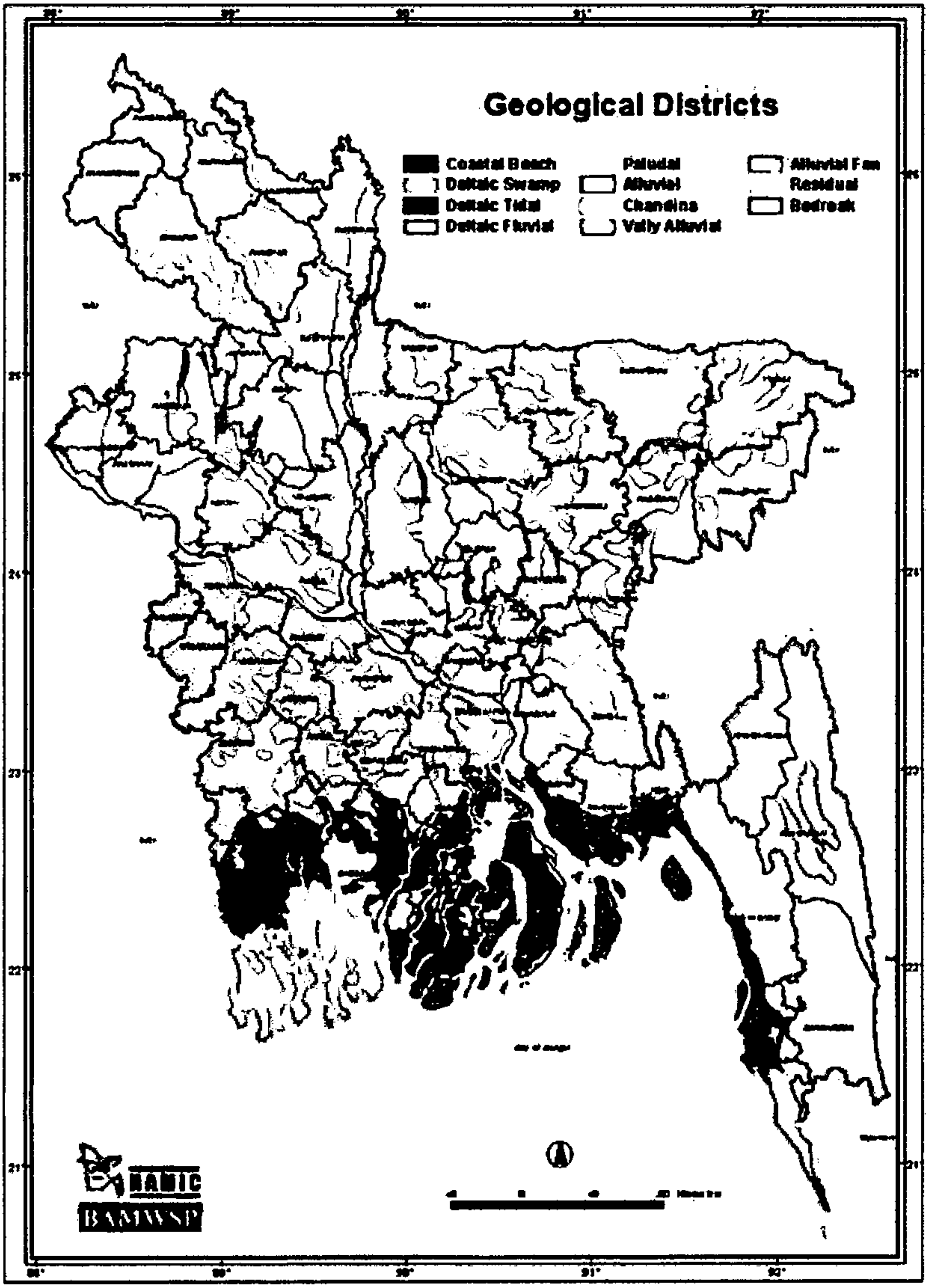

Fig-17: Soil Classification Map of Bangladesh

Source: Bangladesh Arsenic Mitigation and Water Supply Project)

Handling Earthquake

Information of earthquake is very important for a designer. Specially in the recent days, the experts are contemplating a major earthquake at any time in Bangladesh. Being a leading department in the field of infrastructure, PWD should be well equipped with all the available information on earthquake and apply the knowledge not only in designing the infrastructure but also to disseminate the knowledge to other stakeholders in the field. Low-lying Bangladesh is at greater risk of flooding, lying as it does in the great Ganges-Brahmaputra delta. But its northern and eastern districts are also highly quake-prone.

GIS is used to manage the large volume of data needed for the hazard and risk assessment of earthquake. In disaster preparedness phase it is a tool for the planning of evacuation routes, for the design of centers for emergency operations, and for integration of satellite data with other relevant data in the design of disaster warning systems.

In order to reduce damage in a future earthquake, it is important that the weak points that came to light in the damage pattern of the earthquake be avoided in future development. The earthquake risk can be reduced by means of various preventative measures. The most effective measures are the reduction of the vulnerability of buildings and other structures and the development and application of appropriate land use plans (microzonation). Microzonation relates earthquake hazard to corresponding utilization and building regulations. In short "Microzonation is the identification of separate individual areas having different potentials for hazardous earthquake effects."

Earthquake disasters are the outcome of many complex geophysical characteristics and the related social circumstances that are subjected to a hazard. All these events are location dependent in the sense that a hazard is aggravated by the geological, topographical and land cover at the location of the hazard. Similarly, natural hazards turn into disasters when they affect societies. The degree of damage is dependent on the population density, infrastructure and means available for mitigation such as flood control dams and evacuation facilities. In order to grasp the impact of different disasters, it is necessary to understand the interactions and inter-relationships among these diverse and complex entities subjected to a given magnitude of the hazardous event.

The strength of GIS lies in the ability to represent the real world situation closely with layers of information (maps) that can be combined in a predetermined manner to identify the impacts of a natural hazard through the introduction of hazard dimension. In the case of earthquakes, this information could be ground shaking intensities due to an earthquake, which again can be combined with population, housing and infrastructure information to assess disaster impact and plan response and relief strategies.

GIS information, especially, can be easily combined with detailed land cover information obtainable from remote sensing, thereby updating the dynamic component of information. The most expensive part of the GIS use lies in the data preparation.

The automation provided by GIS could be directly used in microzonation, as the basic information fusion process involving comparison, indices and overlaying in microzonation is the same for basic GIS operations. Another approach is the vulnerability analysis, where the hazard potential is considered to be equally distributed regionally. This approach is adopted in earthquake microzonation where each location is subjected to the same type of ground motion and vulnerability is assessed based on the geological structure of each location.

GIS is effective in carrying out such analysis as automated processes within the GIS, and different outcomes resulting form changed input parameters, assumptions and scenarios can be easily compared with due consideration given to uncertainties in methodology and the input data.

Bolt analyzed different seismic sources in and around Bangladesh and arrived at conclusions related to maximum likely earthquake magnitude (Bolt. 1987). He identified the following four major seismic sources:

(i) Assam Fault Zone

(ii) Tripura Fault Zone

(iii) Sub-Dauki Fault Zone

(iv) Bogra Fault Zone

Seismic Zoning Maps

The first seismic zoning map of the sub-continent was compiled by the Geological Survey of India in 1935. Three zones were indicated in the maps, viz. liable to severe damage, liable to moderate damage and liable to slight damage. Areas which, suffered moderate to severe damage in past earthquakes with an intensity approximately higher than Rossi-Forrel VII (M.M. VIII) within the first zone were also delineated. This qualitative map was based mainly on records of earthquake occurrence in the past. A major part of Bangladesh (in the north, north-east and south-east) was shown under "liable to sever damage" In the sixties, the metrological department prepared a Zoning map, which was adopted by Bangladesh Metrological Department in 1972. The country was divided into four zones, viz. Major damage (seismic factor g/5 to g/10), moderate damage (g/10 to g/15), minor damage (g/15 to g/20) and negligible damage (g/20).

Bangladesh National Building Code (commonly referred to as BNBC 93) includes detailed guidelines for earthquake resistant design of concrete and steel structures where Bangladesh has been divided into three seismic zones as shown in Fig-18. Unfortunately, the Code is yet to be officially enforced. The Ministry of Works formed a committee in 1997 to develop mechanism for its enforcement; however, it has not made any progress. In the absence of enforcement mechanism, many of the new buildings, which are being designed and constructed in different parts of Zones 2 and 3, do not have adequate provisions for seismic resistance. With increasing urbanization leading to construction of a large number of engineered and non-engineered buildings in the cities, the number of people living in unsafe houses would obviously increase. To avoid catastrophes in case of future earthquakes it is imperative that measures are initiated to strictly enforce the provisions of BNBC 93.

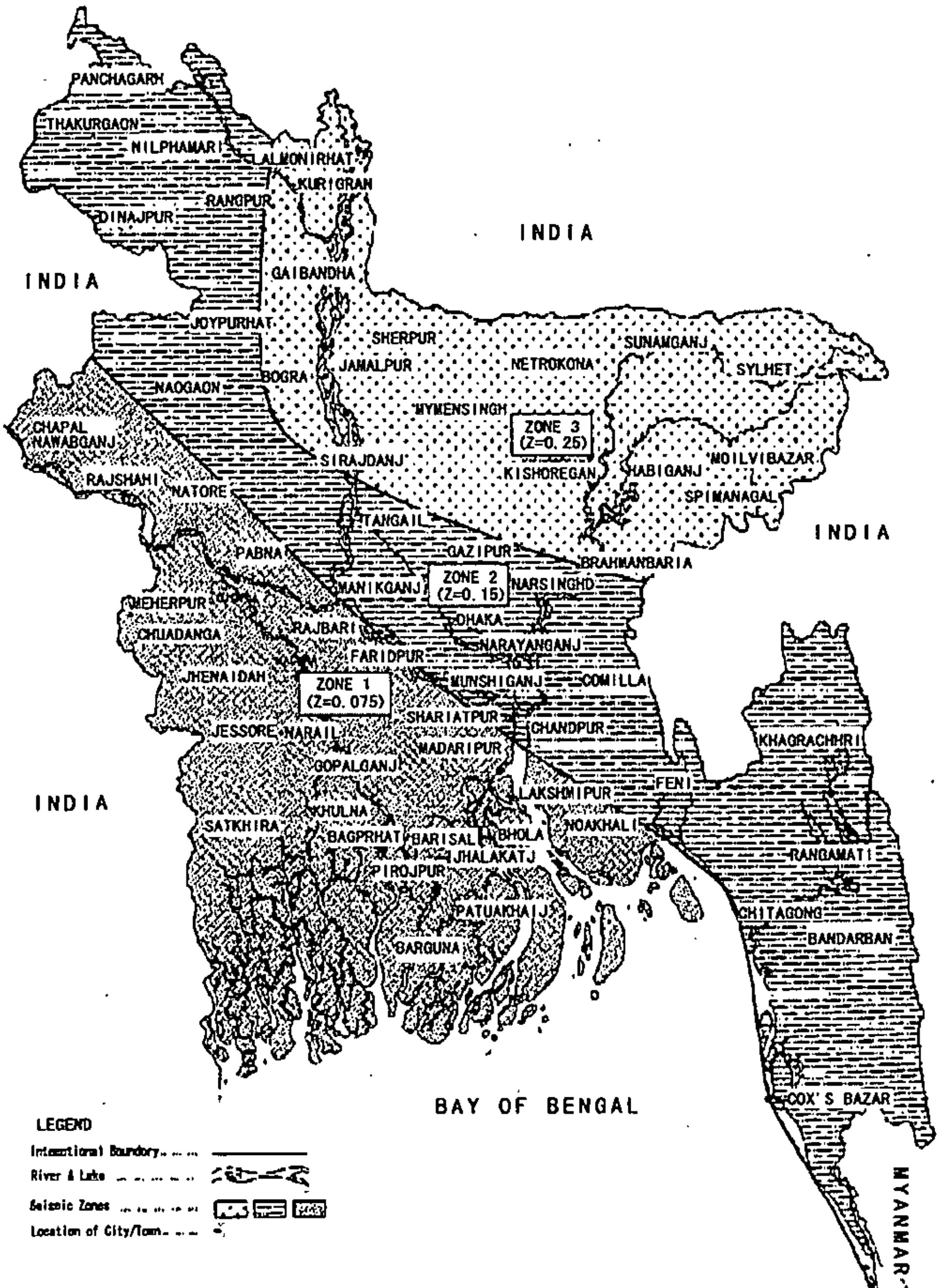

Fig-18 : Seismic Zones of Bangladesh

Source: Bangladesh National Building Code, 1993)

In the present days, a good designer have to consider the seismic condition beyond the boundary of his country to see the problem holistically. During the last 150 years, seven major earthquakes (M> 7) have affected Bangladesh. (Table 2). The epicentral distances from Dhaka for each earthquake are also shown in the table. Out of the seven earthquakes, only two (viz. 1885 and 1918) had their epicenters within Bangladesh.

Table 3 :List of Major Earthquakes Affecting Bangladesh

Date	Name of Earthquake	Magnitude(Richter)	Epicentral Distance from Dhaka (km)
10, January, 1869	Cachar Earthquake	7.5	250
14 July, 1885	Bengal Earthquake	7.0	170
12 June, 1897	Great Indian Earthquake	8.7	230
8 July, 1918	Srimongal Earthquake	7.6	150
2 July, 1930	Dhubri Earthquake	7.1	250
15 January, 1934	Bihar-Nepal Earthquake	8.3	510
15 August, 1950	Assam Earthquake	8.5	780

In a triumph of science in the political setting, the whole world has been mapped consistently in terms of its earthquake hazard. The resulting map is shown in Fig-19.

The map was made as part of GSHAP (Global Seismic Hazard Assessment Project) by some 500 scientists over seven years, and their challenges were great.

First, the state of science differs around the world. Earthquake monitoring is advanced in prosperous countries, while the Russian system is in a state of decay. Much of Africa had never been properly assessed at all. And scientists in different countries use different standards. So when this project, part of the United Nations International Decade of Natural Disaster Reduction, arrived at a single standard of hazard and a clean worldwide database, it was quite an achievement.

Second, seismic hazard can be sensitive knowledge. Prosperous nations make builders meet building codes that are based on the degree of earthquake shaking a site can expect. Poor nations need sound risk data for their important projects when they apply for international loans. The safer one can make a place appear, the cheaper it is to build there. Many countries therefore consider this subject part of their national interest. But that obstacle, too, was overcome.

Third, simply discussing a region's geology can be difficult when the wrong border crosses it. Geologists don't care about borders, but their governments do. India and China, for example, took three years to meet and adjust their hazard map—India raised its hazard levels by as much as 40 percent in some places. Greece and Turkey surmounted similar hurdles for hazard zoning in the Adriatic Sea.

Seismic hazard is basically the degree of earthquake shaking that one can expect in a given place during a given time. To simplify things, the mappers assume that we are on solid rock and that we are interested in relatively fast shaking (0.2 second period), which strongly affects ordinary houses. Different ground and different periods are important in determining the exact seismic *risk* for a particular structure.

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The map shows the peak ground acceleration (PGA) that a site can expect during the next 50 years with 10 percent probability.

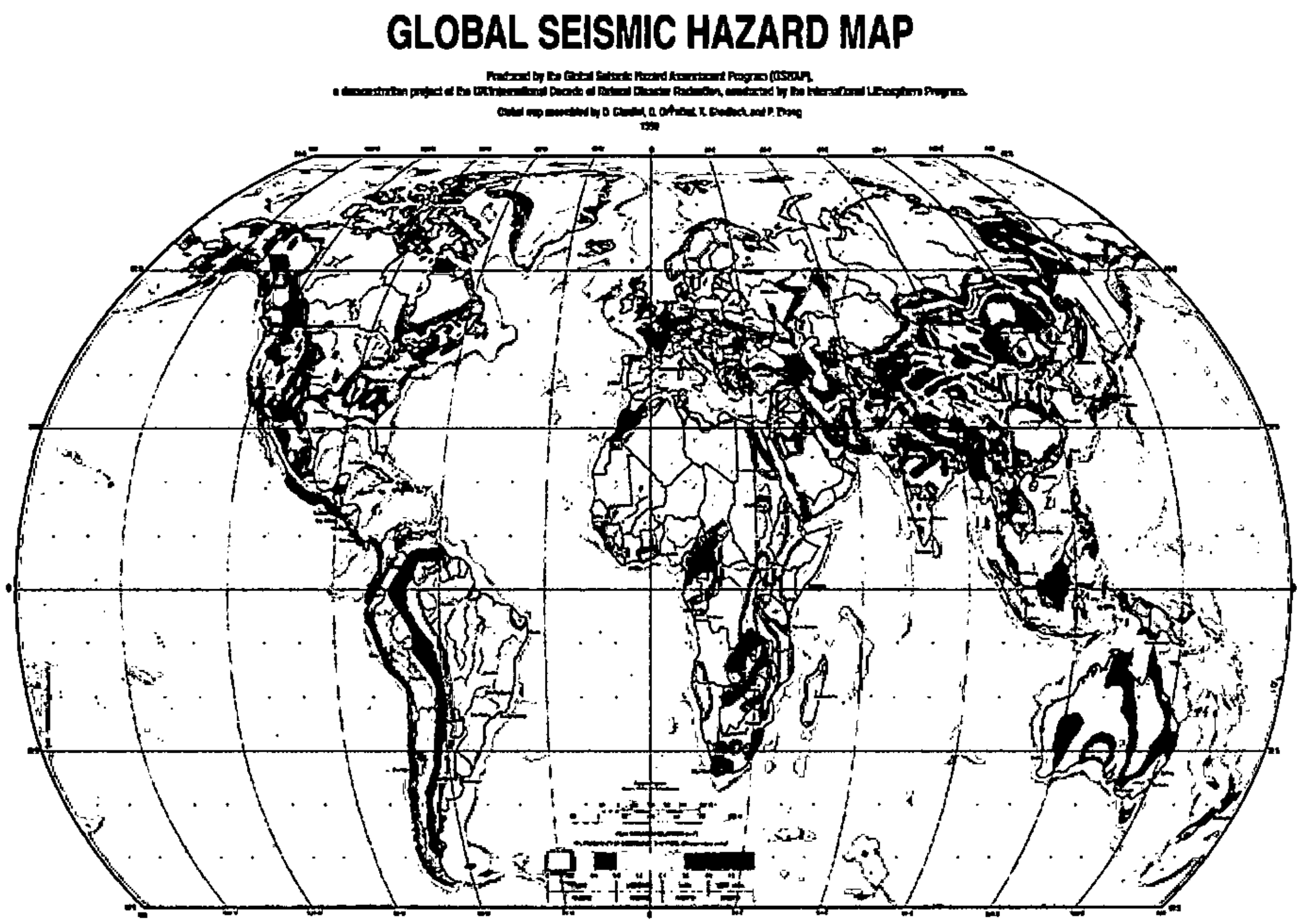

Fig-19 : Global Seismic Hazard Map
Source : Global Seismic Hazard Assessment Program (GSHAP)

The new map was released December 16, 1999.

The following maps are pieces of this world map, reproduced at full size or close to it:

U.S. 48 States

Western Canada and Alaska

Eastern Canada

Mexico

Central America and Caribbean

South America

Peru (with 23 June 2001 quake)

Europe

Africa

Western Maghreb (Morocco/Algeria/Tunisia)

Eastern Maghreb (Tunisia/Libya/Egypt)

Middle East

India

South Asia

Afghanistan and Pakistan

Eastern Himalaya (Nepal/Bhutan/Bangladesh)

China (with 14 November 2001 quake)

Japan

East Asia

Australia

Australia and Indonesia

Fig-20 shows the way of interpretation of the global seismic map.

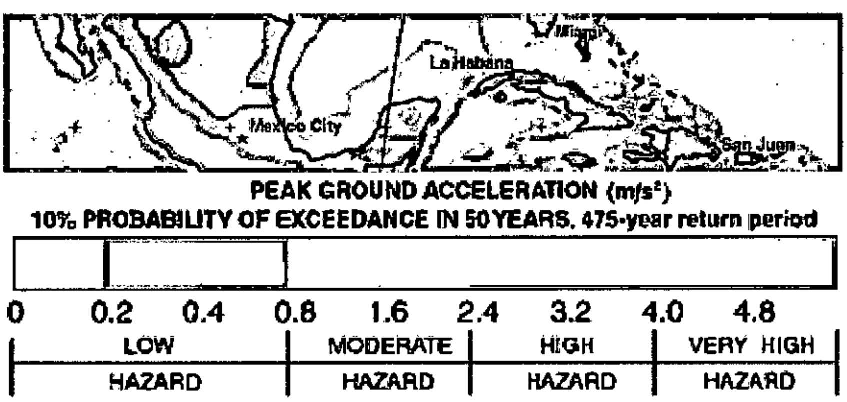

Fig-20: Interpretation of Global Seismic Map
Source : Global Seismic Hazard Assessment Program (GSHAP)

The middle value of the PGA scale, where the gold color meets the salmon color, corresponds to one-fourth the force of gravity and the highest section (brown) is half of gravity—remember, this is *sideways* acceleration.

This map makes a difference for everyone. For instance, <u>Africa</u> was not well mapped in the geologically active Rift Valley region on its east side. Now many nations there have their very first official seismic hazard map, and they can begin useful planning for preparedness, for mitigation, and for public education. They can begin saving lives.

Australia has a low to moderate seismic hazard level, but that is still higher than previously thought. But now Australian planners can compare their building standards to other areas of similar geology and hazard level, such as the eastern United States and Canada, or Europe, or parts of China.

India has higher but more accurate hazard levels along the Himalaya, thanks to its meeting with Chinese scientists. Now the nation is taking a fresh look at its infrastructure in light of this information, seeing what must be reevaluated before the public can be assured of its safety.

The seismic hazard map for the United States does not change—in fact, American knowledge of seismic hazard far exceeds what is on the new global map—but this country still benefits. America has examples of every kind of tectonic terrain, from hard continental rocks to volcanic areas to soft sedimentary basins, and these can be compared to similar areas in other countries. Many of those have earthquake records that go back thousands of years, and American scientists can learn from that data.

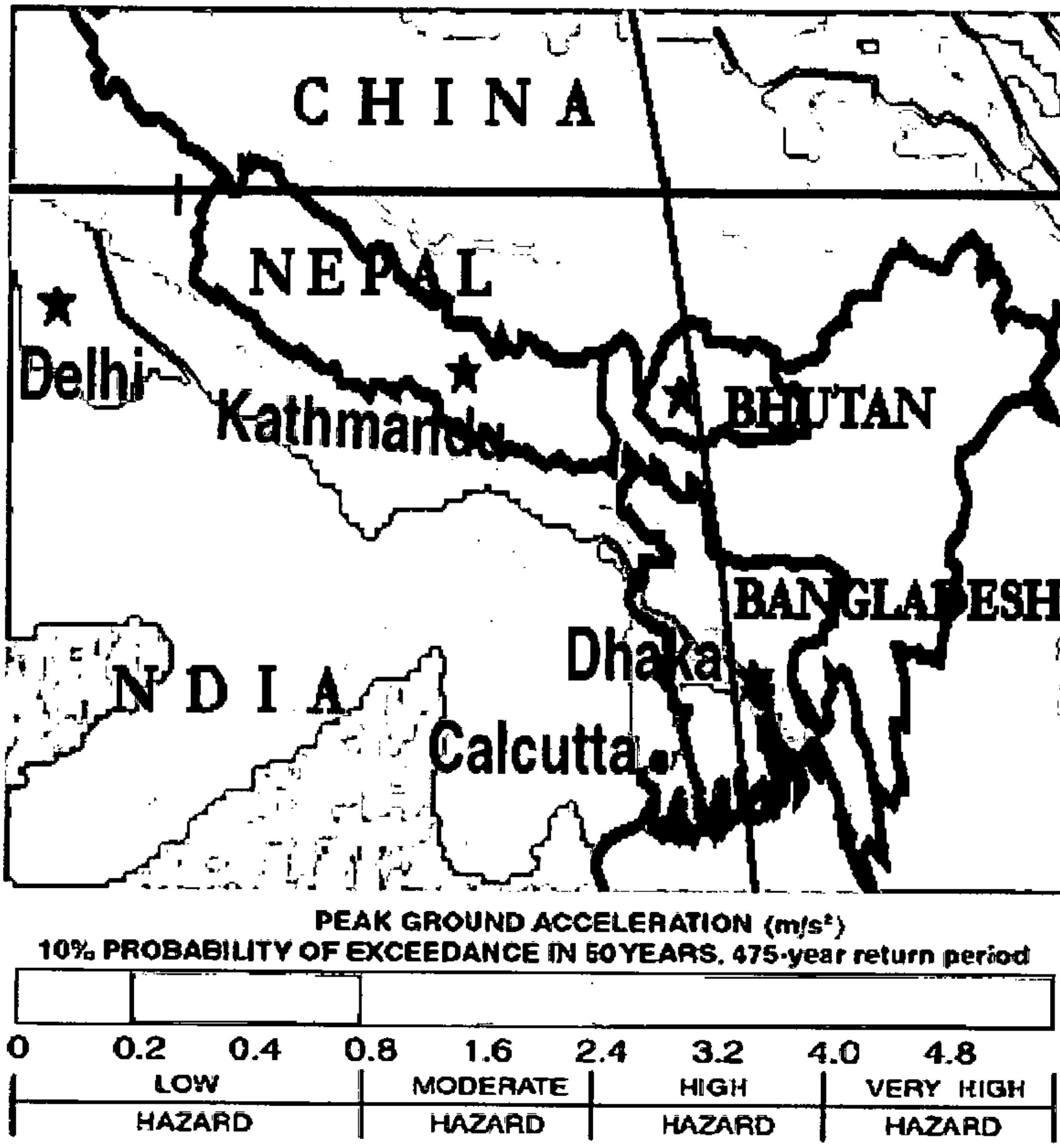

Fig-21 : Seismic Hazard Map of Eastern Himalayan
Source : Global Seismic Hazard Assessment Program (GSHAP)

It is known that Bangladesh has been divided into three zones depending on the intensity of earthquake. This zones, if applied with GIS, can give a planner a better idea about the location of a certain structure as well as give designer an idea about the earthquake load to be considered in designing a certain infrastructure. GIS would provide the opportunity to combine this information with other information like soil properties, wind speed etc to visualize the combined effect on a piece of land and see its suitability for a particular purpose.

Information on Salinity:

Salinity is an important parameter to be considered in design, specially the foundation. A salinity map can be a good source of information to a designer in this regard. This will guide a designer to think about the clear cover to be provided which is vitally important for an infrastructure situated in saline zone.

Salinity mapping assists agencies in:

- targeting salinity control activities
- focusing on the areas with the best opportunity for cost-effective control
- creating a database with saline areas specified by the legal land location
- generating the colour-coded salinity maps from the database
- calculating the areas affected by each salinity type
- creating regional salinity maps and database
- targeting regional soil salinity control programs

The saline zone can be plotted for various degrees of salinity which would be more helpful to someone. A heavily saline zone would require a more in depth study of the site before finalizing design.

Information on wind speed:

Wind speed is also very important in case of designing building specially the high rise buildings in the coastal belt or even the core of a city depending on the location of other infrastructure. A wind speed contour map can help a designer in this respect. This type of contour map can be produced with the help of GIS software.

5.2.3 GIS in Management of Government Khas Land:

PWD has a huge area of khas land in its disposal which are being misused by illegal occupants in various ways. Presently PWD does not have a good management system for these Khas lands. Introduction of GIS can help a lot in managing this. GIS provides the opportunity to find out a piece of khas land available for certain type of infrastructure. If we have a database on the different physical properties of each khas land which may include soil properties, vegetation condition etc, it is possible to find out a piece of land of 20 katha which is located within 50 ft of a road having a bearing capacity of 2tsf and having no vegetation. This can be done with the help of simple operation of GIS software like arc view. This type of operation would help the chief executive of the department to place the proposal to the policy makers with ample justification.

5.2.4 GIS in Fund Management:

PWD gets fund for the construction of new infrastructure as well as for maintenance of new existing ones. Fund for new construction is easy to allocate as it can be done on the basis of the progress made at different Districts. But the allocation of fund for maintenance is not straight forward. It should depend on the total maintainable plinth area, the type of buildings and also on age of the buildings. Presently fund management of PWD is one of the weakest areas which needs to be improved. Introduction of GIS can help the Chief Executive to allocate the maintenance fund more rationally. If the District can be categorized according to the amount of total plinth area under the jurisdiction of PWD, one can visualize the distribution of plinth area spread over the whole country. We can have another layer on the average age of the infrastructure. Then superimposition of these two layers can give a basis to find out the Districts/ Division which are eligible for maintenance fund and then this scare resource can rationally be distributed among these Districts or Divisions.

5.2.5 GIS in Human Resource Management:

PWD is a large organization having manpower at every District. Each District is covered by Division headed by an Executive Engineer. The next tire is the Circles headed by the Superintending Engineers. There are several Districts under the Jurisdiction of a circle. Then comes the Zones headed by the Additional Chief Engineers and comprising of several circles. The Additional Chief Engineers are reportable to the Chief Engineer. In large Districts like Dhaka, Chittagong, Khulna and Rajshahi there are more than one Divisions and in some cases there are more than one circle within the same city. The area of jurisdiction is not clearly marked specially in case of the large Districts where GIS can be very effectively used. If PWD has maps showing the jurisdiction of every Division, circle and Zone, then the management would be able to avoid confusion arose time to time in this respect. Not only this, a combination of the plinth area map along with the type of building would provide the management of PWD to redistribute the area of jurisdiction more rationally. This should be a dynamic process in a modern organization. Area of jurisdiction should vary with the change of the external environment. The new administrative units like new Upazila, new Districts and new Divisions are emerging from time to time and management of PWD should have a close eye to these and adjust themselves accordingly. Even the area of jurisdiction of the Divisions of large cities could be varied depending upon the demand of the time. The manpower strength of each Division/Circle/Zone should be constituted as per the work load (plinth area, work in hand, maintainable building, type and importance of building etc.) and could be reorganized to provide better service to the beneficiaries.

5.2.6 GIS in Disaster Management

We now have access to information gathering and organizing technologies like remote sensing and GIS, which have proven their usefulness in disaster management. Remote sensing and GIS provides a data base from which the evidence left behind by disaster that have occurred before can be interpreted, and combine with the other information to arrive at hazard maps, indicating which area is potentially dangerous. Using remote sensing data, such as satellite imageries and aerial photos, allows us to map the variabilities of terrain properties, such as vegetation, water, geology, both in space and time. Satellite images give a synoptic overview and provide a very useful environmental information, for a wide range of scales, from entire continents to detail of a few meters. The vantage position of satellite makes it ideal for us to think of, plan for and operationally monitor the event.

The impact and departure of the disaster event leaves behind an area of immense devastation. Remote Sensing can assists in damage assessment monitoring, providing a quantitative base for relief operation. After that it can be used to map the new situation and update the database used for the reconstruction of an area. It can help to prevent the occurrence of such disasters again in future.

A complete strategy for disaster management is required to effectively reduce the impact of disaster, which is as referred to as disaster management cycle. Disaster management consists of two phases that takes place before disaster occurs, disaster prevention and disaster preparedness, a three phases that happens after the occurrence of a disaster i.e. disaster Estimation, relief, rehabilitation and reconstruction.

Earthquake Disaster Estimation, Relief, Rehabilitation & Reconstruction

Use of Remote Sensing Systems:

The emergence of airborne and space borne remote sensing systems, from optical to microwave spectral bands, has created arguably the most significant opportunity for improving loss estimation methodologies. When fully operational for natural hazards risk management applications sometime in the next decade, these systems and attendant data visualization technologies will provide enhanced measurement accuracy, near-real-time capability, greater geographic coverage and hold the promise of reduced operational cost.

The benefits of using this technology in loss estimation include the development of:

- Innovative procedures for assessing the seismic hazard potential of large urban regions
- Alternative approaches for developing regional damage or vulnerability models for buildings and lifelines
- Cost-effective procedures for creating building and lifeline inventories
- Rapid loss estimation and model calibration methodologies for post-earthquake damage assessment.

There are two possibilities to detect damages using photo interpretation analysis: a mono temporal technique based on a post event image, and a multi temporal approach, where a before event scene is compared with an after event scene. The mono temporal procedure consists in the visual recognition of the damaged elements, and it is directly related with the image resolution. With a medium resolution (around 10 meters) only larges zones completely destroyed can be observed. The 1 meter resolution allows the detection of damaged buildings one by one, the building size being considerably greater than the pixel size. Damage states are generally not recognizable by remote sensing, only buildings completely destroyed being detectable.

In the disaster relief phase, Remote Sensing & GIS is extremely useful in search and rescue operations in areas that have been devastated and where it is difficult to orientate. A GIS map can be helpful in finding different routes available during normal time and disaster period. Such maps are extremely helpful in conducting relief operation. In the disaster rehabilitation phase GIS is used to organize the damage information and the post-disaster census information, and in the evaluation of sites for reconstruction. Hence, GIS is the useful tool in disaster management if it is used effectively and efficiently

Chapter 6

Process of Implementing GIS

6.1 GIS Specification, evaluation and implementation:

Before introducing GIS, some procedures are recommended to be followed by every agency which are described below. Before adopting a GIS, the following stages should be followed:

Stage-1: Analysis of requirements

a. Definition of objectives

b. User requirements analysis

c. Preliminary design

d. Cost benefit analysis

e. Pilot study

Stage-2: Specification of requirements

f. Final design

g. Request for proposals

Stage 3 : Evaluation of alternatives

h. Short listing

i. Benchmark testing

j. Cost effectiveness evaluation

Stage 4: Implementation of the system

k. Implementation plan

l. Contract

m. Acceptance testing

n. Implementation

The importance of a particular step will vary from project to project and the cost involved must be kept in proportion to the size of the GIS.

6.1.1 Stage 1: Analysis of requirements

The first stage is an iterative process for identifying and refining user requirements and for determining the business case for acquiring GIS. After each step is completed, the resulting report should be discussed with users and management, and the conclusions from the previous steps should be reexamined and if necessary, refined.

a. Definition of objectives

The objectives of this step are to define the scope and objectives of the GIS acquisition project, and to obtain management and user support for them. The activities are:

- Review overall agency objectives
- Develop GIS project objectives.
- Negotiate with management and users

The acquisition of a GIS must be compatible with the agency mission statement and business plan. Those documents should provide a framework within which specific project objectives can be developed. Objectives should be stated form from management's perspective, focus on results and be measurable. Key aspects include cost, time, quality, accuracy and staff impact. Vague statements regarding new technology or improved decision making are not adequate. Users must also be satisfied that the project will result in benefits for them.

Th outcome from step 1 is a document which has management and user endorsement and which commits the agency to proceed through to a GIS cost-benefit analysis (step-d). The agreed objectives may, of course, be refined after further analysis.

b. User requirements analysis

The objectives of this step are to determine the user requirements upon which the GIS will be designed and evaluated. The output from a GIS is an information product, obtained by processing geographical data. Three levels of user requirements can therefore be identified: information, processing and data. The analysis activities are :

- Assess existing information, process and data.
- Identify potential users
- Define required information products.
- Analyze data requirements.
- Estimate workloads and required performance.

The initial assessment should result in an understanding of what information is being used, who is using it, and how the source data are being collected, processed , stored and maintained. This is the base against which the alternative of acquiring a GIS will be tested. The required information can be obtained through interviews, documentation reviews and workshops. The report should clearly identify the work flows which relate to spatial data, as well as the characteristics of those data including source, accuracy, format and volume. The costs of operating those parts of the current system which may be replaced by the proposed GIS must also be identified for use in the cost-benefit analysis.

Potential GIS users include the users of information products (decision makers), people who process data to obtain information (application specialists) and people who collect and maintain data. For some agencies, these functions may be performed by an individual, while for others they will be performed separately by many people. The end product users may be external clients for whom the agency provides services. Th process and data users will be hands-on users of the proposed GIS and should be relatively easy to identify based on the current systems and processes. However, potential end-product users may include decision makers who do not currently have access to geographical information products due to time, cost or availability constraints. These may be the most difficult and important potential users to identify (Guptill 1988).

The definition of required information products is the key to the user requirements analysis. Products may be in the form of hardcopy and soft copy graphics and reports, and digital data in a range of formats. Applications and data capture staff may require a range of intermediate products for verification purposes. The current geographical information products provide the starting point for determining user needs, but there may well be potential for new and enhanced products. The GIS product definition process should result in a clear statement of the media, format and content of the required information products.

Data requirements are determined directly from the product definition. Th analysis should identify the classifications, accuracy and update frequency required for each data type.

Workshops and demonstrations may be necessary to explain the options and issues in defining product and data requirements. Structured methods for requirements analysis such as strategic data planning, decision analysis and modeling may be appropriate (McRae and Cleaves 1986).

The final activity in step (b) is to estimate the work loads and required performance characteristics of the GIS. These will have a large impact on the proposed hardware configuration and hence on costs. Important aspects include the number of simultaneous users, data volumes, response times and required production rates. The analysis of user requirements may lead to some refinement in the definition of objectives.

c. Preliminary Design

The information gathered during step-b enables a preliminary design for the GIS to be developed. The design will be used for the cost-benefit analysis of the proposed GIS and will enable specification of the pilot study. The preliminary design step activities are:

- Develop preliminary database specification.
- Develop preliminary functional specifications.
- Develop preliminary system models.
- Survey the market for the potential systems.

The classifications, accuracy and update frequency for each data type are identified during the analysis of data requirements. The preliminary database specifications must also identify the sources, volumes and structures for both spatial and attribute data. Preliminary consideration must be given to the choice of vector or raster (or both) spatial data model and to whether a fully relational or other model is required for attribute data.

Functional specifications are determined directly from the product definition in step (b) and the database specifications. They define the functions and processes which are required to enable the database to be developed and the information products to be produced.

Conceptual models should be developed and documented to describe the logical and physical design of the proposed system. Aspects include hardware, software, communications, processes, people and organizational arrangements. Alternative models for the hardware and communications architecture may be included. For some agencies, the choice between a distributed and centralized GIS may be critical design issue.

A market survey should then be conducted to determine to determine the capabilities of systems in relation to the preliminary design. Initially, this may be done through visits to vendors and users sites. The objective is to determine whether the preliminary specifications can be met with current technology. If not, the options are to lower the functionality and performance specifications, or to accept that a major system development component may be included in the acquisition. This informal market survey could be conducted in conjunction with step (a) and (b) and the previous activities in step (c).

A formal market survey involves issuing a call for expression of interest from GIS vendors, based on the preliminary system specification. The objectives are to identify potential suppliers and the nature of their products and to advise vendors formally of the agency's GIS plans. This enables the agency to refine the preliminary specifications and system models and the vendors to prepare for the request for proposals (step-g).

d. Cost-benefit analysis

The objective of the cost benefit analysis is to establish the business case for the GIS acquisition proposal. The cost , benefits, impacts and risks of acquiring a GIS are measured against the alternative of continuing with the current data, process and information products. If the preliminary design models include fundamentally different approaches, such as distributed versus centralized system for an agency with regional offices, it may be necessary to analyze the costs and benefits of the alternatives. The cost benefit analysis activities are:

- Estimate all costs
- Identify all benefits.
- Assess impacts on organization and staff.
- Assess risks.
- Analyze results.

Cost for GIS implementation and operation include those for acquisition and maintenance of hardware and software, data capture and maintenance, training, additional and more highly qualified staff (required for system management, in-house programming, user support and the running of applications), consumables, site preparation and all overheads. The cost of the acquisition process may also be included. Recurrent costs should be determined over a nominal system life of at least five years, discounted to present value. Discounting reflects the opportunity cost of capital and enables comparison of costs and benefits which occur at different times during the system life.

Indicative hardware, software, maintenance and training costs should be obtained from two or three appropriate vendors identified during step-3. If possible, these costs should be validated by discussion with existing user agencies. Data capture cost may range from 10 to 100 times the hardware and software costs (Guptll 1988).

Three categories of GIS benefits may be defined: efficiency, effectiveness and intangible (Prisley and Mead 1987, Maffini and Saxon 1987). Efficiency benefits relate to time and cost savings through faster data processing and reduction in duplicate effort, while effectiveness benefits relate to improvements in decision making process through more timely or new information. Intangible benefits may include an improved public image for the agency, a reduction in confusion caused by contradiction data, improved cooperation between users through data sharing, increased staff professionalism and morale, better ability to cope with unexpected events, new knowledge through improved data analysis and unanticipated applications.

While an economic value can readily be assigned to efficiency benefits, the effectiveness and intangible benefits are harder to quantify. Dickinson and Calkins (1988) and Dickinson (1989) describe methods for estimating the economic value of non-quantifiable GIS benefits. However, Dickinson and Calkins (1988) also recommend that such value be reported separately as they have a larger element of uncertainty. Chorley (1988) argues that rather than quantifying benefits which are inherently intangible, it is more appropriate to provide a clear description and analysis of such benefits to enable judgement by senior decision makers.

The impact of the proposed GIS on the organization and staff of the agency may be major and so could have a significant bearing on the cost-benefit analysis. The impacts on data collection, data processing and decision making staff can be assessed from the from the user requirement analysis. The impacts on the organization may include changes to the organizational and management structure associated with new technology, new roles and procedures and new requirements for consultation and cooperation. These institutional issues may have a larger influence on the success of the GIS than technical issues (Foley 1988; Seldon 1987). Early consultation with staff and their representatives regarding these impacts will help to avoid disputes during implementation. There may be political and legal implications for the agency in terms of responsibility, authority and guarantees associated with the collection and maintenance of data and the dissemination of information products.

The cost benefit analysis should include an assessment of the risk that the project will not achieve a successful outcome in terms of time, cost, specifications and benefits. Economic risks may be assessed through a sensitivity analysis by determining the most pessimistic and optimistic values for the quantified costs and benefits. Other risk factors include the complexity of the data and system by being considered, the experience and composition of the GIS project team and the anticipated impact of the of the system on the organization and staff. Describing at this early stage enables senior management either to take action to reduce the risks or to monitor them closely during the project.

The cost, benefits, impacts and risks may be analyzed and presented in a number of ways. Dickinson and Calkins (1988) described a benefit/cost model based on GIS product values.

Griffin and Hickman (1988) described results of analyses of the present value, savings and investment ratio, discounted payback, breakeven and benefit-cost of an implemented GIS. The minimum requirement is to present the basic economics of the proposal, together with a statement of factors not included in the economic analysis. The basic economic equation is :

Operating cost of the system to be replaced –operating and capital cost of proposed GIS + quantified benefits of proposed GIS= net economic benefit of the proposed GIS +-sensitivity.

This net economic benefit must then be assessed against concise statements of intangible benefits and risks and the impacts on the organization and staff.

Consideration of the cost-benefit analysis is a major milestone in the GIS acquisition project. It may indicate that the proposal should be deferred, that further work must be done on the objectives, requirements and preliminary design, or that the acquisition should proceed to the pilot study step.

e. Pilot Study

The preliminary objective of the pilot study is to test the preliminary GIS design before finalizing the system specifications and committing major resources. Secondary objectives are to develop the understanding and confidence of users in the technology by demonstrating applications with their data, and to gain some operational experience to assist design of the benchmark test (step-i). The pilot study activities are:

- Design the pilot study
- Select the system
- Acquire pilot data.
- Produce pilot products.
- Analyze results.

The pilot study design documents must state the study objectives, address the selection of the pilot system, data and products, and identify the required resources and proposed timetable. It is important for the users to agree the objectives and scope of the pilot study.

A number of potential systems will have been identified during the preliminary design step. The apparent match of capabilities to requirements , and the cost of establishing the pilot system. Hardware and software may be leased for the duration of the pilot, or vendors may be prepared to loan systems and provide support. However, it must be emphasized to all parties that choice of a system for the pilot does not pre-empt the decision on which system will be finally acquired. Users must avoid the pitfall of becoming committed to the system chosen for the pilot through their familiarity with it.

The pilot data should include examples of all data types specified in the preliminary design. A common approach is to select a small but representative geographical area and to acquire all data of that area. The pilot product should also be representative of the final system, and include those considered by the users to be critical for the success of the system. If the choice between raster and vector data models is contentious, the pilot data and products must be selected to enable resolution of that issue.

The pilot study should yield valuable experience and user comments. These results may lead to refinement of the database and system specifications and to review of the cost and benefits, impacts and risks.

6.1.2 Stage 2 : Specification of requirements

In the second stage of the GIS acquisition model, the results of the analyses of user requirements are developed into a specification against which proposals can be solicited and evaluated.

f. Final Design

The objective of this step is to produce design documentation for inclusion in the request for proposals. Activities are:

- Finalize database specification.
- Finalize functional specifications.
- Finalize performance specifications.
- Specify constraints.
- Specify generic system requirements.

The database functional and performance specifications are finalized by incorporating the results of the pilot study into the preliminary design document. The database specifications are required by vendors for designing their proposed systems. Functional requirements must be specified in detail and classified as either mandatory, desirable or optional. Only those requirements which are essential to the operation of the system should be specified mandatory, as over specification will make the evaluation alternatives difficult and may result in the elimination of innovative proposals. Performance specifications should be sated in terms of the minimum acceptable performance (mandatory workloads) and optimum requirements.

Constraints which must be identified and specified may include existing hardware, software, communication systems, interface requirements and agency policies regarding compatibility and standards. Generic system requirements include maintenance, support, training, user and system documentation, development tools, upgrade paths, security and ergonomics.

g. Request for proposals

The request for proposals (RFP) document combines the final design with the contractual requirements of the agency. The RFP is then released to the vendors. The activities are:

- Specify contractual requirements.
- Specify evaluation methodology.
- Release the RFP.

Contractual issues which must be addressed in the RFP include: the acceptability of multiple vendor solutions; the required maturity of the proposed systems; provisions for special software development; how constraints must be addressed; general conditions of the proposal, and draft conditions of contract.

The optimum solutions to a complex GIS requirement may involve multiple hardware and software vendors. The agency must specify whether it requires a primary contractor to coordinate and accept responsibility for the total project, or whether separate vendors may be contracted to implement parts of the system under the direction of agency staff. The primary contractor may be either the primary vendor or a company which specializes in system integration. Similarly, the RFP must state whether proposals must address the total requirement or whether proposals for discrete parts (such as hardware or data capture systems) will be considered.

The agency must also specify whether proposed solutions must be mature (fully operational), or whether systems currently under development will be considered. There are risks with both positions. System under development may appear to promise greater benefits than some operational systems, but there is a significant risk that they will not meet their time or performance specifications. The risk in eliminating such system is that medium to long term potential benefits will be foregone. One intermediate approach is to nominate the benchmark testing date (step-i) as the cut-off; only those functions which are demonstrable by that date will be considered in the evaluation.

Special software development may include customization of user interfaces, translation software for existing data, unique processing functions and interfaces to other systems. The process for developing and reviewing the software specification and design and for monitoring the implementation should be specified.

The design consultants identified in step- f may be stated in the RFP as mandatory requirement or, preferably, as issues to be addressed by the vendors. The latter approach enables the vendors to propose alternatives which they consider to be more cost effective than constrained solutions.

General conditions of the proposal will include the closing date, minimum information for a formal tender, conditions for variations to proposals during the evaluation period and price basis. The RFP documents request vendors to respond to a large number of technical and contractual requirements. Vendors should be required to explain how their proposal complies with each mandatory, desirable and optional functional and performance requirement. They also must respond to every constraint and generic system requirement, and to the draft contractual conditions. The RFP should state that simple responses to complex technical requirements, such as, 'complies' or 'understood', will disqualify the proposal as a formal tender. A useful approach is to include a questionnaire in the RFP which address the issues of most concern to the agency.

Draft conditions of contract (step-l) and the evaluation methodology to be employed by the agency should also be outlined in the RFP. The evaluation methodology would be a summary of the shortlisting, benchmark testing and cost-effectiveness evaluation process (step h-j), and a general description of the evaluation criteria to be used for each step.

Finally, the RFP is released to vendors by letter, advertisement or both. A minimum period of eight weeks should be allowed for vendors to prepare proposals for complex systems. A formal briefing may be provided to interested vendors during the released period.

6.1.3 Stage 3 : Evaluation of alternatives:

The third stage comprise three successive evaluations designed to identify which one of the proposed systems is the most appropriate for the agency. Boehm (1981) describes a number of performance and cost-effectiveness models which provide decision criteria for choosing between alternative computer systems. The approach described here employs shortlisting based on mandatory functionality and performance criteria, followed by a cost-effectiveness evaluation. Effectiveness is determined by benchmark testing and is qualified by a weighted sum analysis.

h. Short listing

The objective of this step is to determine an initial shortlist of feasible systems by evaluating and scoring the information submitted by vendors. Activities are:

- Perform preliminary evaluation.
- Score functional requirements.
- Produce initial shortlist.

The preliminary evaluation of detailed proposals should identify any relationships between the proposals, and whether any should be rejected without further evaluation. Reasons for the rejection at this early step may include clear failure to meet a mandatory functional requirement, inadequate detail in the response, unacceptable maturity, inability to form part of a total solution and having cost which greatly exceed the alternatives and the projected budget.

Non-mandatory functional and generic system requirements are then scored from the vendor responses. Each requirement is assigned a weight and each is scored against a numerical scale (Boehm 1981). The weights should be determined in consultation with the users, prior to receipt of the proposals. The experience gained during the pilot study should provide a basis for determining the relative importance of functions. Uncertain scores should be highlighted for special attention during benchmark testing. Discussions with others will greatly assist the scoring of aspects such as the quality of maintenance and support.

The preliminary evaluation and scoring enable an initial shortlist to be produced. A maximum shortlist of five systems is recommended in order to keep the benchmark testing step manageable.

i. Benchmark testing

The objective of benchmark testing is to confirm the scoring of functional requirements and to determine realistic estimates of performance in terms of workload. This step also enables an informal evaluation of the people behind the proposal. Benchmark testing activities are:

- Design the benchmark.
- Develop the benchmark data and documentation.
- Execute the benchmark.
- Analyze the result.

The benchmark design must be based on the functional and performance requirements specified in the RFP. The design must establish the tasks to be performed, the data on which they will be performed and the output required. Guptill (1988) defines a comprehensive set of GIS benchmark tests, and Marble and en (1986) present design for an application independent benchmark for spatial database systems. Data to be used may include existing digital maps and attribute tables. Benchmark outputs may include measures of elapsed, CPU and operator times, together with products such as graphics and statistics. Other factors to be evaluated such as the user interface and system documentation should also be noted in the design document. Some vendors may be ambivalent about benchmarks because often the specification s are vague, the cost is out of proportion the value of the potential contract, and insufficient time is allowed for preparation and completion (Reed 1988). These factors must be considered in the benchmark design.

The benchmark documentation should provide a general description of the tasks to be performed and a copy of the data to be used. Vendors must be able to prepare for the benchmark by loading existing data and ensuring that staff with the appropriate knowledge and expertise are available, but it is neither appropriate nor necessary to provide details of every tasks to be performed in advance.

Careful records must be kept during execution of the benchmark. The configuration, loading and software version being used for the benchmark must be noted, in addition to the actual results. Structuring the benchmark design document as a proforma may assist this process. Evaluation must ensure that they understand what is being demonstrated and that all functions are being executed in real time.

The results of the benchmark tests will enable refinement of the functionality scores, and assessment of the scores for workload performance. Proposals which prove unable to meet mandatory functional requirements or which cannot achieve the minimum workload levels are eliminated at this point.

Goodchild and Rizzo (1987) and Goodchild (1987) distinguish between what they call qualitative and quantitative benchmarks. The purpose of a qualitative benchmark is to determine the degree to which the proposed system can perform the required functions to the satisfaction of the benchmark team. They propose a scale of 'inhibition' to assess the degree to which a given function falls below the ideal performance, and thus inhibits the ability of the system to generate particular products which depend on the function. A quantitative benchmark is used to assess the degree to which the system can indeed perform the required workload within the constraints of personnel working time, available CPU cycles, peripheral devices, and storage capacity.

Each required function is exercised at least once during the benchmark test. Its qualitative performance is assessed by the benchmark team, and its resource utilized is recorded, along with various measures of problem size. These are then used to build predictive models of resource utilization by each function, so that workload can be estimated given the anticipated sizes of production problems. The result is a series of estimates of total resource utilization, which can be compared against the capacities of the proposed system. In one example (Goodchild 1987) the quantitative benchmark showed that the vendor had seriously overestimated the rates of digitizing which could be achieved in production, and also seriously over-configured the system's CPU.

j. Cost-effectiveness Evaluation

Proposals which survive the initial shortlisting and benchmark testing steps are finally evaluated for their cost effectiveness. Activities are:

- Form national configuration.
- Analyze costs for each configuration.
- Analyze result.

National configuration are formed by defining the hardware and software required. Some normalization of hardware, such as the volume of the disk storage and number of workstations, may be necessary.

Capital and recurrent operating costs for these configuration over a nominal system life of at least five years are then determined. While only the cost differences are actually required for the purpose of evaluating alternative configurations, the total costs must also be determined to ensure that the original cost-benefit analysis remains valid. Schedules should be prepared showing capital and operating costs in each year, at both constant price and present value.

The cost effectiveness ratio for each configuration is then computed by dividing the whole-of-life present value cost by the functional and workload performance score, giving a cost per notional unit of performance. Because those systems which do not meet the required minimum levels of functionality and workload are not on the final shortlist, the ratios are actually a measure of the marginal increase in the effectiveness that would be achieved with each surviving configuration.

While the configuration with the best cost-effectiveness ratio (lowest cost per unit of marginal performance) is in the theory the optimum choice, it may not be affordable and there may be other factors not included in the evaluation which should also be considered. Other factors may include uncosted differences in the impact each configuration would have on the agency and staff, and concerns regarding the financial viability of vendors. The final report of the evaluation stage must therefore include, for each configuration on the final shortlist: the schedules of total costs (constant prices discounted to present value); the scores for non-mandatory functionality; performance and generic system requirements; a statement of relevant factors which are not included in the costs and scores; and a review of the original cost-benefit analysis.

6.1.4 Stage 4 : Implementation of system

The final stage in the GIS acquisition model involves planning the implementation, contracting with selected vendor or vendors, testing the delivered system, and actual implementation.

k. Implementation plan

The objectives of this step are to ensure smooth implementation and early delivery of benefits by developing a structured implementation plan. Implementation planning activities are:

- Identify priorities.
- Define schedule tasks.
- Develop a resource budget and management plan.

The priorities for products and data should be reviewed in consultation with the end-product users to identify where early benefits can be achieved. The rationale is that a positive result early in the implementation, even if of modest proportions, will be more beneficial to the success of the GIS than a plan which does not deliver any tangible benefits to end-product users until late in the implementation.

Implementation tasks must then be defined and scheduled. Tasks may include: installation and acceptance testing (step-m); customization of user interfaces; training of operators and support staff; initial data capture and product development; and medium to long term data capture and product development. Staff and cash budgets must then be linked to the schedule and management responsibility assigned.

l. Contract

This step involves integration of the agency's draft conditions of contract with the vendor's response and the implementation plan, to produce legal contract. Activities are:

- Negotiate general contractual conditions.
- Negotiate special contractual conditions.

General contractual conditions include the contract period, payment schedule ,reporting requirements, responsibilities of parties, insurance, warranty, indemnity, arbitration, and provisions for penalties and contract termination.

Special contractual conditions relate to the actual site and implementation plan. Reference must be made to the functionality and performance to be delivered. Other aspects are the processes and schedules for site preparation, delivery, installation, acceptance testing, training, support and maintenance. Procedures for the management of any special software developments must be defined, and the allocation of rights to such software must be stated.

m. Acceptance testing

The objective of this step is to ensure that the delivered GIS meets the contracted performance. Final payment should not be made until all tests have been satisfactorily completed. Activities are:

- Install the system
- Test functionality
- Test performance
- Test reliability

Installation may involve site preparation, establishment of communication system and development of special software and customized interface. The functionality and performance tests should be designed to ensure that contracted specifications can be achieved under normal operating conditions.

Reliability refers to system availability and recovery, under both normal operating conditions and stress. The contract may specify an availability requirement in terms of the maximum down time allowed per week to accommodate routine and emergency maintenance. Down-time should be closely monitored during acceptance testing. Recovery characteristics should be tested under all combinations of partial and total crash of both hardware and software.

n. Implementation

Activities in this final step are:

- Train users and support staff.
- Perform initial data capture and product development.
- Continue performance monitoring.

Training may be done in phases to build on the experience gained under operating conditions. The effectiveness of the training should be formally evaluated after each phase and the results reviewed in consultation with the vendor. The initial data capture and products should also be evaluated in consultation with the users and, if problems occur, the vendor.

Once the system is in routine operation, continuous performance monitoring should be introduced as a system management task. The performance data collected will help identify bottlenecks in the production process and enable system upgrades or procedure changes to be initiated.

Chapter 7

Recommendations for introducing GIS in PWD

While setting up of an extensive GIS require a series of activities, PWD can start the process with its in-house capacities with minimum cost implication. As planning and design are the two main areas where GIS can be of great help, a small GIS cell can be started with the existing human resources with some training. There is one Additional Chief Engineer (P & SP) who is responsible for planning and special projects who leads two project circles which are responsible for project planning. He also leads the Design Circles which are responsible for structural design of the infrastructures to be constructed by PWD. PWD has a good set up at the District level headed by at least one Executive Engineer at each District. The Department has experience in the field of construction for more than one hundred and fifty years and has a huge database at its record specially data on sub-soil exploration. These data can be utilized in preparing a database on soil properties for different Districts. A review of the location of the data must be carried out to prepare a strategy on how to divide a District into different geological zones and then sample sub-soil exploration on those zones can be carried out if existing data is not available. Thus a test GIS cell can be formed under the direct supervision of the Additional Chief Engineer (P & SP). PWD has a very good database on the inventory of the buildings which was constructed by PWD and also being maintained by it. This includes information like plinth area of the building, type of the building, year of construction, plinth level, highest flood level of the area, building material etc. What is necessary is to transfer these hard data into soft data to form a digital database. Then we need to put geo-code to each data to identify its location. Geo-code of each District, Thana, Union and Mouza is available. We have to use these codes to locate an infrastructure in District or Thana or even in the Unin or Mouza.This database can be linked with GIS software to show the spatial distribution of different types of infrastructure at a particular area. Once we have the data, we can prepare different theme or layer to show a specific aspect like the distribution of building exceeding a floor area by a certain amount.

The following set of actions are recommended to initiate GIS activities in PWD. Such as

- Formation of a small GIS cell under the direct supervision of Additional Chief Engineer (P & SP) with the help of the Sub-Divisional Engineers/Assistant Engineers working in Project Circles and with the Officers posted in Reserve.
- Providing training to these set of people on GIS software.
- Procurement of a GIS software. This can be operated with the existing hardware for the test run. PWD already has a plotter. So only a digitizer and some GPS machines would be necessary in some instances which can be procured under a project after the success of the test run of GIS cell.
- Arrange an orientation of the field staff about the objective of the program and also the types of data necessary at the moment.
- Exploration of the availability of all kind of sources of existing data both internal and external and taking all out initiative to collect them.
- Preparation of a good digital database with the help of these data. This would need to transfer the hard data into digital data by giving data entry into the database software. Hence a few data entry operator would be necessary.
- After completion of the database, this can be linked with GIS software to prepare different maps on different themes.
- After a test run of six months, a sharing session can be arranged to update the concerned staff about the facilities and analysis that can be provided and done with the help of GIS software.
- If found useful, demonstration can be shown to the line Ministry and also to the client Ministries.
- If found useful, a Technical Assistance Project can be prepared to seek donor to sponsor the project and to get approval of the Planning Commission. If no donor is found, it cane be implemented form GOB budget. It can be mentioned here that Government encourages such types of project based on information technology.

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