Urban Fire Hazard Modelling in Dhaka City Using GIS

by

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Abstract

Although disasters like cyclones and floods have overshadowed the threat from hazard, fire do cause considerable damage in our country. Urban areas are particularly vulnerable. The concentration of human settlements and the nature of economic activities in cities raise the risk of fire. As urbanization spreads and grows both horizontally and vertically, fire hazard poses an increasing threat that needs to be reckoned with. The study analyzes data on the incidents of fire in the area covered by the Mohammadpur Fire Station as a case study to draw an insight into the current situation regarding fires and fire fighting, identify site characteristics and assess risk of fire and also how the location of fire stations and access affect the spatial and temporal pattern of conflagrations the study uses the data obtained from official records and field surveys.

It was found that in absolute terms more incidents of fire have occurred in residential establishments than in either commercial or industrial areas. However, when the fact that there are many more residences than commercial or industrial units are considered, the incidences of fire in the latter do appear to be relatively more frequent. More importantly, there have been a high number of multiple incidents of fire in the same location for commercial land use, while not a single such case was found in land under residential use. Although the study area contains extensive tracts of slums, only about a fifth of the fires reported in residential establishments were in the slums. Electric short circuit was identified as by far the most significant source of fire for all types of settings, except for slums, where only one-tenth of the fires originated from short circuits. Leakage of gas lines turned out to be the second most prevalent source. It was found that shopping centres and filling stations have very high frequency of fire-feature ratio (0.1838 and 0.50 respectively). In spite of the commonly held view of very high vulnerability of slums and garment factories, they have a low frequency ratio. But duration of fire in slums is longer. When the composite score of risk of fire was calculated, it was found that commercial land use is in risk. Both planned and mixed residential areas, slums and institutional areas fall in low hazardous zone and industrial areas are in moderately hazardous zone. A little less than 60 percent of the fires were extinguished without the intervention from the fire station. Most of these incidents were short-lived. Fire fighters from the station extinguished nearly a fourth of fires that lasted for up to 15 minutes and all fires that had duration of over 45 minutes. In nearly 40 percent of cases, hindrances to fire fighting were reported. Access was a hindrance in only eight percent of reported cases. However, lack of fire fighting material and crowd obstruction were reported as significant hindrances. Based on the findings of the analysis, some policy measures for reducing the potential of damage from fire have been suggested.

CHAPTER ONE

1 INTRODUCTION

1.1 Background Information

The use of fire has been indispensable to Man since the very inception civilization. Fire has been put to a myriad of uses, from warding off predators to providing heat in a cold climate; from cooking food to running machinery. Although other forms of energy are now often used to perform many of these and other functions, these alternative forms of energy can create fire in an unwanted manner. While fire is essential for human society, failure to control it can unleash its inherent destructive power and cause great harm to society. Fire is then considered a disaster.

Disasters are often categorized as being either natural or man-made, though 'natural' disasters can often be linked to human intervention into the environment if traced back through successive links in a chain of triggers. Fire is a form of disaster that can have its origin either in nature per se or in human activities. Whatever the case, fire is a phenomenon that usually involves a process of occurrence, spreading, human countermeasures and then disappearance (Yan and Kubo, 1996). Fires can occur almost anywhere where inflammable material are present, spread in any direction depending on topographic and climatic factors and elements on the ground, and sustain itself for any period varying from a few minutes to days or weeks, depending on the fire load, effective countermeasures or natural deterrents, before finally dying out.

Although other forms of disasters, like cyclones and floods, have overshadowed the threat from fire hazard, fires do cause considerable damage in our country. Official records from the Fire Service and Civil Defense (FSCD) show that material damage due to fire in the Greater Dhaka districts (Dhaka, Narayanganj, Manikganj, Narsingdi and Munshiganj) alone were to the tune of Tk. 384.59 million in 1997. In Dhaka City much loss is caused every year due to incidents of fire and establishment of settlements, industries and expansion of trade and commercial activities with inadequate provision of mitigation facilities for fire hazard. Apart from human death and injury, damage of property in Dhaka City worth more than Taka 6 crore on the average is caused by fires every year (Sayeeduzzaman, 1990).

Urban settlements are particularly vulnerable to fire hazard. Urban areas are characterized by intense human activities in production, transport, service provision etc., and in virtually all these activities the danger of a fire breaking out exists to varying degrees. The density of human settlements with all their pertinent structures abates the spread of fire. The greater concentration of people and wealth means fires of similar intensity would risk more lives and property in a city than in a rural settlement.

Urbanization is taking place in Bangladesh very rapidly. Much of the measured urbanization is due to the migration into existing urban area from the countryside. Dhaka as the capital city of Bangladesh is growing both in area and population since after the independence of the country. Dhaka grew by 7.6 percent between 1970 and 1990 and grew by more than 3 percent per year between 1990 and 2000 which is much higher than the national growth rate. The present population of the city is about 6.5 million spreads over an area of 1500 sq. km. In recent days its area and population is increasing at a faster rate and it is expected to emerge as a megacity in 2015. (UNFPA, 1996), but this expansion of Dhaka City is taking place in a haphazard and unplanned manner with little or no attention to the issue of land use planning, which leads to increased occurrence of fire hazard. Increased population has been linked with more frequent urban conflagrations worldwide (Haessler, 1989). In Dhaka itself the rising frequency of fires has been noted (Sayeeduzzaman, 1990). During the study by Sayeeduzzaman, the number of incidents of fire in *thanas* of Dhaka Statistical Metropolitan Area had been reported to be 484 and 418 in the year 1987 and 1988 respectively. The Table 1.1 reveals the occurrence of incidents of fire in Greater Dhaka Districts in the last few years.

Table 1.1: Incidents of Fire in Greater Dhaka District in Different Years

Year	Incidents of Fire							Total
	Residential	Slum	Shop/ Shopping Centre	Garments	Gas/ Electricity	Industry	Others	
1995	133	31	153	40	118	112	70	657
1996	133	24	176	38	151	101	84	707
1997	144	34	132	42	131	114	109	706
1998	136	24	118	49	125	89	129	670
Total	546	113	579	169	525	416	392	2740

Source: Office Records, HQ, BFSCD, Dhaka, 1999.

Still now, fire risk areas in the city have not yet been identified. Moreover, due to lack of segregation of land uses, traffic congestion and narrow roads, in many cases, fire-fighting vehicles cannot reach the site of fire in time. Again, due to lack of adequate mitigation facilities, i.e., shortage of water supply and filling up of water bodies in Dhaka City, fire fighting appears to be facing severe operational problems. Therefore, the city seems to have suffered from more severe fires in the recent period, compared to those in the past. Since, incidents of fire tend to exhibit pronounced spatial variations in terms of frequency and magnitude, area specific intervention strategies appear to be more fruitful in mitigating fire losses (Sayeeduzzaman, 1990).

1.2 Objectives of the Study

The aim of the study is to analyze the probable fire proneness of the study area and its spatial relationship.

The specific objectives of the study are as follows:

1. To identify the characteristics of the area where incidents of fire occurred.
2. To examine the relationship of land use with incidents of fire.
3. To determine the fire hazard-proneness of the area and also assess the effects of existing mitigating facilities on the incidents of fire.

1.3 Rationality of the Study

Over recent days, even as progress has been made in understanding nature and controlling some of its negative effects, vulnerability appears to be rising. The number of disasters has risen, and the number of people affected and the value of property destroyed have also increased (International Federation of Red Cross and Red Crescent Societies, 1993). This is true for all types of hazards, both natural and man-made, including fire hazard.

Vulnerability has to do with future jeopardy and potential harm. To be vulnerable is to exist with a likelihood that some kind of crisis event may occur that will cause damage to one's health, life or the property and resources on which health and life depend. Early disaster studies identified natural hazards as the cause of vulnerability. Where the frequency or magnitude of the hazards are greater, vulnerability was greater. Where such events were infrequent, vulnerability was considered low (Anderson, 1993). According to UNDRO (1979), vulnerability represents the relationship between hazards (natural events, including their strength, magnitude and duration) and risk (exposure to events, measured essentially in terms of proximity). With this understanding of vulnerability, scientists, technologists and engineers have undertaken efforts to predict natural hazard events and to develop technologies that will enable human structures and systems to withstand their impacts. The assumption has been that such events, as "acts of nature", cannot be prevented. However, vulnerability could be reduced, these researchers believe, if it can be more accurately predicted as to where, when and in what magnitude these events will occur, and if it is possible to develop adequate controlling technologies to mitigate their negative effects (Anderson, 1993).

Technologies for mapping hazard-proneness, down to small specific micro-zones, provide precise scientific assessments of the likelihood of disaster vulnerability that can be used by local communities to decide whether and how to respond to reduce their risks (27^{th} International Geological Congress, Moscow, 1984).

Systematic and policy oriented research into hazard assessment and hazard reduction first began with the work of Gilbert White (1936, 1945). But until the 1970s there had been a limited amount of research in the field of structural fire prevention. On the other hand, there had been some excellent research in forestry fire prevention. A great deal of research has been done in both structural and forest fire prevention during the last quarter of the 20^{th} century (Robertson, 1989). From the various relevant research publications it is found that till now much research has been conducted on the issue of fire hazard including fire risk assessment and hazard analysis, and fire prevention, and a lot of models have been developed. But no in-depth study has been carried out in the field of spatial distribution of fire hazard and its probability of occurrence particularly in Bangladesh. So this study is the first such attempt in this regard.

1.4 Scope and Limitations of the Study

The scope of the study is limited within the framework of fact finding towards identifying the characteristics of the sites where incidents of fire occurred, relationship of incidents of fire with land use, determining the probability of occurrence of fire and developing a methodology for fire hazard mapping and also assessing the performances of fire service station in extinguishing fire hazard.

Relevant literature shows that the numbers of incidents of fire are comparatively lower in Bangladesh than in the United Kingdom. This is because many of the fire incidents are minor and are not reported (Ahmed, 1992). For the purpose of this study, only those fire incidents that were reported to fire serviee station or fire service headquarter irrespective of size or consequent damage, have been considered, although there may have been other unrecorded incidents of fire in the study area during the specified time period.

This model has been developed for the urban areas of Dhaka City. Due to limitation of time and resources, the study was kept limited to only within the service area of Mohammadpur Fire Station. But as far as the methodology is concerned, the model can be applied to any part of the city without modification.

The finding of the study would hopefully add to the knowledge and practice in planning and development of strategies for reducing fire hazard in urban areas of Bangladesh. It is expected that the study will generate interest among the future researchers to improve upon it taking care of other factors to develop multi-dimensional criteria for the establishment of policies for reducing the vulnerability of fire hazard.

1.5 Organization of the Dissertation

The dissertation consists of six chapters. The first chapter (Introduction) provides the background of the study, aim and objectives, rationale of the study and scope and limitations of the dissertation. The second chapter (Methodology of the Study) describes the different techniques and methods adopted to acheive the aims and objectives of the research. The third chapter (Review of Literature) provides the theoretical background of the study including discussion on relevant research done in the past, and various models and methodologies developed for fire risk assessment, hazard analysis and fire risk ranking. Various aspects of the application of GIS and hazard mapping and their integration with land use planning have been discussed in the fourth chapter (Application of GIS and Fire Hazard Mapping in Land Use Planning). Chapter five

(Analysis and Findings) describes the findings of analysis of land use and fire locations. This chapter also dwells upon the impact of existing fire mitigation facilities. The last chapter (Conclusion and Recommendations) provides policy guidelines for further improvement of fire situation in Dhaka City and a summary of major findings of the study. This chapter examines the acievement of aims and objectives of the study and indicates the areas for further research. This dissertation is also supplemented with appendices at the end

CHAPTER TWO

2 METHODOLOGY OF THE STUDY

In order to achieve the objectives of this study as described in chapter one, the following methodology was followed:

2.1 Selection of Study Area

The service area of Mohammadpur Fire Station (FS) was selected for the study. This is one of the largest areas served by a single FS. It has a wide a variety of land use and a diverse physical character. There are residential, commercial, some industrial and mixed land use in the area, as well as a number of educational institutions. Posh residences of the elite of the city adorn a part of the area, but there are also large tracts of slums in other parts. Some portions of the area are planned, the rest has developed in an unplanned, organic fashion. This varied quality of the area would suit the purpose of the study.

2.2 Collection of Data/Information

i. **Literature Survey:** Survey of relevant literature had been conducted for obtaining a thorough understanding of the problem. Special attention was given to risk/hazard analysis/assessment in this study with data from secondary sources. Relevant reading materials have been collected from various organizations such as Federal Emergency Management Agency (FEMA), U.S. Fire Administration (USFA), National Fire Protection Association (NFPA), International Association of Fire Chiefs, Country Fire Authority, Victoria etc. overseas organisations and relevant organisations in Bangladesh. Besides, the Internet was explored to obtain relevant information about fire hazard analysis.

ii. **Collection of Data from BFSCD and Compilation:** Firstly, the procedure of maintaining the records relating to fire incident data by BFSCD was observed.

Then a survey format was developed to collect relevant data relating to occurrence of fire including its locations, causes, consequences and duration of fire from BFSCD for the period under study i.e., from 1996 to 1998 and data was collected accordingly. A checklist of the aspects included in the survey format is presented in Annexure - 'A'. After gathering data from BFSCD, it was sorted and compiled, and was prepared for field investigation.

iii. **Collection of Base Map:** Cadastral survey (CS) map, which was used as base map, had been collected from the **Directorate of Land Records (DLRS).** A hard copy of digitized DCC road network map also had been collected from UCHP (Urban Community Health Partnership). Besides, map of location of slums in Dhaka City was collected from the Centre for Urban Studies (CUS) to know the location slums in the study area during study period.

iv. **Reconnaissance Survey:** In order to familiarize with the field condition reconnaissance visit was made. This helped to obtain preliminary information about land use, road network of the study area.

v. **Preparation, Pre-testing and Finalization of Questionnaires for Collecting Primary Data:** A set of questionnaire was prepared to collect data/information for the subject under study. The questionnaire was prepared for collection of information about the incident of fire from the owner/occupant of the property. The questionnaire had embodied the questions addressing the different aspects of the incident of fire in line with the objectives. The draft questionnaire has been tested and verified from the field to see how far the questions asked that could extract answers from the interviewees. The pre-tested questionnaire had then been modified and finalized. A checklist of the aspects included in the questionnaire is presented in Annexure - 'B'.

vi. **Field Survey:** The field survey was conducted to identify the locations where incidents of fire occurred, and broad land use for a period of fifteen days time span. During the survey work, location of Fire Service Station, garments industry, filling station, shopping centre etc. also been identified. Broad land use of the area was delineated in cluster according to their characteristics rather than plot to plot identification (such as slum area, residential area, commercial area etc.).

2.3 Digitization of Spatial Data and Database Preparation

Spatial data collected from field survey and other relevant sources were then digitized and prepared for further progress and analysis. The different steps of digitization and database preparation are discussed below:

i. **Digitization of Spatial Data:** The base map, slum coverage map and transportation network map collected from secondary sources have been digitized as different coverages. Broad land use data of the area including settlements, industrial and residential areas and rivers and/or water bodies and different locations where incidents of fire occurred as identified from the field survey ware digitized in two separate coverages. Other significant features including location of garment factories, filling stations, shopping centres, and slums also have been digitized and kept in different coverages as **Shape Files.**

ii. **Editing Digitized Data and Removing Errors:** The digitized maps were not free from errors. To remove the errors the digital maps were edited with the application of different editing commands of the Arcedit module of PC ARC/INFO. Mainly the following three types of errors are found during digitization: (i) Arc error (Dangle ARC)-undershoot and overshoot, (ii) Node error-dangling error and (iii) Label error-missing labels, too many labels and wrong label_ids.

iii. **Building Topology:** The CLEAN and BUILD commands have been executed after removing errors to build topology (i.e., point, line and polygon topology). After cleaning and building topology PAT (Point or Polygon Attribute Tables) and AAT (Arc Attribute Tables) have beeo prepared for further analysis.

iv. **Generating a Grid Based Database:** The whole study area was overlaid with a grid of 50 m. × 50 m. cells using the **Generate** command of **ARC/INFO Starter Kit** to perform quadrat-based analysis. This grid was generated to estimate the total number of different kinds features as explained in 2.4 and 2.5 ii.

v. **Generation of Sample Quadrats:** The themes of land use and grid database were merged using **Union** option of **Geoprocessing** extension tool of ArcView. The attribute data of the merged themes were then transfered into MS Excel and builtup areas were segregated from non-builtup areas. A random sample of 50 quadrats have been taken from the quadrats that contain builtup areas. Then the sample quadrats were plotted over the road network map using ArcView for collecting the structure-based data from the field.

vi. **Calculating the Shortest Route:** Shortest route distance from the FS to the point of fire was derived deploying **ADDROUTE** command of **NETWORK** module of **ARC\INFO,** by using the transportation network map collected from UCHP.

2.4 Field Survey (Sample Survey), Counting of Structures from Sample Quadrats and Data Entry into GIS

Again a field survey was conducted to count the number of structures and gather information about their (structure) use (such as non-slum residential uses, shop etc.) contain in each sample quadrat.

2.5 Data Analysis and Interpretation

Collected data were then analyzed and interpretation was made. Different steps of data analysis and interpretation are discussed below:

I. **Identification of Site Characteristics:** Characteristics of the site where incidents of fire took place was identified through field investigation. As site characteristics have changed in some cases since the occurrence of fire, local people were asked about the characteristics of the site at the time of fire. Characteristics include use of structure/land such as residence, slum, shopping centre, shop, filling station, garment factory etc. Besides, during reconnaissance survey and field survey, observation was made for identifying site characteristics of the whole area and this was compared with the characters of the location of fire incidents to identify characteristics of site having potential for fire hazard.

ii. **Estimating/Counting Various Land Use Features:** The total count of land use features including non-slum residential, shop etc. in the study area was estimated by multiplying the total number of quadrats in a particular type of broad land use with the count of features obtained from the sample survey in the same type of land use.

Some special features such as filling stations and shopping centres were counted from the field during conducting the land use survey. The number of garment factories that existed in the study area has been counted from the *Bangladesh Apparels & Industrial Directory 1998* (Shahjahan, 1998). The areas of slums and hospitals have been calculated from the land use map in terms of number of quadrats.

iii. **Determining the Ratio of Frequency of Fire Hazard:** The ratio of incidents of fire has been determined by dividing the observed frequency of fire of a particular type of land use during the study period with the total number of estimated or counted features of the same category. With this ratio of incidents of fire proneness of the area has been determined.

iv. **Analysis of Spatial Pattern of Incidents of Fire:** Along with calculating the frequency-feature ratio, Spatial Nearest Neighbor Analysis was performed applying **Arc View Scripts** to identify whether the incidents were clustered or randomly distributed over the area under study using the location of incidents of fire. 'R' value from the analysis indicates that how clustered or dispersed the points (or centroids of polygons and polylines) are distributed. A more detailed description of the logical framework of the process is given the Annexure-"C".

v. **Computing Composite Score of Fire Hazard in the Area:** Since the spatial data of different categories of land use features have been kept in different layers, an item on the ratio of the number of incidents of fire in a particular kind of feature and the total number of that kind of features was joined with that particular database of spatial coverage through database operation. Then, these different data layers were joined together through database operation. Hence, by adding fire proneness of different types of land use features contained in each quadrat, a composite score to fire hazard in each quadrat has been determined. Firstly, the composite score was obtained as floating point data. It was then converted into discrete integer values for ranking fire hazard proneness of the whole area.

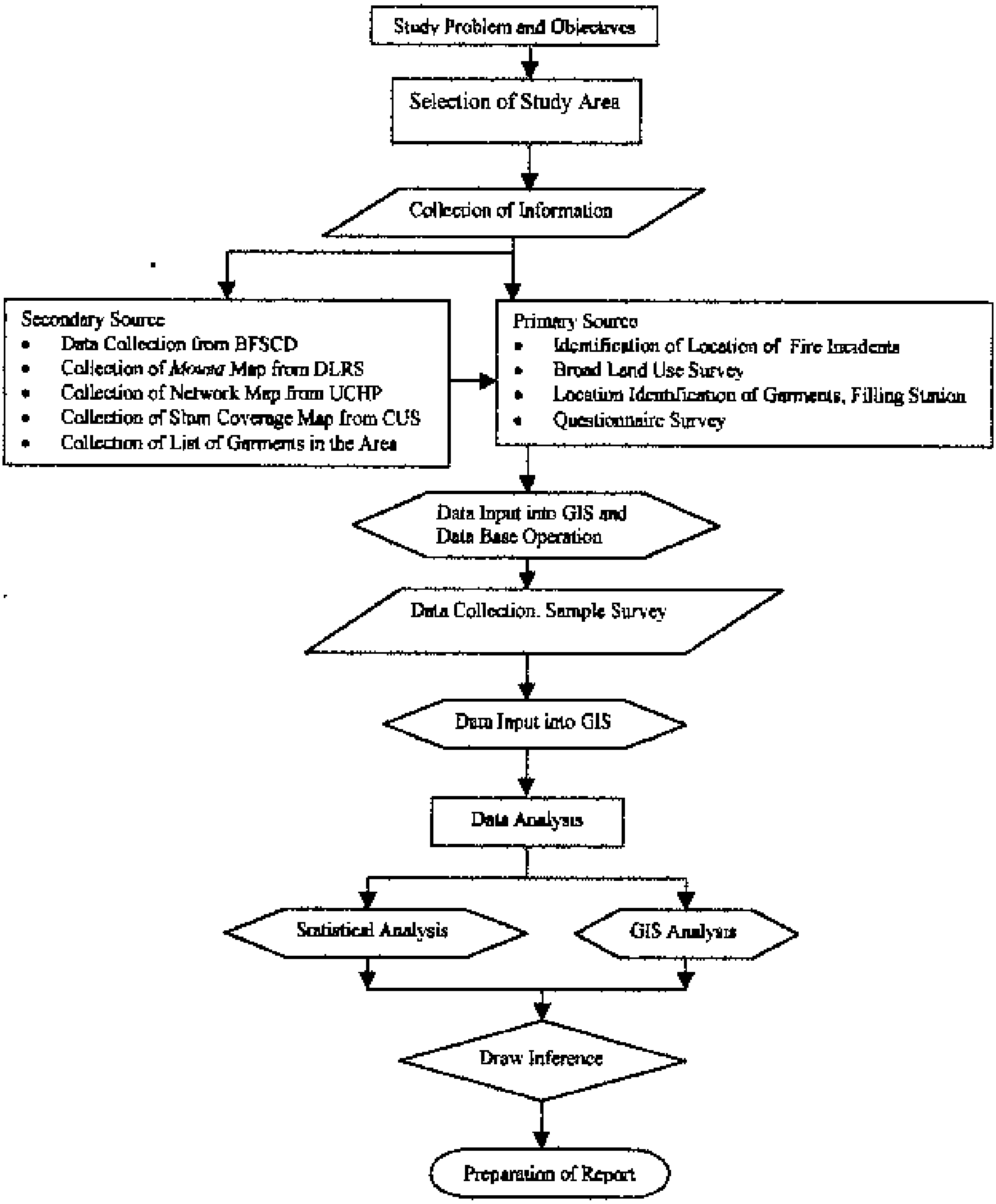
vi. **Ranking Hazard Proneness of the Area and Producing Hazard Map:** The obtained value of composite score is then categorized into twenty percent interval and then a five-point nominal scale has been chosen for categorizing fire proneness of the area. According to their severity such as very low, low, moderate, high and very high, final hazard proneness of the area has been determined. Finally, on the basis of ranking of fire hazard proneness of the area, a fire hazard map has been produced.

vii. **Determination of Effects of Existing Mitigation Facilities on Incidents of Fire:** Effectiveness of existing fire mitigation facilities has also been examined. This was done mainly by performing a chi-square test between duration of fire and distance of the FS from the location of incidents of fire. This was done in the following way:

Performing Chi-square Test: duration of fire for a particular type of vulnerability category may be influenced by a number factors. But due to lack of data, only the impact of service of fire service station on duration of fire has been taken into account to assess the influence of existing fire mitigating facilities. With this objective, shortest distance from fire service station to locations where incidents if fire occurred has been categorized into classes (such as very close, close, not so close and not so far, far, very far etc). Then, Chi-square was performed, assuming the null hypothesis that "there is no relationship between distance and duration", to identify whether there is any relationship between distance from fire service station and point of fires.

2.6 Flowchart Showing the whole study Process

Fig. 2.1: Schematic Diagram Shown below Indicating the Approach to the Study



CHAPTER THREE

3 REVIEW OF LITERATURE

3.1 Relevant Fire Researches

3.1.1 Early History of Fire Research

Until the 1970's there had been a limited amount of research in the field of structural fire prevention. On the other hand, there had been some excellent research in forestry fire prevention. A great deal of research effort has been expended in both structural and forest fire prevention during the last quarter of the 20^{th} century.

A revealing research project was conducted in the 1950's by the Ithaca (New York), Fire Department. The department decided to have feature articles written for the local newspaper to depict dangers inherent in the use of portable kerosene heaters and also to discourage its use. They learned that the newspaper campaign was of practically no value in reducing fire losses (Robertson, 1989). As a result of this experience, a survey was conducted to determine the newspaper reading habits of the individuals with the portable heater problem. An analysis of the city's fire records showed that practically all of the fires involving portable heaters occurred in lower-income residences. But most of them did not read the feature page of the newspaper.

3.1.2 U.S. Forest Service Fire Prevention Research

The Forest Service of the United States Department of Agriculture has carried out a number of excellent fire prevention research projects. Among them, the significant researches are: (i) smoking regulation sign (Folkman, 1965), (ii) children with matches (Folkman, 1966), (iii) public awareness of fire prevention importance (Folkman, 1965), (iv) research in fire prevention promotion and enforcement (LaMois, 1961), (v) research on arson fire (Bradshaw and Huff, 1985) etc.

3.1.3 High Risk Area Research in U.S.A.

New Orleans was the site of two significant research projects in fire prevention carried out with US federal government support. Both the studies were conducted by Planning and Research Associates, Inc. with the assistance of the New Orleans Fire Department. The researches are:

The first study concentrated on the human factor in high risk urban neighbourhoods (Planning and Research Associates, Inc., 1976). The goal of the study was to determine the economic, cultural, and demographic variables related to fire occurrence in a high fire risk urban residential area. The findings of the study are as follows: (1) the types and kinds of fire in the study area were similar to those found in high-risk areas in other cities, (2) fires are primarily caused by careless behaviour, by tolerant attitudes towards trash and debris and behaviour of juveniles and vagrants, and (3) fire proneness is the result of some human factors with specific sub-cultural characteristics such as (i) lack of strong spirit of the community, (ii) lack of fire safety training, (iii) lack of practice of fire precautions, (iv) lack of fire fighting facilities, and (v) an attitude towards fatalism towards fire.

The second study was on fire prevention program planning in a social action perspective. It was an exploratory study of knowledge, attitudes and leaders in a high fire risk area of New Orleans, Louisiana (Planning and Research Associates, Inc., 1977). The study attempted to determine what social action could be initiated at the local level to reduce the rate of fires and fire losses in residential areas with high-risk characteristics. It was found that there was often a distrust of outsiders in neighbourhoods. There was also a fear of involvement and distrust of programmes as well as a casual attitude towards fire prevention. It was also found that the residents of the area studied has a strong awareness of fire prevention programmes at the city level.

3.1.4 Fire Research in Australia

Jordan (1989) developed a fire hazard assessment model for the Country Fire Authority (Victoria), Australia. In developing the model he used the product of fire frequency and average sum insured, as the determinant of the level of fire hazard proneness of any property. Due to the absence of detailed damage statistics, he used the average sum insured for any property as the prime indicator of the consequence that may result if that property is under fire.

3.1.5 Research on Investigating City Characteristics and Residential Fire Rates

Tridata Corporation (1998) conducted a research on city characteristics and residential fire rates for United States Fire Administration (USFA), Federal Emergency Management Agency (FEMA) and National Fire Data Center. Objective of the study was to identify relationship between city characteristics and residential fire rates and also to help identify and clarify relationships between characteristics of people and places and fire risk. The causes included fire due to arson, children playing, careless smoking, cooking, heating, electrical distribution, appliances, and open flames. This represented that eight leading causes of fire account for over 90 percent of all residential fires in the U.S.A. Predictions about the relationship between city characteristics and city fire rates were tested by computing correlation coefficients and performing multiple regression analysis. It was found from the study that a high proportion of all fires that occur in the residential structures are directly attributable to human activities. Among the major findings of this study are: (i) particular city characteristics were found to be strongly related to fire rates. Cities with worse climates and older housing stocks had a greater likelihood of fire, (ii) fires due to arsoo, children playing, careless smoking, heating, and electrical distribution were found to be strongly related to at least one city characteristic, and (iii) cooking fires were not found to be strongly related to city characteristics.

3.1.6 Fire Research in Bangladesh

It was found from the literature survey that so far only two studies have been conducted on fire hazard in Bangladesh. One dealt with fire hazard analysis and the other concentrated on fire safety.

The only known research relating to fire hazard analysis in Bangladesh had been conducted by Sayeeduzzaman (1990). The main objective of this study was to develop a model to classify Dhaka SMA according to an index of relative fire hazard of various *thanas* and also to present a fire hazard assessment model and to delineate the fire hazard zones identified by the model to help identify area-specific mitigation strategies.

An Index of Relative Fire Hazardousness (IRFH) was developed in this study as a product of fire frequency and mean fire duration. It was found from the study that the higher population density accompanied by congestion, and lack of segregation of land use appeared to augment the probability of incidents of fire hazards. According to the findings of the study, higher mean duration has been observed in those *thanas* which are located in the peripheral regions of Dhaka SMA. According to the researcher, lower mean duration was mainly due to easy access to fire fighting services. But since access was not correlated with duration of fire in the study, the basis of this claim is dubious. The study area was classified into four hazard zones viz. (a) highly hazardous zone, (b) moderately hazardous zone, (c) less hazardous zone, and (e) least hazardous zone. The IRFH was also correlated with the density of population, and the result suggested that higher population density, with consequent congestion, have a significant role to play in determining the fire hazard of areas.

Another study was on developing criteria for fire safe shopping centres in Dhaka City, which had been conducted by Hossain (1995). The objectives of the study was to establish design guidelines on fire prevention, precaution and control measures of substandard shopping centres of Dhaka City, and also to set standards that might be included into building legislation and growing general awareness to encourage holistic approach against the current unsafe growth of shopping centres.

Qualitative standards of fire safety were developed in this study to provide guidelines to an appropriate design for fire prevention, precaution and control measures in planning shopping centres of Dhaka City. In establishing the design guidelines and standards the researcher reviewed the history of commercial growth, particularly of shopping centres in Dhaka City including the role of public agencies in controlling the growth of shopping centres and also the history of shopping centres in the developed countries. Fire science and fire safety aspects, legislation relating to shopping centres in UK and in Bangladesh also had been reviewed. The researcher also surveyed several aspects of shopping centres such as location, site, access, parking space, existing facilities, physical aspects of building service lines, fire incidents and fire safety measures and so on. Finally the researcher compared the situation of shopping centres of Bangladesh with that of developed countries and recommended design guidelines and set standards of building regulation.

3.2 Fire Hazard Analysis

Historically, most fire safety regulations have been on the basis of fire hazard analysis, where such assessments were based on the judgment of "experts." Today formal, scientifically based fire hazard analysis (FHA) is common and increasingly being required as a means to avert certain outcomes, regardless of their likelihood. Hazard analysis can be thought of as a component of risk analysis.

3.2.1 Steps in Performing an FHA

Performing a FHA is a fairly straightforward, engineering analysis. The steps include (Bukowski, 1997):

1. Selecting a target outcome
2. Selecting an appropriate method(s) for prediction
3. Analyzing the impact of exposure
4. Accounting for uncertainty

3.2.1.1 Selecting a Target Outcome

The target outcome most often specified is to avoid fatalities of occupants of a building. Another might be to ensure that fire fighters are provided with protected areas from which to fight fires in high-rise buildings. The U.S. Department of Energy (DOE) developed a set of objectives for performing an FHA for all DOE facilities (U.S. DOE, 1991). In Boston, the Office of the fire Marshal has also established a set of objectives for FHAs performed in support of the prescriptive requirements of the applicable code.

3.2.1.2 Selecting an Appropriate Method(s) for Prediction

Fire models: A recent survey (Friedman, 1991) documented 62 models and calculation methods that could be applied to FHA. Thus the need is to determine which ones are appropriate to a given situation and which are not. The key to this decision is a thorough understanding of the assumptions and limitations of the individual model or calculation and how these relate to the situation being analyzed.

Fire is a dynamic process of interacting physics and chemistry; so predicting what is likely to happen under a given set of circumstances is daunting. The simplest of predictive methods are the algebraic equations. Often developed wholly or in part from correlations to experimental data, they represent, at best, estimates with significant uncertainty. Yet, under the right circumstances, they have been demonstrated to provide useful results, especially where used to assist in setting up a more complex model.

Even if the model is correct, the results can be seriously in error if the data input to the model does not represent the condition being analyzed. Proper specification of the fire is the most critical, and was addressed in detail in the preceding subsection on selecting the design fire (s). Next in importance is specifying sources of air supply to the fire.

3.2.1.3 Analyzing the Impact of Exposure

In most cases, the exposure will be to people, and the methods used to assess the impacts of exposure of people to heat and combustion gases involves the application of combustion toxicology models.

3.2.1.4 Accounting for Uncertainty

Uncertainty accountability refers to dealing with the uncertainty that is inherent in any prediction. In the calculation, this uncertainty is derived from assumption in the models and from the representativeness of the input data. The FHA report should include a discussion of uncertainty. This discussion should address the representativeness of the data used and the sensitivity of the results to data and assumptions made. If the sensitivity is not readily apparent, a sensitivity analysis should be performed.

Finally it can be said that quantitative fire hazard analysis is becoming the fundamental tool of modern fire safety engineering practice, and is the enabling technology for the transition to performance-based codes and standards.

3.3 Fire Risk Analysis

Fire risk analysis is the most comprehensive form of analysis that can be applied to any fire safety choice. It provides a flexible framework for estimating the impact of any type of fire safety programme or strategy in terms of actual reductions in loss–deaths, injuries, property damage–and in terms that can be compared to the costs of those programs and strategies.

A measure of fire risk always has two parts: (1) a measure of severity (2) a probability distribution. The severity measure may also be separated, for the sake of clarity, into two parts. The first part is a specificatioo of the scale that measures severity. The second part is a specification of the rules for calculating the specific severity measure to be used for a particular fire. The probability distribution gives a probability for each value that the severity measure can take. Most often, a probability distribution gives a probability for every type of fire, and then rules for calculating the value of the severity measure for each type of fire provide the translation to a probability distribution for the measure of severity.

Three key elements of the fire risk analysis approach are; (1) the explicit estimation of all relevant probabilities, (2) the use of well-defined measures of severity, and (3) the explicit consideration of the uncertainty attached to all estimates developed in the analysis.

The term fire risk analysis has sometimes been used to refer to an exercise of listing locations under the jurisdiction of the analyst that present the greatest potential for fire damage or for demand on fire suppression resources. Fire risk analysis can sometimes be separated into (1) risk estimation and (2) risk evaluation. Risk estimation includes the estimation and analysis of the measures of severity and probability and their associated uncertainties. The most common approach to risk evaluation is cost-benefit analysis, a technique in which all benefits of risk reduction are translated into monetary equivalents. A variation is cost effectiveness analysis, in which the benefits of risk reduction are translated into a single non-monetary scale.

3.3.1 Methods of Fire Risk Assessment

Formal fire risk assessment evolved with the insurance industry in the 19th century. However, in the last few decades, there has been a move to develop more wide spread analytical procedures. Methods of fire risk analysis may be classified into four categories: (1) narratives, (2) check lists, (3) ranking, and (4) probabilistic methods (Watts, 1981).

Narratives: In the narrative risk assessment procedure, the information is presented in the form of descriptions of various hazardous conditions and ways to reduce or eliminate them. Narratives do not attempt to evaluate the fire risk quantitatively, rather, a risk is judged acceptable if it complies with published recommendations.

Checklists: A common accessory of fire safety is a listing of hazards and recommended practices. These checklists are valuable tools for identifying fire risk factors. Checklists attempt to identify important fire risk features.

Ranking: Quantitative fire risk assessment originated with the insurance rating schedule. The approach has broadened to include a wide variety of applications (Marchant, 1984; Nelson, 1988; Watts, 1992). In general, fire risk rating schedules assign values to selected variables based on professional judgement and past experience. The selected variables represent both positive and negative fire safety features and the assigned values are then operated on by some combination of arithmetic functions to arrive at a single value. This single value can be compared to other similar assessments or to a standard to rank the fire risk.

Probabilistic Methods: Growing interest in analytical fire risk assessment and an increasing data base have led to the use of more sophisticated mathematical techniques. Probabilistic methods manipulate fire safety variables according to recognized theoretical principles. These methods include computer simulation, linear regression, network analysis, and stochastic modelling.

3.3.2 Models of Fire Risk Assessment

The major aspects to be modelled can be grouped into six models (Hall, 1997): (1) decision model, (2) ignition-initiation model, (3) post-ignition model, (4) loss evaluation model, (5) cost model, and (6) cost-benefit comparison model.

Decision Model: In addition to defining types of fires and specifying general building and occupant characteristics, it is necessary to specify all the differences that would occur if the proposed changes were made. These specifications will dictate precisely what fire protection and fire-related features would be in place to influence the course of fire if one occurs.

Ignition-Initiation Model: The ignition-initiation model is needed to produce estimates of the probability of ignition per year, by type of fire, given a structure of fire scenarios and fire-relevant characteristics of the building and its occupants. The ignition-initiation model is a device for combining known probabilities in order to infer unknown probabilities.

Post-Ignition Model: The post-ignition model is used for estimating the severity of specified types of fires, given specified building and occupant characteristics and the status of all systems, features, products, and other changes being analyzed. It is a model of fire development and the outcomes consist of a set of linked time functiuns of fire characteristics and their effects.

Loss Evaluation model: The explicit or implicit assignment of monetary values to lives saved and injuries averted is the key element of this model. It is a difficult step that many people find distasteful or even immoral. The first and most important point to make is that individuals are not being asked to name a price for which they would be willing to die or suffer crippling injury. Instead, they are being asked to name a price they would be willing to accept to allow their current low risk of incurring death or injury in fire to increase or what they would pay to make that risk still smaller. If that point is made, the next task is identifying what particular figures should be used for the value of life and the value of injury when considering alternatives that change risks in the range characteristic of fire risk.

Cost Model: Cost may be divided into; (1) initial costs of the proposed changes being studied (2) the ongoing costs of these changes once they have been made and (3) the ripple effects on other costs, such as the need to increase the water supply to support a sprinkler system. The last could involve cost increases or cost reductions, including calculation of costs for many years into the future. To make this task manageable, the analysis can be set up in terms of the normal periods of maintaining, repairing, and replacing the items being analyzed. This is called life cycle costing.

Cost-Benefit Comparison Model: The cost model and loss evaluation model produce time streams of costs and risk reduction benefits that is, year-by-year estimates of costs and of reductions in fire deaths, injuries, and property damage, with the latter expressed as total monetized losses. To compare the costs to the benefits, the two time streams need to be combined into a single, manageable, indicator of net benefits. To compare future and present costs and benefits, it is necessary to decide what the future costs and benefits are worth in the present. This involves the concept of opportunity cost.

3.3.3 Steps of Fire Risk Assessment

Fire risk analysis is a technique capable of pulling together, reducing, and providing perspectives on large quantities of data from many sources. Recent rapid advances in the size and quality of fire-related data bases and in the power and affordability of computers have helped turn fire risk analysis into a practical tool for individual decision making and especially for large-scale decision making by governments and companies. The accelerating pace of development of computerized models of the development and occupant behavior will eventually produce integrated deterministic/probabilistic models, providing even more powerful tools for fire risk analysis.

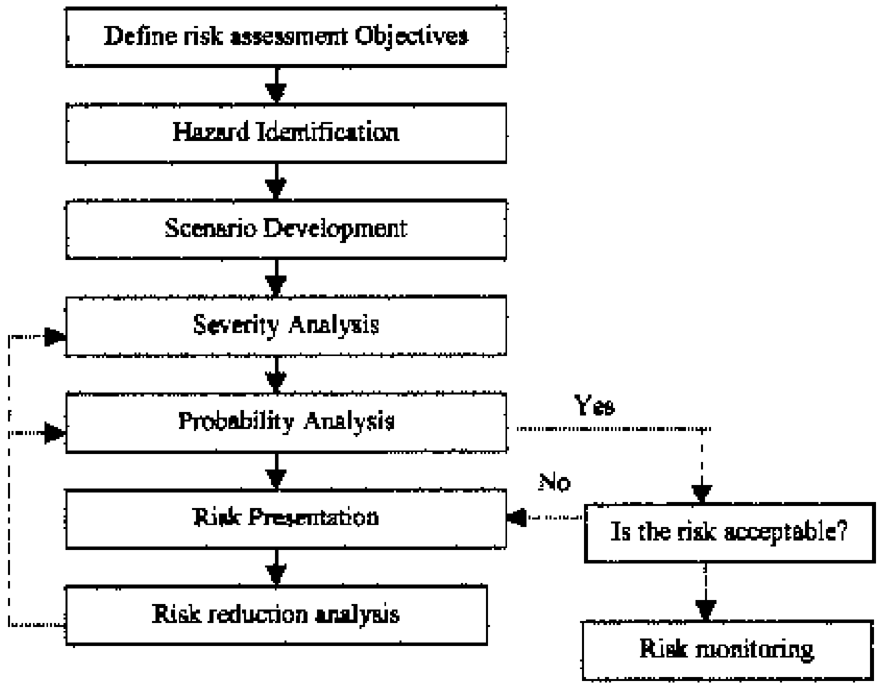


Fig. 3.1: Steps of Fire Risk Assessment

At present there are only a few abbreviated published examples of fire risk analysis. The largest single source of developmental studies in general-purpose fire risk analysis in the United States has been the National Fire Protection Research foundation, whose multi-year developmental project led to a method called FRAME works (for Fire Risk Assessmeot Method) (Emmons, 1990). Until better materials are available to demonstrate the specific analytic techniques of fire risk analysis, it is useful to recognize the essence of fire risk analysis. Whether the estimates consist of nothing more than a series of guesses or are the result of an elaborate network of sophisticated models, laboratory tests, and fire experience, the framework in principle remains the same. Task of probability analysis and risk presentation are specific to finding a solution for the project but are dependent on the completion of the other tasks.

3.4 Fire Risk Ranking

Fire risk ranking is a link between fire science and fire safety. Fire risk ranking is evolving as a method of evaluating fire safety that is valuable in assimilating research results. Detailed risk assessment can be an expensive and labor intensive process, and there is considerable room for improving the presentation of results. Ranking can provide a cost-effective means of risk evaluation that is both useful and valid. Fire risk ranking systems are heuristic models of fire safety. They constitute various processes of analyzing and scoring hazard and other risk parameters to produce a rapid and simple estimate of relative fire risk.

Fire risk ranking has gained widespread acceptance as a cost-effective prioritization and screening tool for fire risk assessment programs. It is a useful and powerful tool that can provide valuable information on the risks associated with fire. As defined here, it is the process of modelling and scoring hazard and exposure parameters to produce a rapid and simple estimate of relative risk. Fire risk ranking can be considered to be at the other end of the quantitative assessment spectrum. It defines the relationship between hazard and exposure by using more simplistic models requiring less data and less analysis. This approach produces measures of relative risk that can be compared to one another or to a standard.

3.4.1 Different Approaches to Fire Risk Ranking

It is difficult to describe a typical fire risk ranking method. The practical necessity of trying to assess dozens or hundreds of risks with limited resources has led to the creation of an array of fire risk ranking systems. Approaches to fire risk ranking are virtually limitless in their possible variations. Few examples of fire risk ranking are as follows (Watts, 1995):

3.4.1.1 Insurance Rating

The purpose of risk analysis is to facilitate the process of risk management. One of the most fundamental tools of risk management is transfer of risk by insurance. To be acceptable to an insurer, the risk is rated by actual means, applying principles of mathematics to the particular pricing problems of the insurance industry.

ISO Specific Commercial Property Evaluation Schedule: The most commonly used insurance rating schedule in the U.S. is the ISO (Insurance Services Office) Specific Commercial Property Evaluation Schedule (SCOPES). An important concept of insurance rating is the use of loss experience. In general, tabulated values and conversion factors are based on actuarial analysis of fire losses paid by insurers and reported to the insurance industry.

Gretener Method: In 1960, M. Gretener of the Swiss Fire Prevention Service began to study the possibility of an arithmetical evaluation of fire risk in buildings. His premise was that determining fire risk by statistical methods based on loss experience was no longer adequate for the some specific reasons (BVD, 1973).

As a result of this work, a new approach to schedule rating, the Gretener method, has been developing in Switzerland and Austria (BVD, 1973; Kaisar, 1980). The basic idea of the process consists of expressing, in relative, empirically derived numerical values, factors for a fire to start and spread and factors for fire protection.

3.4.1.2 Dow's Fire and Explosion Index

Today there are many risk assessment methods available that can examine a chemical plant in great detail. The Fire and Explosion Index (FEI), developed by Dow Chemical Company, remains a valuable screening tool that serves to quantify the expected damage from potential fire, explosion, and reactivity incidents and to identify equipment that could likely contribute to the creation or escalation of an incident (Scheffler, 1994). The concept of the Fire and Explosion Index (FEI) is to divide a process plant into separate operations or units and consider each of these individually. The key feature of the method is to identify the dominant combustible material in the unit being studied and assess its thermodynamic properties.

3.4.1.3 Fire Safety Evaluation System

The Fire Safety Evaluation System (FSES), (Benjamin, 1979; Nelson and Shibe, 1980) is a Schedule approach to determining equivalencies to the NFPA *101 Life Safety Code* (NFPA, 1994) for certain institutional occupancies. The technique was developed at the Center for Fire Research, National Bureau of Standards in cooperation with the U.S. Department of Health and Human Services in new editions of the *Life Safety Code* and is presently published in NFPA 101A, *Alternate Approaches to Life Safety* (NFPA, 1995).

Equivalency Concept: The FSES was developed to provide a uniform method of evaluation health care facilities to determine what fire safety measures would provide a level of fire safety equivalent to that provided by the *Life Safety Code.*

Fire Zone Concept: Unlike the *Life Safety Code,* the FSES subdivides a building into fire zones for evaluation. A fire zone is defined as a space separated from other parts of the building by floors, fire barriers, of smoke barriers.

Risk: Also unlike the *Life Safety Code,* the FSES begins with a determination of relative risk deriving from characteristics of a health care occupancy. Five occupancy risk parameters are used: (1) patient mobility, (2) patient density, (3) fire zone location, (4) ratio of patients to attendants, and (5) average patient age. Occupancy risk factor for a zone is calculated as the product of the assigned values for the five risk parameters.

3.4.1.4 Hierarchical Approach

Development of a hierarchical approach to fire risk ranking was initially undertaken at the University of Edinburgh, sponsored by the U.K. Department of Health and Social Services. This approach was further developed at the University of Ulster for application to dwelling occupancies. Most recently, it has been refined and implemented for the assessment of fire risk in telecommunications facilities. A generalized procedure for ranking fire safety parameters to determine their relative importance are as follows: (i) identify hierarchical levels of fire safety specification, (ii) specific items comprising each level, (iii) construct and assign values to matrices of each sequential pair of levels and, (iv) combine matrices to yield importance ranking of items.

The purpose of fire risk ranking is to provide a useful aid to decision making. It must be easy to apply but sophisticated enough to provide a minimum of technical viability. Credibility can also be improved through consistency and transparency.

From the above discussion, it is clear that since the beginning of fire research, a lot research has been conducted and much are still under way. As a result of such research, many models and methods have been developed mainly in the field of fire hazard analysis, risk assessment and fire risk ranking as an integral part of fire risk assessment. But the review of literature reveals that no significant research has been conducted in the particular field of spatial risk analysis, which is important to understand the land use impact of fire hazard. Hence, an attempt has been made in this study to spatially analyze the risk of fire.

CHAPTER FOUR

4 APPLICATION OF GIS AND FIRE HAZARD MAPPING IN LAND USE PLANNING

4.1 Introduction

In order to reduce the possible risk of fire hazard, there are two considerations to follow: (1) fire safety and/or prevention and (2) fire detection and control (protection) (Grimaldi and Simonds, 1996). All the aspects of fire protection, prevention and fighting involve site planning, internal planning, and the forms and materials of construction. Access roads for operating fire brigade appliances, distance between buildings to reduce radiation hazard and spread between buildings and access from roads and open spaces into the buildings for fire fighting must all be provided for effective fire protection (Ahmed, 1992). Along with these architectural treatments, land use planning in combination with hazard analysis and hazard mapping can play a vital role to mitigate fire hazard.

4.2 Land Use Planning and Control

The task of physical planning and design of any given area (city, district, region) is to translate the socio-economic aims of development into physical patterns of land use and to achieve an appropriate quality of organized environment necessary for human activities, well-being and satisfaction (UNDRO, 1976). Many communities, both developed and developing, continue to develop social activities, create new industry and invest in areas which have been recognized as risk areas without taking any protective measures or even bothering to estimate the risk (Akther, 1998). Inadequate land use also decreases resistance against disaster (Ogawa, 1995). Therefore, defining areas of potential risk and of differentiated risk level is one of the most important initial steps for physical planning (UNDRO, 1976). Many disasters can be reduced through a clear understanding of the natural phenomena, and careful planning before the disaster happens (ElDeen, 1981).

Whenever a disaster strikes, it strikes a certain type of land use. Within built-up areas of the cities there are some areas with a higher level of risk than others. Land use planing operates to prevent the market from developing at cross-purposes with the goals of other plans. This becomes a crucial issue for disaster prevention and it is particularly important that land use be regulated in disaster prone areas. Poor or nonexistent land use control not only maintains risk at a higher level but also has a cumulative effect, compounding and magnifying disaster over time (Akther, 1998). To deal with any specific hazard land use regulation and land use zoning as an integral part of land use planning can be an effective measure.

4.2.1 Land Use Regulation

Land use regulation and development restriction are the best long term means of firstly, planning of land to reduce hazard and secondly, of limiting the future growth in hazard prone areas. The purpose of these controls is to ensure that developments are appropriately sited and are used to prevent potential damage from unwise use of land in hazard prone areas.

4.2.2 Land Use Zoning

Zoning is the legal tool that is to zone the hazard prone lands in accordance with the probability of the land being an event taken place. It is used by towns, cities and countries to control and direct the use and development of land and property within their jurisdiction.

As a matter of fact, land use planning alone can do little to prevent any hazard. Risk analysis and hazard mapping in combination with land use planning can play a vital role to deal with.

4.3 Significance of Hazard Mapping in Preventing Hazard

The effect of disasters and its consequences on man and his physical environment depends on the location of socio-economic development as well as the magnitude of disaster. Hazard mapping tries to identify the land use at risk. It is the superimposition of risk zoning map over the existing land use map. Thus hazard mapping tries to identify the areas at risk. In drawing fire hazard map, fire probability map, accessibility map, population density map, land use map etc. are needed.

For preparing a comprehensive and more detail hazard map all necessary facts regarding the use of land including total number of population, population density, zone of influence of the service, building standard, ete. should be incorporated. Hazard map can be done for applications at different levels i.e., for urban, regional and national planning. The degree of complexity of hazard map depends upon usage and data required for specific application in a particular disaster zone. The map should be simple and understandable by the authorities and general public and also should avoid irreverent and sophisticated detail.

4.4 Scope of GIS in Potential Risk Analysis and Hazard Mapping

At present there is very little use of Land Information System (LIS) or Geographic Information System (GIS) in the whole planning process in third world countries including Bangladesh. Moreover, most of the planning is done in large scale with little detail.

GIS offers a valuable suite of tools and techniques for identifying and measuring hazard and assessing its spatial manifestation. Since GIS allows a researcher to identify both the composite hazard and vulnerability index, and the underlying dimensions of hazard and vulnerability, it might be interesting to study the difference in public policy interventions that might be needed in different areas in the event of a hazard. One of the key advantages of the GIS is the ability to vary parameters in a model to look at various outcomes in the form of "what if" analyses. Data on socio-economic classes could be incorporated into the study and the different impact of the variables on them may be studied (Ramchandran and Ronald, 1999). If socio-economic data along with location of incidents of a particular hazard and their magnitude, accessibility, human attitude and behaviour, mitigation facilities and so on, this would help to understand the magnitude of the effect of the hazard in a particular area.

For better understanding of potential risk of fire hazard, fire probability map including frequency, duration and magnitude along with location of occurrence, extent of damage, accessibility, distance from safer zone (such as water body, fire service station), ratio of structures, building material, human attitude and behaviour, existing mitigation facilities and so on should be incorporated into the hazard analysis model. GIS, as a decision support tool, allows the researcher to include all these parameters into the model as input indicator to obtain a clear picture of fire hazard proneness of the area.

4.5 Integration of Hazard Mapping with Land Use Planning

The prerequisite for producing a synthesis in the planning is a normative model of optimum land use or clear identification of tolerable risk (ElDeen, 1981). The location of each class of land use in different risk zones should be based on judgement by the technical person in consultation view the technical body. In zones of greater risk only restricted land use should be permitted. In zones of lesser risk, buildings that might be used during and after disaster (for example, flood shelter, temporary hospital) would be allowed. Certain activities (like storage of dangerous materials, communication facilities) should be located in non-hazardous areas or areas of least risk (Akther, 1998).

Hazard mapping as a component of hazard analysis evaluates and estimates the level of potential risk of a particular land use in an area. This could be integrated with risk zoning. Risk zoning can be used to identify the probability of damage for the particular land use. Hazard mapping is currently only aimed to identify the land use in risk. But with the integration of risk zoning it would be able to determine the extent of that risk.

Moreover, as the high-risk areas are identified in detail, it would be possible to perform the estimation in much more detail and reduce the impact.

Hazard reduction should be considered a significant parameter in development planning of a community and to do so hazard analysis should be incorporated as an integral part of the total development process. Every proposed development must analyze the risk of the location of an investment. New establishment should be encouraged to develop in low risk areas. For this hazard analysis is a must.

CHAPTER FIVE

5 ANALYSIS AND FINDINGS

5.1 Introduction

This chapter describes the findings of the analysis of land use and site characteristics of locations where fire took place. The study area was divided into 9 land use categories (Fig. 5.3). For the purpose of analysis residential land use has been categorized into non-slum and slum usage. For identifying location of slums, slum coverage map of 1996 produced by Centre for Urban Studies (CUS) has been used (Fig. 5.1). Because, the study started with the data beginning from 1996 to 1998, the slum coverage map appeared to be useful, since the slums are temporary settlements and at the time of conducting the land use survey most of the slums had been converted into other uses. So the actual location of slums for the study period could only be obtained from the map collected from CUS. Non-slum residential use includes detached houses, flat/apartments, public residential quarters, semi-*pucca* houses, *kutcha* houses etc. Commercial land use has been subdivided into shopping centres and others. Other commercial land includes shops, filling stations, banks, workshops, warehouses, auto repair shops, restaurants, *kutcha bazars* and so on. Clustering of shopping centres and other commercial activities has been defined as commercial area in the land use map (Fig. 5.3). Industrial land use has been classified as garments industry and others. Others include tanneries, different factories and bakeries. Institutional land use has been grouped into hospitals/clinics and others. Others consist of religious use (e.g. mosque), clubs, public office buildings etc.

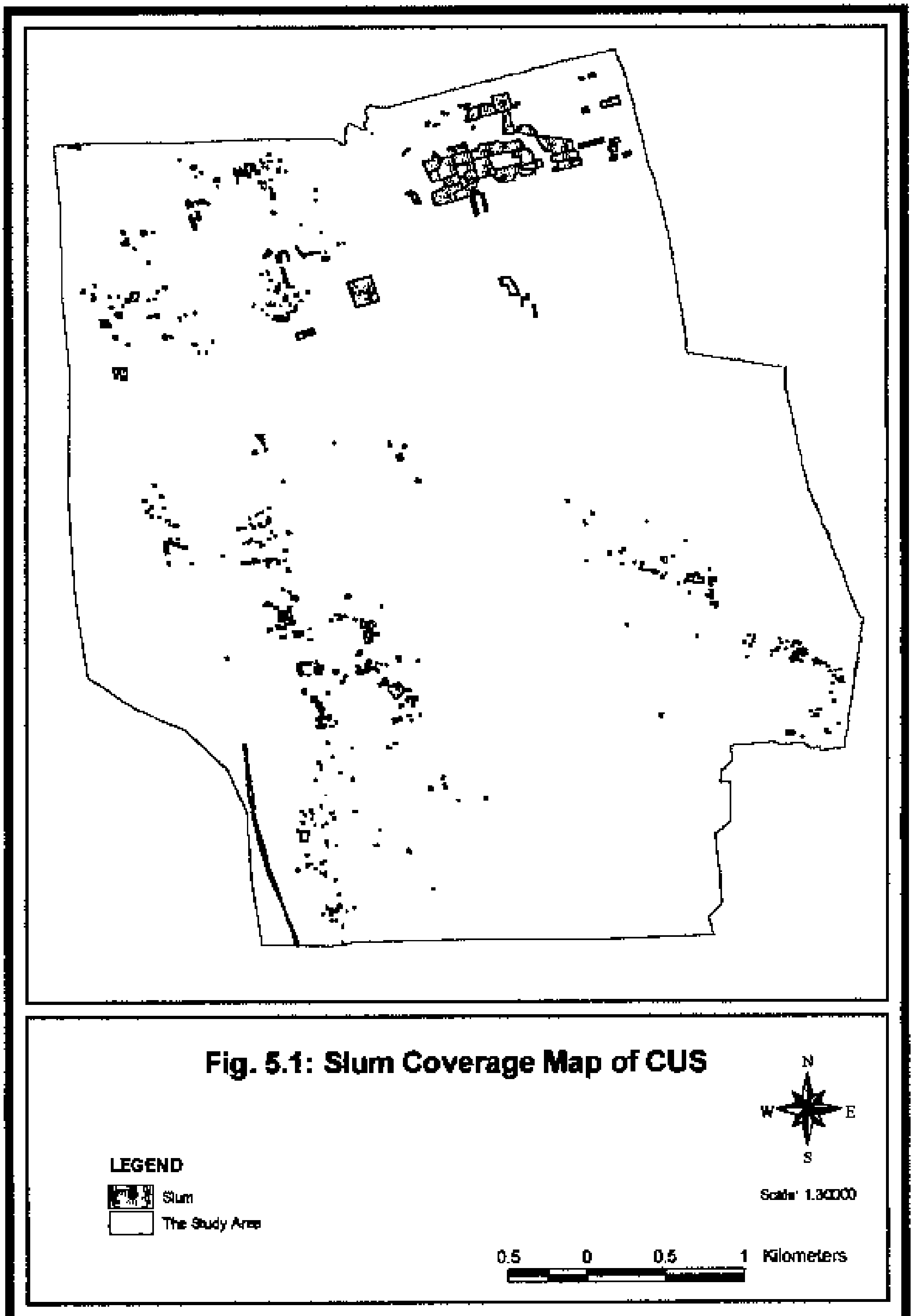


Fig. 5.1: Slum Coverage Map of CUS

5.2 The Study Area

The study area (Fig. 5.2) is roughly 18.66 km^2 of urban land bounded by the Turag River to the west, the Tejgaon area to the east, Agargaon at the northern end and the New Market area in the south. Fig. 5 3 shows the broad land use pattern of the area. Table 5.1 shows area of different categories of broad land use in the study area:

Table 5.1: Area of Different Categories of Broad Land use in the Study Area

Land Use	Area (in sq. km.)	Percentage
Planned Residential	4.51	24.17
Mixed Residential	5.63	30.17
Commercial	0.31	1.66
Industrial	0.21	1.13
Institutional	3.11	16.67
Slum	0.79	4.23
Recreational and Open Space	1.23	6.59
Water Body	0.18	0.96
Low Area	2.69	14.42
Total	18.66	100.00

Source: Calculated from Field Survey, 1999.

5.2.1 Service Population of Mohammadpur Fire station

Since the detailed results of the 2001 population census have not been published yet, the service population of the Mohammadpur FS for the year 2001 was estimated from the Census data of 1991 by using the decadal growth rate for each thana served by the FS The estimate shows that the total number of population served by the FS was 6,72,489 (Table 5.2).

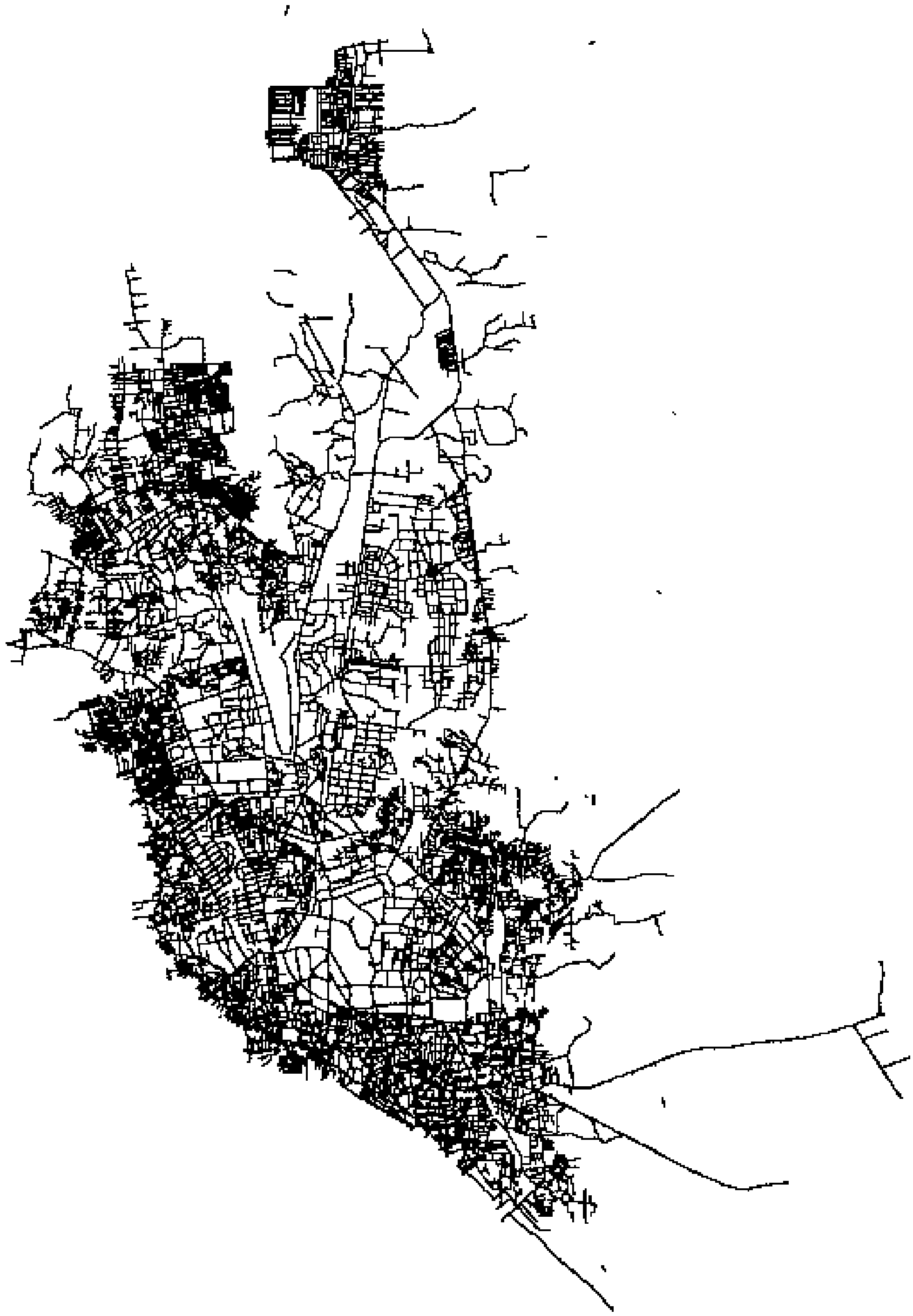


Fig. 5.2: Location of the Study Area with Respect to Dhaka City

Table 5.2: Service Population of Mohammadpur Fire Station

Thana	Population in 1991	Growth Rate (Decadal)	Population in 2001 (Estimated)	Area (in Sq. km.)		Population of the Study Area
				Thana	Study Area	
Dhanmondi	201529	78.33	359387	9.74	7.9875	294723
Mohammadpur	316203	43.98	455269	11.65	6.5525	256064
Tejgaon	220012	17.48	258470	8.75	4.12	121702
Total	737744	-	1073126	30.14	18.66	672489

Source: Estimated from the Census Data, B.B.S., 1991.

5.2.2 Site Characteristics of the Study Area

It has been found from observation that in mixed residential areas different structures of varying uses are established in an unplanned and haphazard way. It is a common sight in the study area that the same plot is being used, for example, for welding workshop, auto repairing workshop, restaurant, different shops, rickshaw depot etc. along with residential use in an unplanned way. In many cases, residential structures have been converted into garment and other factories Many of them are incompatible to residential land use, consume heavy electricity, gas and other combustible materials.

In this study, residential neighbourhoods designed by the Housing and Settlements Directorate (HSD) and private developers are considered planned residential areas. Among them, Dhanmondi, Mohammadpur and Lalmatia have been developed by HSD. At present Mohammadpur has been turned into a mixed residential area with varying uses. Garments industries have developed in the area by converting residential buildings. Unlike Mohammadpur, Lalmatia has not yet been converted. But, detached housing is being converted into large apartments. Data show that the frequency of fire is quite low in Lalmatia than in Mohammadpur. This is because of less invasion and succession of the area by non-residential uses. Dhanmondi, a planned residential area, has almost been turned into a commercial and institutional area. Several incidents of fire have been reported from Dhanmondi also.

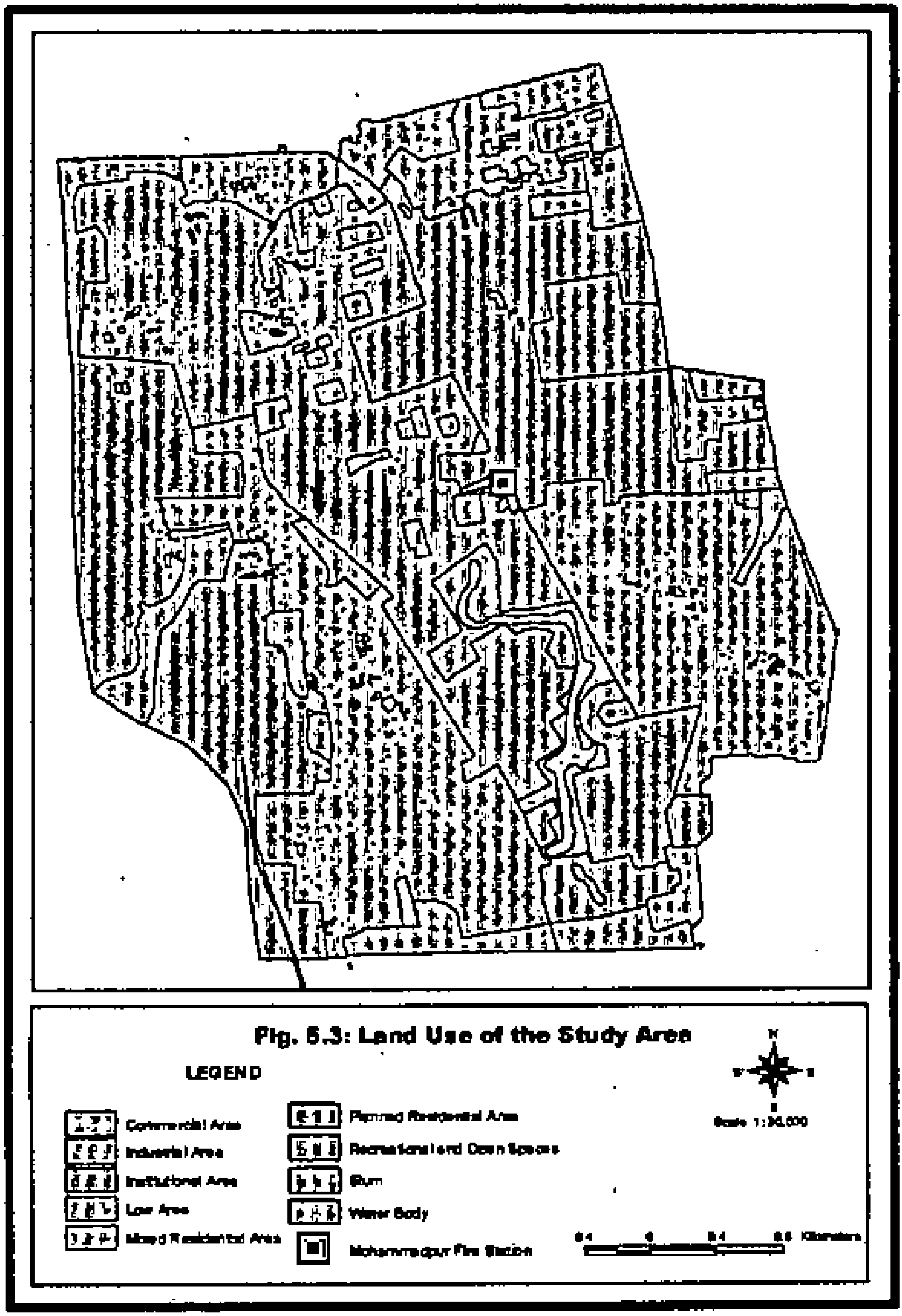


Fig. 5.3: Land Use of the Study Area

In this study areas with a large concentration of shopping centres and/or agglomeration of different commercial activities have been considered as commercial areas. These areas are most susceptible to incidents of fire, the frequency of fire reported in these areas is quite high.

There is a concentration of tanneries in the industrial area. These industries use different chemicals, which are inflammable. In case of institutional areas, there is low concentration of structures with significant amount of intervening open spaces. Therefore the number of incidents of fire reported in these areas is quite low.

5.2.3 Distribution of Hazardous and Incompatible Land Use in the Area

Table 5.3 indicates that hazardous and incompatible land uses including garment factories, shopping centers and filling stations are located in an unplanned way over space. The locations of these had been identified during the land use survey. Only those shopping centers which have developed in isolation in residential areas, rather than clustering in a commercial area, are shown here. The areas where shopping centres are clustered are not shown here. Those shopping centres have been indicated as commercial area as a whole, rather than identifying each individual shopping centre in the land use map. A total of 258 garment factories have been counted from *the Bangladesh Apparels & Industrial Directory 1998* (Shahjahan, 1998). Since secondary data used for the study is from 1996 to 1998, the directory of 1998 seemed useful as it contains such factories that existed during the same period. As a matter of fact, while identifying locations of the garment factories all the industries mentioned in the directory could not be found. It was possible to identify and locate only 81 garment factories in the field during the survey.

Data show that among the 81 garments, 33.33 percent are located in planned residential areas mainly in Lalmatia and Mohammadpur and 35.35 percent are located in mixed residential areas. In case of shopping centres, 8.08 percent are located in a planned residential area i.e., Dhanmondi residential area. Residential buildings have been converted to garment factories and shopping centres have been developed by demolishing residential buildings with no or insignificant fire prevention facilities. This is also true for garment factories. Among the six filling stations, two are located in planned residential areas and commercial areas each.

Since garment factories require heavy electricity consumption and use inflammable materials like cloths, these should be located in specially designed locations. But this sort of industries has mushroomed in residential areas without any planning consideration. On the other hand, although shopping centres are compatible to residential land use, the locations of most of shopping centres are not planned for the said purpose. They are simply converted from residential purpose to present uses. This type of use also requires heavy electricity consumption and also has various inflammable materials. Filling stations also use electricity and sell gasoline, which is a highly combustible material. Fig. 5.4 shows the locations of garment factories, shopping centres and filling stations by broad land use in the study area.

Table 5.3: Location of garments, shopping centers and filling stations over land use

Use of Structure	**Land Use of the Area**					**Total**
	Planned Residential	Mixed Residential	Commercial Area	Institutional Area	Slum	
Garments	33 (33.33)*	35 (35.35)	6 (6.06)	3 (3.03)	4 (4.04)	81 (81.82)
Shopping Centres	8 (8.08)	4 (4.04)	0 (0.00)	0 (0.00)	0 (0.00)	12 (12.12)
Filling Station	2 (2.02)	1 (1.01)	2 (2.02)	1 (1.01)	0 (0.00)	6 (6.06)
Total	43 (43.43)	40 (40.40)	8 (8.08)	4 (4.04)	4 (4.04)	99 (100)

Note: * Figures in the parentheses indicate percentage of column total

Source: Field Survey, 1999.

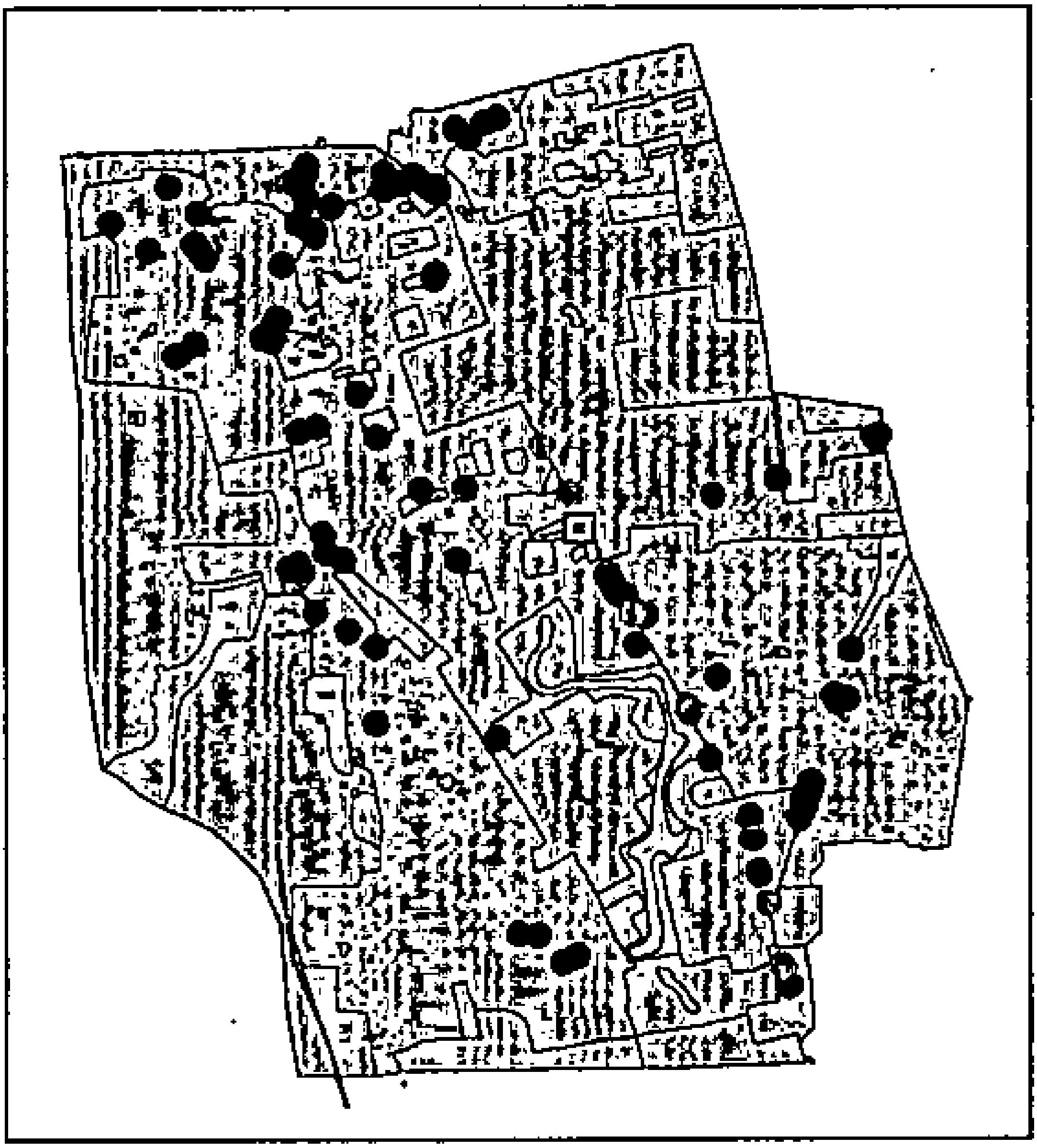


Fig. 5.4: Locations of Garment Factories, Filling Stations and Shopping Centres in Broad Land Use Zones

5.3 Distribution of Location of Fire Incidents and Site Characteristics

5.3.1 Pattern of Fire Location

Fig. 5.5 shows the locations where incidents of fire were reported between 1996 and 1998. It can be seen that some locations had multiple incidents within the span of three years. There were a total of 125 incidents of fire at 110 locations.

Table 5.4 shows the number of locations where there were reported incidents of fire and the number of such incidents by land use category. Apparently residential establishments have a higher share of the locations (48.18 percent) and incidents (53 percent) as compared to, say, commercial establishments (34 percent and 48 percent, respectively). However, since there are possibly many more residential structures than commercial or industrial, if the total number of each category of establishments is taken into consideration, the share of fire in those latter categories of land use may emerge to be significantly higher. Although figures do not exist on the total number or inventory of structures by category, a methodology has been devised to obtain an estimate. There is a widespread popular notion that slums are particularly susceptible to fire. However, this notion was not strongly supported by observed data. When the residential category of land use was further divided into slums and non-slum residential, only about 18 percent of the fires in residences were found to be in slums. 25 incidents of fire took place in 12 such centers within a span of three years. Field investigation revealed that most of these centers have 'sweatshops' in the top floors where workers work with inflammable material like cloth and paper in cramped, overcrowded conditions.

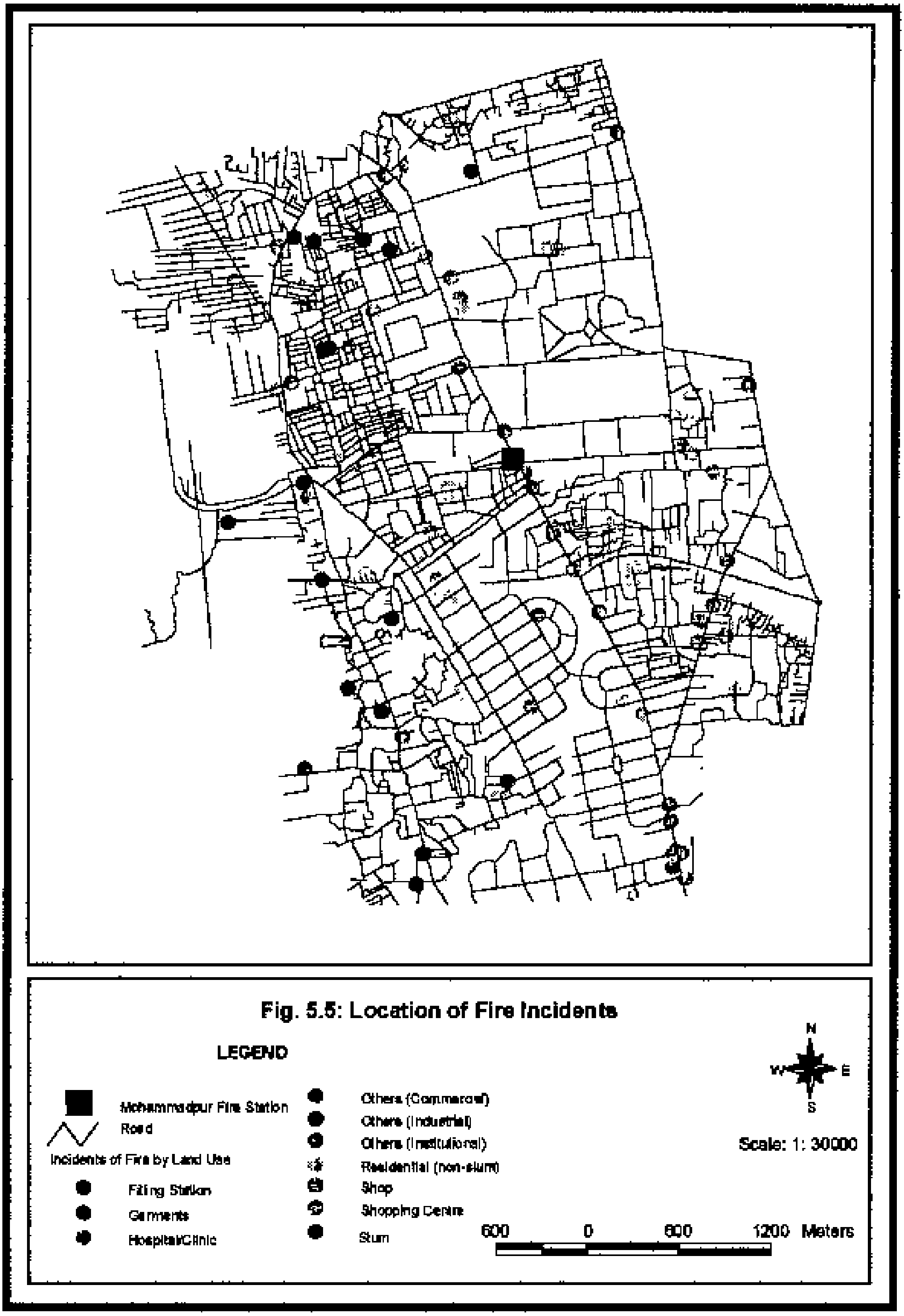


Fig. 5.5: Location of Fire Incidents

Table 5.4: Number of Fire Locations and Incidents by Land Use Category

Land Use/Use of Structure		No. of Fire Locations	No. of Fire Incidents
Residential :	Total	53 (48.18)*	53 (42.40)
	Slum	10 (9.09)	10 (8.0)
	Non-Slum	43 (39.09)	43 (34.40)
Commercial :	Total	34 (30.91)	48 (38.40)
	Shopping Centre	12 (9.60)	25 (20.00)
	Others	22 (20.00)	23 (18.40)
Industrial		13 (11.82)	13 (10.40)
Hospital/Clinic		3 (2.73)	3 (2.40)
Institutional/ Office		5 (4.55)	6 (4.80)
Others		3 (2.73)	3 (2.40)
Total		110 (100)	125 (100)

Note: * Figures in the parentheses indicate percentage of column total

Source: Field Survey, 1999.

5.3.2 Incidents of Fire by Structures

Table 5.5 shows the structures where incidents of fire occurred. The table reveals that for residential area most incidents of fire occurred in the *pucca* structures. When location is considered this share has been found to be 32.73 percent and if number of incidents is considered this share has been reduced (28.80). But the reverse situation is observed in case of commercial structures. At the location of incidents of fire, there were 19.09 percent of *pucca* structures. But the percentage increases to 28.80 percent, when number of incidents is considered. It is true for semi-*pucca* structures also and reverse situation is found in case of *kutcha* structures. Since, base data on structure is unavailable, it is not possible to draw any inference, whether *pucca*, semi-*pucca* or *kutcha* structures are more vulnerable.

Table 5.5: Number of Fire Locations and Incidents by Structure Category

Land Use/Use of Structure		No. of Fire Locations	No. of Fire Incidents
Residential :	Total	53 (48.18)*	53 (42.40)
	Slum	10 (9.09)	10 (8.0)
	Pucca	36 (32.73)	36 (28.80)
	Semi-pucca	5 (4.54)	5 (4.0)
	Kutcha	2 (1.82)	2 (1.6)
Commercial :	Total	34 (30.91)	48 (38.40)
	Pucca	21 (19.09)	30 (24.00)
	Semi-pucca	9 (8.18)	14 (11.20)
	Kutcha	4 (3.64)	4 (3.20)
Industrial	Total	13 (11.82)	13 (10.40)
	Pucca	9 (8.18)	9 (7.20)
	Semi-pucca	4 (3.64)	4 (3.20)
Institutional	Total	10 (9.09)	11 (8.80)
	Pucca	9 (8.18)	10 (8.0)
	Semi-pucca	1 (0.91)	1 (0.8)
Total		110 (100)	125 (100)

Note: * Figure in the parenthesis indicates percentage

Source: Field Survey, 1999

5.3.3 Distribution of Location of Fires in Land Use

Table 5.6 shows the incidents of fire over the land use. The table indicates how the different establishments where incidents of fire occurred, such as garment factories, different industries, commercial activities etc. are often located in inappropriate land use zones. Garment factories are labour intensive industries and a nuisance to residential use. They also require heavy consumption of electricity. A significant share of incidents of fire (5.45%) took place in garment factories located in the planned residential areas, and shopping centres (3.64%) located in mixed residential areas. The locations of other categories are also shown in the table. This indicates that the use of structures is not taking place in a planned way, which is contributing to the risk of fire in safe land use zones. Distribution of incidents of fire over land use zones is shown in Fig. 5.6.

Table 5.6: Distribution of Fire Locations by Land Use of the Area

Type of Land Use	Planned Residential Area	Mixed Residential Area	Slum	Commercial Area	Industrial Area	Institutional Area	Grand Total
Residential (non-slum)	16 (14.55)*	24 (21.82)	0	0	1 (0.91)	2 (1.82)	43 (39.09)
Slum	2 (1.82)	1 (0.91)	7 (6.36)	0	0	0	10 (9.09)
Filling Station	0	0	0	1 (0.91)	0	1 (0.91)	2 (1.82)
Shop	2 (1.82)	3 (2.73)	0	0	0	2(1.82)	7 (6.36)
Shopping Centre	1 (0.91)	4 (3.64)	0	7 (6.36)	0	0	12 (10.91)
Others (Commercial)	5 (4.55)	6 (5.45)	0	1 (0.91)	0	1 (0.91)	13 (11.82)
Garments	6 (5.45)	1 (0.91)	0	0	0	0	7 (6.36)
Others (Industrial)	1 (0.91)	3 (2.73)	1 (0.91)	0	1 (0.91)	0	6 (5.45)
Hospital/Clinic	1 (0.91)	0	0	0	0	2 (1.82)	3 (2.73)
Others (Institutional)	1 (0.91)	1 (0.91)	0	1 (0.91)	0	4 (3.64)	7 (6.36)
Grand Total	35 (31.82)	43 (39.09)	8 (7.27)	10 (9.09)	2 (1.82)	13 (11.82)	110 (100)

Note: * Figures in parentheses indicate percentage of matrix total

Source: Field Survey, 1999

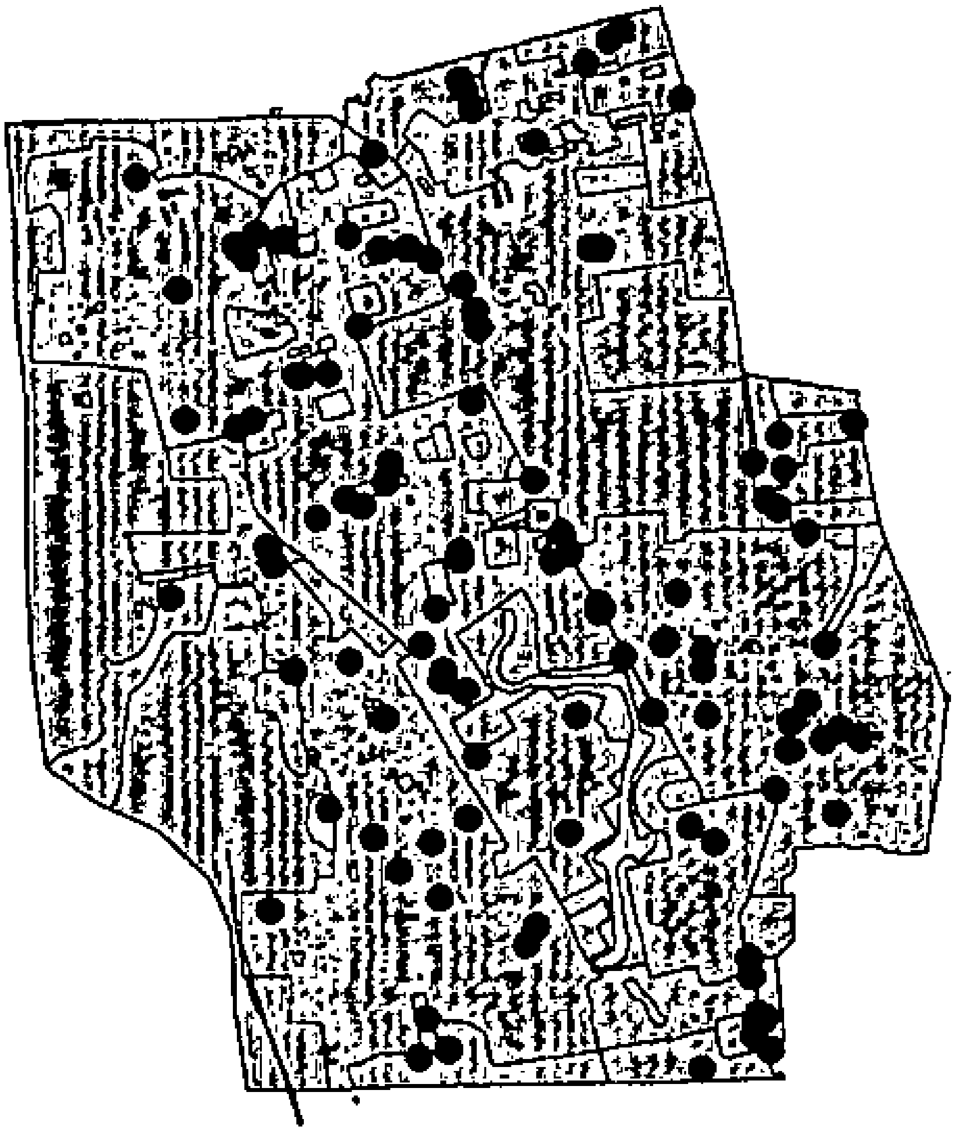
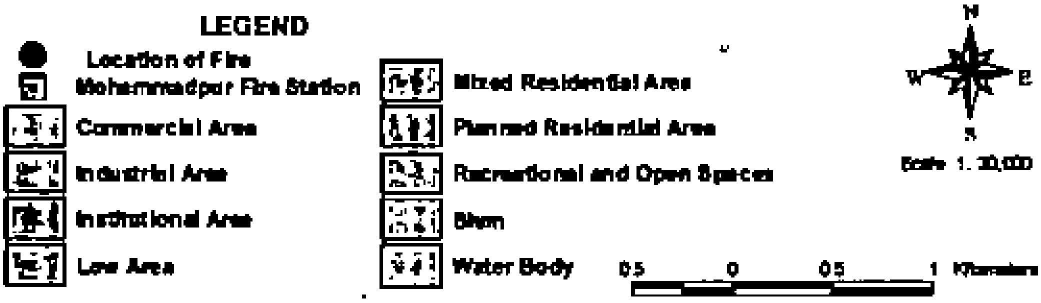


Fig. 5.6: Distribution of Incidents of Fire in Land Use



5.4 Source of Fire

It is important to learn what the major causes of fire are to assess the risks involved in a given situation as well as to formulate strategies to reduce risks. In an overwhelmingly majority (61.60 percent) of causes, the root of the fire has been found to be in electric short circuits (Table 5.7). Short circuit was the major source in all types of land use except in slums, where only one out ten incidents (10 percent) had originated in an electric short circuit (Table 5.8). Gas line leakage came in a distant second with 12.00 percent of cases.

Table 5.7: Sources of Fire

Source of Fire	Frequency	Percentage
Electriu short circuit	77	61.60
Gas line leakage	15	12.00
Kerosene/gas stove	7	5.60
Open lamp/candle	7	5.60
Cigarette	4	3.20
Arson	3	2.40
Electric heater (cooking)	3	2.40
Over heated machine	3	2.40
Mosquito coil	1	0.80
Unknown	5	4.00
Total	125	100.00

Source: Field Survey, 1999.

Table 5.8: Percentage of Fires Originating from Electric Short Circuit

Land Use/ Use of Structure	No. of Fire Incidents Originating in Short Circuit	% of Fire Incidents Originating in Short Circuit
Residential: Total	30 (53)*	56.60
Slum	1 (10)	10.00
Non-Slum	29 (43)	67.44
Commercial: Total	29 (48)	61.70
Shopping	19 (25)	76.00
Centre	10 (23)	45.45
Others		
Industrial	10 (13)	76 92
Institutional	8 (11)	72.73
Total	77 (125)	61.60

Note: *Figure in the parenthesis indicates total number of incidents of fire

Source: Field Survey, 1999.

5.5 Duration of Fire

Table 5.9 shows that 37 (29.60 percent) of the 125 reported fires were rather minor, lasting for less than 15 minutes, while it took more than 45 minutes to extinguish 16 (12.80 percent) of the 125 fires. It is seen from the table that the mean duration for residential area (35.58) is higher than the sample mean (32.30). This is due to higher average duration in the slums. The mean duration of fire was significantly higher in slums, 67.8 minutes as compared to 28.09 minutes in the non-slum residential category. The higher average duration was largely due to one extreme event, however. Another important fact that is revealed from the table is that commercial establishments, more specifically some shopping centers, are particularly prone to fire hazards. The table also illustates that hospitals and clinics have a higher mean duration (55.00). This may be due to the use of different medicines and chemicals that are inflammable.

Table 5.9: Duration of Fire by Land Use Category

Land Use/Use of Structure		Range of Duration of Fire (in Minute)				Total	Mean
		0-15	16-30	31-45	45+		Duration
Residential: Total		15 (12.00)*	18 (14.40)	13 (10.40)	7 (5.60)	53 (42.40)	35.58
	Non-Slum	14 (11.20)	14 (11.20)	11 (8.80)	4 (3.20)	43 (34.4)	28.09
	Slum	1 (0.80)	4 (3.20)	2 (1.60)	3 (2.40)	10 (8.00)	67.80
Commercial: Total		15 (12.00)	11 (8.80)	17 (13.60)	5 (4.00)	48 (38.40)	30.06
	Shopping Centre	6 (4.80)	6 (4.80)	9 (7.20)	4 (3.20)	25 (20.00)	33.16
	Others	9 (7.20)	5 (4.00)	8 (6.40)	1 (0.80)	23 (18.40)	26.70
Industrial: Total		5 (4.00)	4 (3.20)	2 (1.60)	2 (1.60)	13 (10.40)	29.77
	Garments	3 (2.40)	3 (2.40)	1 (0.80)	-	7 (5.60)	21.71
	Others	2 (1.60)	1 (0.80)	1 (0.80)	2 (1.60)	6 (4.80)	39.17
Institutional: Total		2 (1.60)	6 (4.80)	1 (0.80)	2 (1.60)	11 (8.80)	29.27
	Hospital/clinic	1 (0.80)	-	-	2 (1.60)	3 (2.40)	55.00
	Others	1 (0.80)	6 (4.80)	1 (0.80)	-	8 (6.40)	23.56
Total		37 (29.60)	39 (31.20)	33 (26.40)	16 (12.8)	125 (100)	32.30

Note: * Figure in the parenthesis indicates percentage

Source: Field Survey, 1999.

5.6 Spatial Relationship of Incidents of Fire

To determine the spatial relationship of fire hazard Nearest-Neighbour Algorithm of Cluster analysis has been carried out by adopting an Avenue Script of ArcView to know whether the locations of fire are randomly distributed or clustered. Besides, a technique has been devised to reveal the ratio of incidents of fire, since plot to plot structure-based data was not available. Finding of the analysis are discussed below:

5.6.1 Cluster Analysis

Cluster analysis involves the grouping of entities that are similar to one another. The entities may be observations. Several decisions must be made by users of cluster analysis. For one thing, they must first decide that it is worthwhile to use formal clustering rather than simply to group their observations or variables on the basis of inspection and judgement. Then, the users must decide how the similarity or dissimilarity between entities is to be measured. They must also select one of many possible procedures for constructing cluster of entities. In fact, cluster analysis might best be thought of as a collection of techniques for grouping entities. In using cluster analysis the user must specify both a measure of dissimilarity (or similarity) and a method of grouping, e.g., ordinary, or Euclidean, distance (or, more accurately, distance squared) to reflect dissimilarity. Different algorithms of cluster analysis are (Jackson, 1983):

- The Nearest- Neighbour Algorithm
- Farthest-Neighbour Algorithm
- Minimum-Squared Error Method
- Hill-and-Valley Methods

For the purpose of the required analysis, the Nearest-Neighbour Algorithm was utilised.

The Nearest- Neighbour Algorithm

Nearest neighbour analysis is a common procedure for determining the spatial arrangement of a pattern of points within a study area. The distance of each point to its "nearest neighbour" is measured and the average nearest neighbour distance for all points is determined. The spacing within a point pattern can be analysed by comparing this observed average distance to some expected average distance, such as that for a random (Poisson) distribution. The nearest neighbour technique was developed originally by biologists who were interested in studying the spacing of plant species within a region. They measured the distance separating each plant from its nearest neighbour of the same species and determined whether this arrangement was organised in some manner or was the result of a random process. Geographers have applied the technique in numerous research problems, including the study of settlements in central place theory, economic functions within an urban region, and the distribution of earthquake epicentres in an active seismic region. In all applications, the objective of nearest neighbour analysis is to describe the pattern of points within a study area and make inferences about the underlying process (McGrew and Monroe, 1993).

The first practical method for grouping i.e., agglomerative method, which is used in nearest-neighbour algorithm. The name arises from the fact that such algorithms begin with the objects, all considered to be individual points, and proceed to build up clusters by joining points successively into groups. The nearest-neighbour algorithm begins by joining closest points, where the distance between each pair of points is calculated in terms of squared Euclidean distance. The nearest-neighbour method next calls for examining the distances between all entities (groups and ungrouped points) and merging the closest two. To follow this procedure, somehow it is required to define the squared distance between a group and a point. In the nearest-neighbour procedure, the distance between two entities is defined as the shortest of the distances between one point in one entity and one point in the other. Hence, the name nearest neighbour. This procedure, like most agglomerative techniques, starts with the individual points and proceeds until all the points have merged into a cluster (Jackson, 1983)

The 'R' value from the analysis indicates how clustered or dispersed the points (or centroids of polygons and polylines) are distributed. An R value of 0 (zero), indicates an intensely clustered pattern, while an R value of 1 indicates a random distribution, and an R value of 2 (or higher) indicates strongly dispersed or organized pattern. The Nearest Neighbourhood technique was employed to ascertain the pattern of the locations of fire incidents. A value of 0.06 was obtained which suggests that the points indicating the locations were more clustered than random.

5.6.2 Relationship of Incidents of Fire with Land Use

Since no data is available on plot to plot structures and their use, it was necessary to resort to some estimation technique to assess the inventory of different kinds of features. The technique used and findings from the process are discussed below:

The employed procedure started with generating a grid containing 7464 quadrats, each with an area of 50×50 m^2, using the **Generate** command of **PC ARC/INFO Starter Kit,** that covered the whole study area. Then, after overlaying the grid over the broad land use map, by using the **Union** option of the **Geoprocessing** extension Tool of ArcView, the attribute database of the merged themes were transferred to **MS Excel** for segregating the quadrats comprising of builtup area and non-builtup area. Table 5.10 shows the quadrats that contain builtup and non-builtup areas. A sample of 50 quadrats was selected (0.85866% of total quadrats that contain built-up area), using a random sampling technique (A list of selected sample quadrats including their land use is shown in **Annexure-"D"**). The locations of the sample quadrats are shown in Fig. 5.7. From the sample survey it was found that there are 134 shops, 231 non-slum residences and 10 institutional land use other than hospital/clinic in the sample quadrats. A list of the number of shops and non-slum residences, commercial establishments other than shopping centres and other institutional establishments by land use category obtained from sample survey is given in **Annexure-E.** Based on the number of sample non-slum residences, shops, other commercial and other institutional establishments the total numbers of non-slum residences, shops, other commercial and institutional structures other than hospital/clinic have been estimated. The total number of features in a broad land use has been estimated using the following expression:

$$N_{ij}=(Q_j \times n_{ij})/ q_j \quad .. \quad .. \quad ... \quad ... \quad ... \quad ... \quad (5.1)$$

Where, N_{ij} = Estimated total number of features of type i in quadrat of land use category j.

Q_j = Total number of quadrats in broad land use category j.

q_j = Number of sample quadrats in land use j.

n_{ij} = Number of features of type i counted in sample quadrats of land use category j

Table 5.11 shows an estimation of shop, non-slum, commercial (others) and institutional (others) land uses by broad land use category in the study area.

Along with this estimation, the areas of shopping centres, slums and other industries in the study area have been calculated in terms of number of quadrats. The number of filling stations, shopping centres and other industries were counted the during field survey. The list of garment factories was obtained from the *Bangladesh Apparels & Industrial Directory 1998*.

On the basis of estimated and counted or calculated total number of features in each land use category, the ratio of frequency of fire for a particular type of feature and total number of features in each land use was calculated (Table 5.12). This is taken to be an indicator of fire vulnerability of land use features. This indicator has been termed as score.

Table 5.10: Number of Quadrats Area by Land Use Category

Type of Area	Land Use	No. of Quadrats	Area (in sq. meters)	Total No. of Quadrats
Builtup Area	Planned Residential	1805	4512500	5823
	Mixed Residential	2253	5632500	
	Commercial	124	310000	
	Industrial	83	207500	
	Institutional	1242	3105000	
	Slum	316	790000	
Non-builtup Area	Recreational and Open Space	492	1230000	1641
	Water Body	71	177500	
	Low Area	1078	2695000	
	Total	7464	18660000	7464

Source: Calculated from Land Use Map.

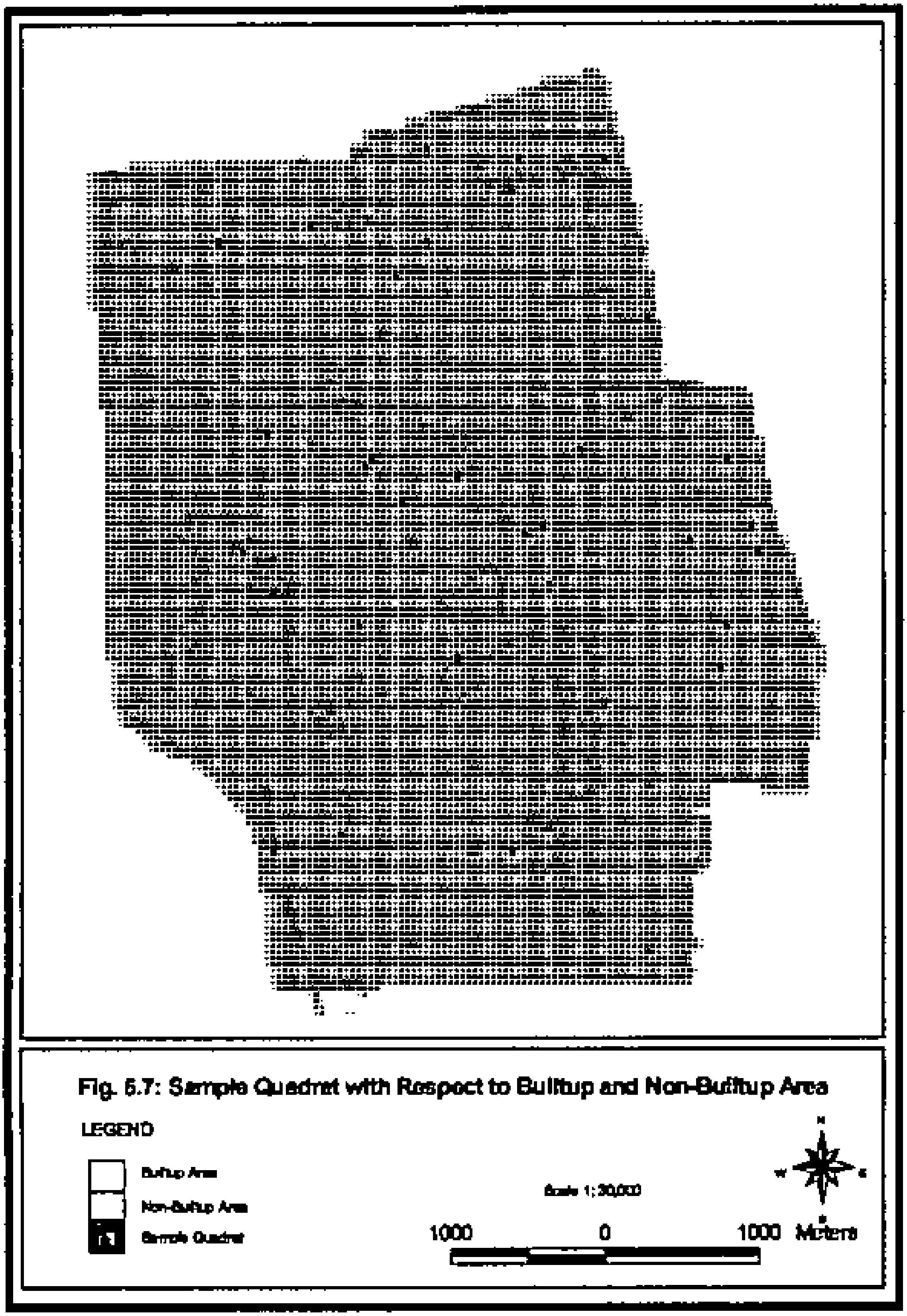


Fig. 5.7: Sample Quadrat with Respect to Builtup and Non-Builtup Area

Table 5.11: Estimated Number of Features from Sample Survey

Land Use	Use of Structure	Total No. of Quadrats	No. of Sample Quadrats	No. of Features in Sample Quadrats	Estimated No. of Features
Planned Residential	Shop	1805	17	46	4884
	Non-Slum			100	10618
	Institutional (Others)			2	212
Mixed Residential	Shop	2253	17	57	7554
	Non-Slum			108	14313
	Commercial (Others)			14	1855
	Institutional (Others)			0	0
Commercial	Shop	124	2	0	0
	Non-Slum			9	558
	Commercial (Others)			3	186
	Institutional (Others)			0	0
Institutional	Shop	1242	9	3	414
	Non-Slum			10	1380
	Institutional (Others)			6	828
Slum	Shop	316	3	28	2949
	Non-Slum			4	421
	Commercial (Others)			1	105
	Institutional (Others)			1	105
Recreational And Open Space	Shop	492	2	0	0
	Non-Slum			0	0
	Institutional (Others)			1	246
Total		6232	50		

Source: Calculated from Field Survey, 1999.

Table 5.12 shows that filling stations are the most vulnerable land use with a score of 0.50. Shopping centres are also highly vulnerable with score of 0.1838 and followed by industries (other than garments) with score 0.0723. Although conventional wisdom is that slum and garments factories are the most vulnerable, the obtained result suggests that slums are not so vulnerable in terms of frequency of fire with a value of 0.0316. On the other hand garment factories are also not so vulnerable in terms of frequency with a score of 0.0443.

Table 5.12: Relationship of Land Use with Incidents of Fire

Land Use	Use of Structure	No. of Features (in Sample)	Total No. of Features			Frequency of Fire	Fire Frequency –Feature Ratio
			Estimated	Counted	Calculated (Quadrats)		
Residential	Non-Slum	231	27290	-	-	43	0.0016
	Slum	-	-	-	316	10	0.0316
Commercial	Shop	134	15801	-	-	7	0.0004
	Shopping Centre	-	-	24	136	25	0.1838
	Filling Station	-	-	6	-	3	0.50
	Others	18	2146	-	-	13	0.0061
Institutional	Hospital/ Clinic	1	128		136	3	0.0220
	Others	10	1391	-	-	8	0.0058
Industrial	Garments	-	-	158	-	7	0.0443
	Others	-	-	25	83	6	0.0723

Source: Field Survey and Calculated, 1999.

5.7 Determination of Hazard Proneness of the Area and Hazard Mapping

Hazard proneness of the area by land use category was assessed which is discussed in this section. On the basis of the quadrat-based hazard proneness of the area, a hazard map has been produced which is presented and discussed in the later part of this section:

5.7.1 Calculating the Number of Features per Quadrat

Based on Table 5.11, the number of features per quadrat was calculated applying the following equation:

$$f_{ij} = F_{ij}/Q_j \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5.2)$$

Where, f_{ij} = Number of features of type i per quadrat of lane use j

F_{ij} = Total number of features of type i estimated in a particular broad land use category j

Q_j = Total number of quadrats in broad land use category j.

Table 5.13 shows the number of features per quadrat.

Table 5.13: Number of Features per Quadrat.

Broad Land Use	No. of Features per Quadrat			
	Non-Slum	Shop	Others (Commercial)	Others (Institutional)
Planned Residential	5.88	2.71	-	0.18
Mixed Residential	6.35	3.35	0.82	-
Commercial	4.50	-	1.50	-
Institutional	1.11	0.33	-	0.67
Slum	1.33	9.33	-	0.33
Industrial	-	-	-	-

Source: Calculated from Field Survey, 1999.

5.7.2 Score of Hazard Proneness of the Area

Score of hazard proneness by broad land use category has been calculated with the use of the following equation:

$$h_{ik} = f_{ik} \times r_i \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5.3)$$

Where, h_{ik} = Hazard score for quadrat k due to feature of type i.

f_{ik} = Number of features of type i in quadrat k.

r_i = Ratio of frequency of fire and number of features for feature type i.

Table 5.14 shows the score of hazard proneness due to different features in different types of broad land use. The table reveals that commercial areas are highly hazardous with a score of 0.2002. Industrial areas are also found to be highly with a score of 0.0723 followed by slums with a score of 0.0413. In spite of the existence of large tracts of open space and intervening green vegetation, institutional areas have a comparatively higher score of hazard proneness (0.0278). Both planned and mixed residential areas are found to be less hazardous according to the score of hazard proneness with the values of 0.0115 and 0.0163 respectively.

Table 5.14: Hazard Proneness of the Area by Broad Land Use Category

Broad Land Use	Score of Hazard Proneness for Different Type of Features								Total
	Non-slum	Slum	Shop	Shopp. Centre	Commer. (Others)	Hosp./ Clinic	Institu. (Others)	Indus. (Others)	
Planned R/A	0.0094	-	0.0011	-	-	-	0.0010	-	0.0115
Mixed R/A	0.010	-	0.0013	-	0.0050	-	-	-	0.0163
Commercial	0.0072	-	-	0.1838	0.0092	-	-	-	0.2002
Institutional	0.0018	-	0.0001	-	-	0.0220	0.0039	-	0.0278
Slum	0.0021	0.0316	0.0037	-	0.0020	-	0.0019	-	0.0413
Industrial					-	-	-	0.0723	0.0723

Source: Calculated from Table 5.12 and 5.13

5.7.3 Calculating the Composite Score of Fire Hazard and Hazard Mapping

Values of different land use features have been defined as different layers and then overlaid and the final values of risk were obtained by summation of values of hazard proneness of corresponding quadrats for different land use features contained in different data layers. The composite score of fire hazard proneness has been obtained using the following expression:

$$H_k = \sum_i r_{ik} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (5.4)$$

Where, H_k = Composite score of hazard proneness for land use category k.

r_{ik} = Score of hazard proneness for feature i of land use category k.

Using the composite score of fire hazard proneness the hazard map has been produced with ArcView (Fig. 5.8). The floating point data of raw aggregate scores were converted to integer values by multiplying by 10,000 and rounding off (Fig. 5.9). Table 5.15 shows composite scores of different land use after conversion to integer values.

Table 5.15: Composite Score and Rank of Fire Hazard Proneness

Ranking of Hazard Proneness	Composite Score
18	0
17	115
16	163
15	278
14	413
13	443
12	558
11	606
10	721
9	723
8	856
7	1953
6	2001
5	2002
4	2445
3	5115
2	5278
1	7002

Source: Calculated from Survey Data, 1999.

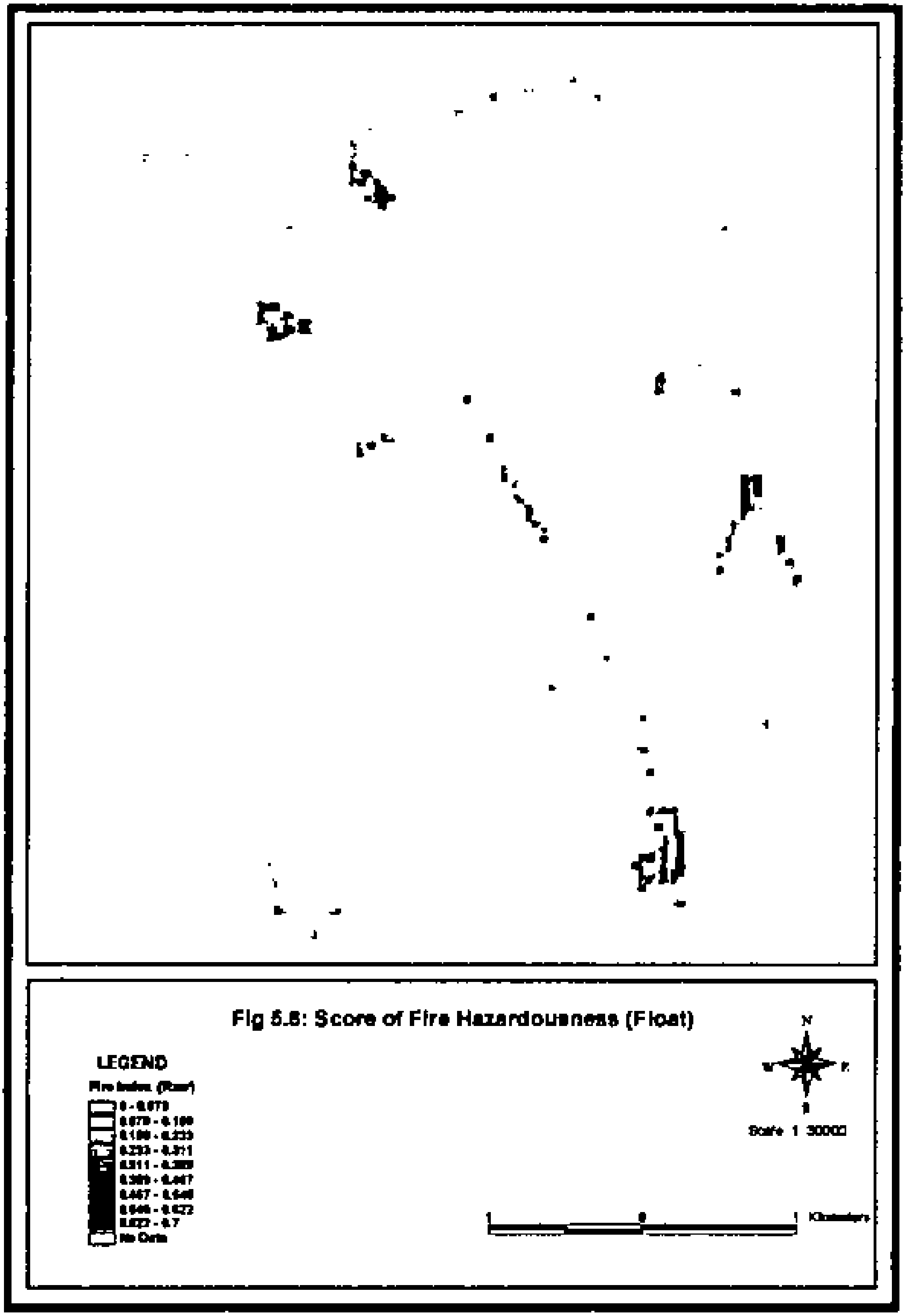


Fig 5.8: Score of Fire Hazardousness (Float)

Fig. 5.9: Fire Risk of Area by Score under Service Area of Mohammadpur Fire Station

5.7.4 Fire Hazard Proneness of the Area by Land Use Category

Table 5.16 shows the fire hazard prone areas by land use category Recreational and open space, water body, and low areas obtained 0 (zero) value (i.e., lowest rank of 18 as in Table 5.15), since there are no built up areas. The second lowest value has been obtained by most of the cells of planned residential areas (1766 cells) with a score of 115 (rank 17). The rest of the cells of planned residential areas received the rank of 12, 7 and 3 by securing the values of 558 (31 cells), 1953 (5 cells) and 5115 (3 cells) respectively. On the other hand, most of the cells of mixed residential areas (2219 cells) obtained the third lowest value of 163 with rank 16. The rest of the cells of mixed residential areas received the rank of 11 and 6 by securing the values of 606 (29 cells) and 2001 (5 cells) respectively. Thus, the residential areas, both planned and mixed, seem to be less hazardous. Cells representing institutional land use rank 15, 10, and 2 by obtaining the scores of 278 (1237 cells), 721 (4 cells), and 5278 (only one cell), respectively. Hence, institutional land use was also found to be less hazardous. Slums received the value of 413 and ranked 14 (313 cells out of 316). The rest 3 cells obtained the value of 856 (rank 8). So, in spite of the prevalent notion that slums are the most hazardous areas, they received comparatively lower value. On the other hand, commercial areas obtained higher values of 2002, 2445 and 7002 (119 cells, 4 and 1 cells respectively) with ranks of 5, 4 and 1 respectively. It is to be noted that commercial areas obtained the overall highest values of hazard proneness. Hence, commercial area is the most hazardous region in the study area. Industrial areas received the value of 723 (all 83 cells) and ranked 9, which is relatively moderately hazardous.

Table 5.16: Values of Composite Score in Cells Representing Different Land Use.

Land Use	Value	Number of Cells	Total Number of Cells
Planned Residential	115	1766	1805
	558	31	
	1953	5	
	5115	3	
Mixed Residential	163	2219	2253
	606	29	
	2001	5	
Slum	413	313	316
	856	3	
Commercial	2002	119	124
	2445	4	
	7002	1	
Industrial	723	83	83
Institutional	278	1237	1242
	721	4	
	5278	1	
Recreational and	443	3	492
Open Space	0	489	
Water Body	0	71	71
Low Area	0	1078	1078
Total		7464	7464

Source. Counted from Hazard Map.

5.7.5 Final Ranking of Fire Hazard and Hazard Mapping

Fig 5 11 shows the hazard map containing final ranking by five categories of risk. A five-point ordinal scale (Fig. 5.10) has been employed to categorize the vulnerability of fire hazard. The cells were sorted in ascending order of composite score and the top 20 percent of cells were categorised as very Low Hazard in the five-point scale The next 20 percent fell under the Low Hazardous category and similarly the rest of the cells were categorised as Moderate, High and Very High Hazard at 20 percent intervals.

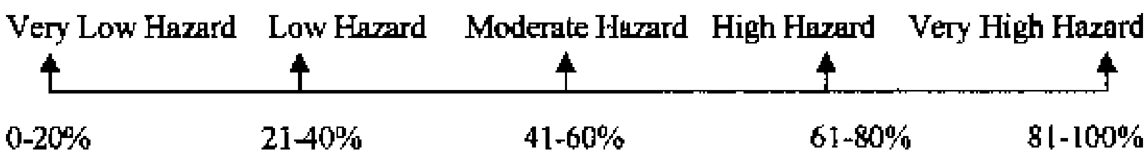


Fig. 5.10: A Five-Point Ordinal Scale

When the ranks from Table 5.15 are considered, it was found that ranks 15 to 18 fall within the first 20 percent of the range with very low hazard proneness. Ranks 12 to 14 fall within the next twenty percent and were classified as low fire hazard prone. Ranks 8 to 11 were classified with moderate hazard proneness. Ranks 5 to 7 were categorised as high fire hazard proneness and the very high hazard prone category included the ranks from 1 to 4.

As shown in Table 5.16, residential areas (both planned and mixed), institutional area, recreational and open space, water body and low area (scores ranging from 0 to 278) basically fall within the range of very low fire proneness. Mostly slums (313 cells out of 316) and a few cells of planned (31 cells) and mixed (29 cells) residential areas were in the low fire proneness region. Industrial area and a very few cells of institutional (only 4 cells) and slum areas (only 3 cells) are within moderate fire risk region (scores ranging from 606 to 856). A lion's share of commercial areas (119 cells out of 124 with a score

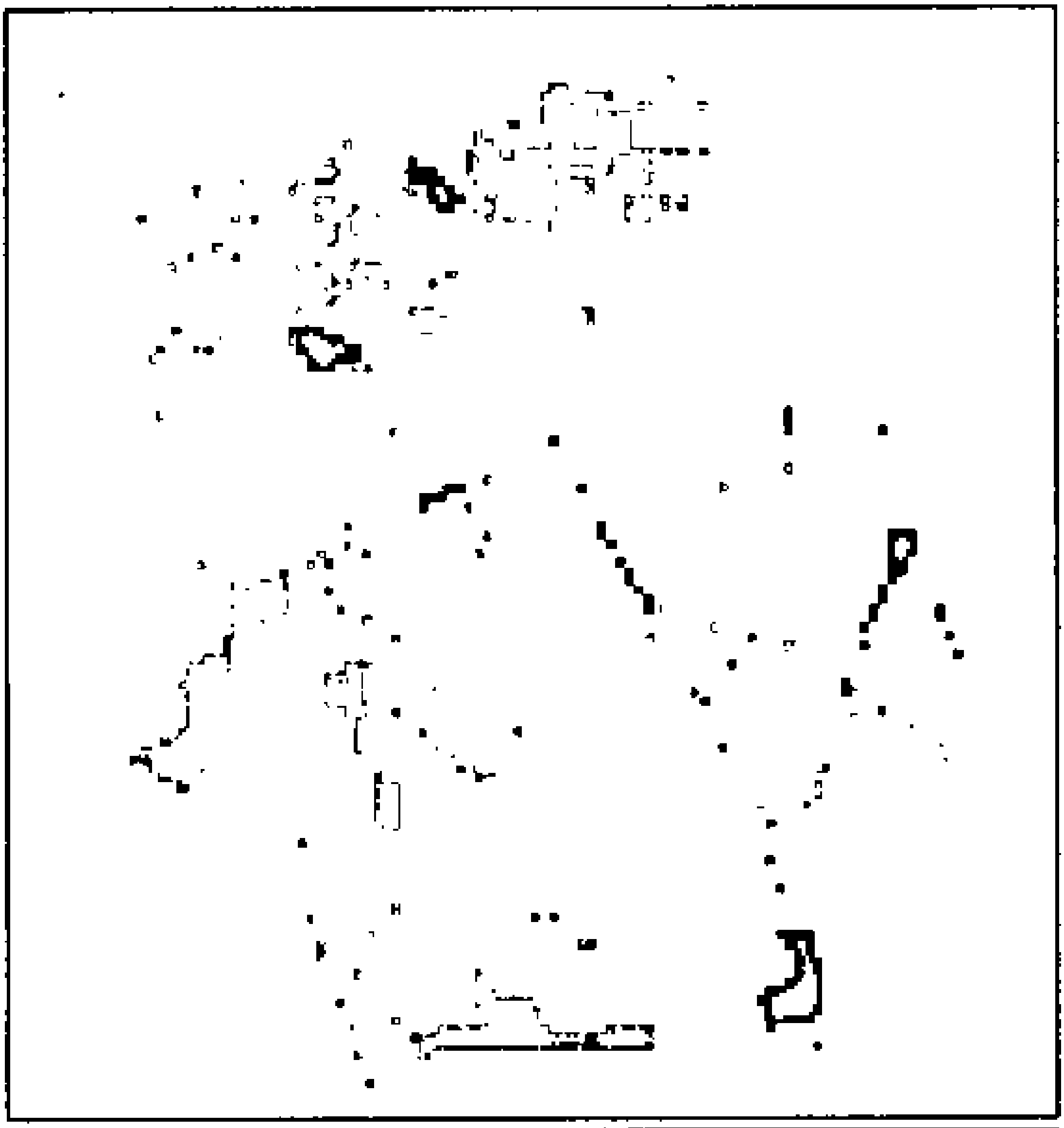


Fig. 5.11: Fire Risk Areas within the Service Area of Mohammadpur Fire Station

of 2002) falls within high fire risk region whereas, very high fire risk region contains only eight cells, among them five belongs to commercial areas. Hence, commercial areas are found to be the most vulnerable to fire hazard and both planned and mixed residential areas, institutional area and slums are less vulnerable to fire hazard, and industrials areas are moderately vulnerable.

5.8 Assessment of Existing Fire Mitigating Facilities

Assessing the existing fire protection facilities requires investigation into the community participation, role played by BFSCD, and existing fire protection facilities within the structure. Community participation and existing fire protection facilities have been identified through the questionnaire survey at the locations of fire, while performance of BFSCD has been identified in an indirect way such as arrival of BFSCD Personnel with respect to duration of fire and determining the relationship of distance with duration. These are discussed below:

5.8.1 Community Participation in Extinguishing Fire

The survey revealed a high level of community participation in fire fighting when a fire breaks out in the neighbourhood. This may be due to both altruistic intentions and the self-serving urge to control the fire before it spreads and engulfs other structures. In 44.80 percent of incidents the fire was extinguished by local people without the intervention of BFSCD. The local people assisted the BFSCD firefighters in extinguishing the blaze in 39.20 percent of cases. The Fire Service personnel had put out the fire without community assistance in only 16 percent of the cases Most of these cases were serious incidents of fire where the local community could do very little except call in the professional firefighters

5.8.2 Time of Arrival of BFSCD Personnel in Relation to Duration of Fire

Table 5.17 shows BFSCD's performance in reaching the fire scene vis-a-vis duration of the fire. Even when only the short-lived fires (lasting for up to 15 minutes) are considered, fire trucks had reached the site before the fire had been put out in almost a fourth of all cases. In a little less than half of the cases they did not reach the scene at all and in the other cases they reached the scene too late. In fires that lasted for more than half-an-hour, there was no case of failure to reach the site, though in nearly a fourth of the cases, they reached there after the fire had been extinguished. This did not happen for the fires that lasted for over 45 minutes.

Table 5.17: Time of Arrival of BFSCD Personnel with Respect to Duration of Fire

Duration of Fire (Minutes)	**Time of Arrival of BFSCD Personnel**			**Total Number of Fires**
	Before fire was put out	**After fire was put out**	**Did not arrive**	
0-15	9	12	16	37
15-30	21	16	2	39
30-45	23	10	0	33
45+	16	0	0	16
Total	69	38	18	125

Source: Field Survey, 1999.

5.8.3 Relationship of Distance with Duration of Fire

To determine the relationship of distance with duration of fire, shortest route has been calculated by using Addroute command of Network module PC ARC/INFO GIS. Fig. 5.12 shows shortest route with the locations of fire.

Table 5.18 reveals that with the increase in distance, the duration of fire increased, as the table shows that duration ranging from 16 minutes to 45 minutes is mostly concentrated between distance 3 and 4 km. While, after 5-km. distance service area of another fire station existed. That is why at 5 km. distance, incidents of fire is less (only 1.60% of total incidents with one incidents out of two of more than 45 minutes duration A Chi square test with 15 degrees of freedom and 0.05 level of significance suggests that the null hypothesis "there is no relationship between distance and duration" can be rejected. Because, at this level of significance and degrees of freedom, the calculated value was 31.3811, while the threshold value is 25.0. Hence the hypothesis has been rejected. Here inference can be drawn that at larger distances the FS personnel would take much more time to reach and that is why duration at greater distance seems higher. Hence, Fire Service Personnel plays role in fighting of fire.

Table 5.18: Relationship of Distance with Duration

Distance (in Km.)	**Duration of Fire (Minute)**				**Grand Total**
	0-15	**16-30**	**31-45**	**45+**	
<1	3 (2.40)*	2 (1.60)	0 (0.00)	0 (0.00)	5 (4.00)
1	9 (7.20)	5 (4.00)	1 (0.80)	3 (2.40)	18 (14.40)
2	11 (8.80)	10 (8.00)	1 (0.80)	4 (3.20)	26 (20.80)
3	5 (4.00)	9 (7.20)	15 (12.00)	3 (2.40)	32 (25.6)
4	8 (6.40)	13 (10.40)	16 (12.80)	5 (4.00)	42 (33.60)
5	1 (0.80)	0 (0.00)	0 (0.00)	1 (0.80)	2 (1.60)
Grand Total	37 (29.60)	39 (31.20)	33 (26.40)	16 (12.80)	125 (100.00)

Note: * Figure in the parenthesis indicates percentage

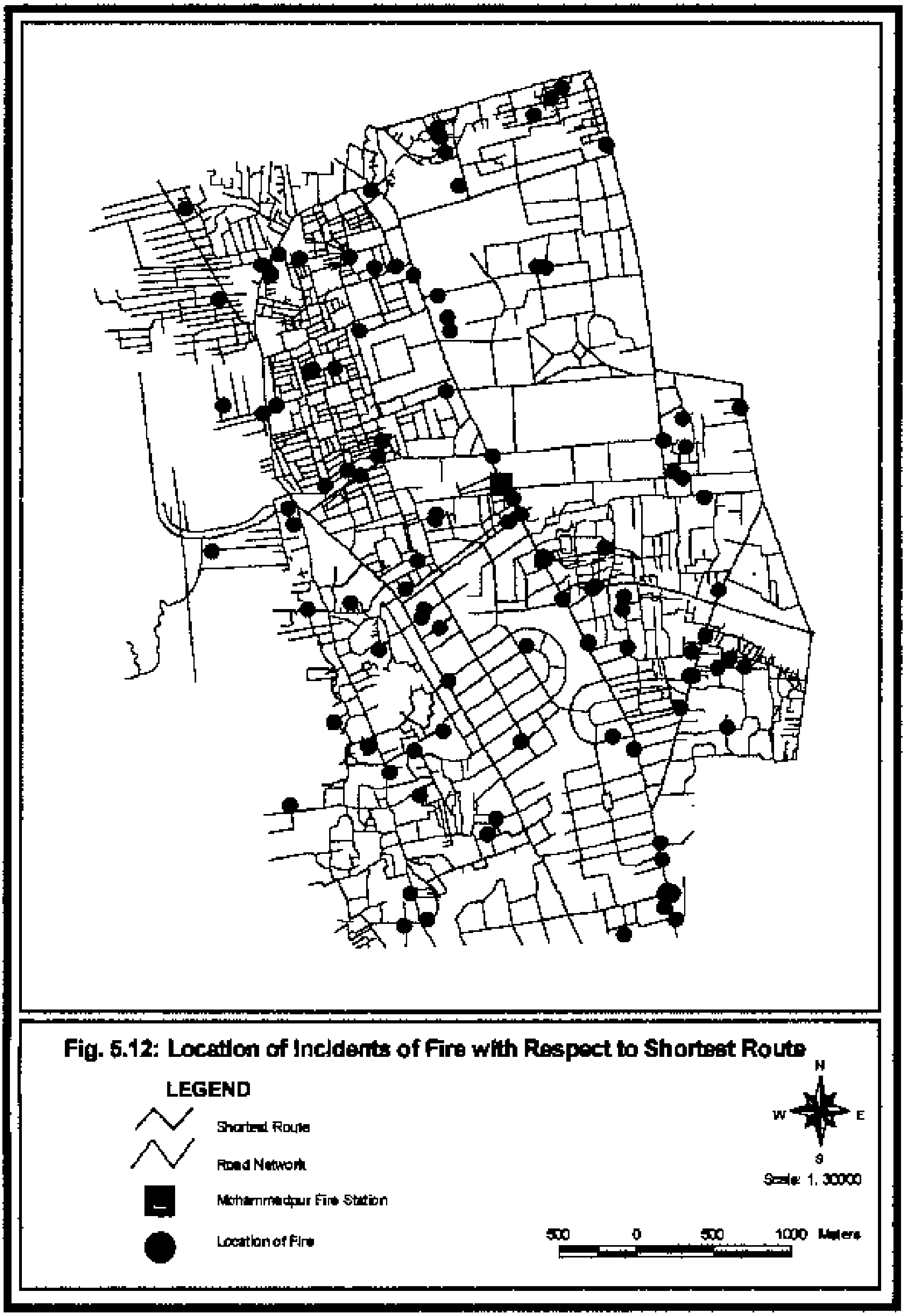


Fig. 5.12: Location of Incidents of Fire with Respect to Shortest Route

5.8.4 Existing Fire Fighting Facilities

The survey revealed that water is the most commonly used material to fight fires. It was used to extinguish 82.40 percent of the fires. In nearly a quarter (26.40 percent) of the cases the electric and/or gas supply lines were turned off. Fire extinguishers and foam were used in 10.40 percent of cases. While water is the most important fire extinguishing material, its scarcity is becoming a critical issue, raising the potential damage from fire incidents. In nearly one in five (20.61 percent) of the surveyed cases lack of water was cited as a hindrance to fighting the fire. Water hydrants for fire fighting are not installed in the city, they were not that essential either, in view of the abundance of canals, ponds, ditches, marshes etc. within a short distance from every point of the city except in small pockets of the most densely built-up areas. However, with increased urbanization and filling up of such water bodies, the availability of water to fight can no longer be taken for granted. Other major fire fighting hindrances reported include obstruction created by the crowd of onlookers (16.80 percent), lack of knowledge of the people about tackling fires (13.60 percent), and difficult access to the fire scene (8.00 percent).

A general lack of preparedness to fight fire was observed throughout the study area. Although shopping centres had a significant share of the reported fires, none of them had any fire warning or fighting facilities. Of the 53 residential establishments where incidents of fire took place, only one had a fire extinguisher Apart from the two petrol pumps, the lone bank and one of the two restaurants, the commercial establishments had no fire fighting equipment either.

CHAPTER SIX

6 CONCLUSION AND RECOMMENDATIONS

6.1 General

There is a general lack of awareness or sense of urgency regarding fire disaster in Dhaka City. There is gross negligence and ignorance with regard to fire prevention and precautions. This lack of awareness and preparedness has been reported by others such as Ahmed (1992, 1998). This is in spite of the fact that fires cause considerable damage and the media have given sensational coverage to major incidents of fire in the city. The rapid growth of the city, filling up of water bodies and open spaces, encroaching on rights-of-ways and cramped living conditions is exacerbating the situation. Fire inspection is lax, if existent at all. The Bangladesh National Building Code has elaborate directives for making buildings relatively safe from the hazard of fire, but they are largely ignored by the builders. This lack is also due to improper enforcement of the code.

One objective of this research was to identify characteristics of the site where incidents of fire had occurred. The study also attempted to assess the risk of fire and existing fire mitigation facilities. With a view to fulfillment of the objectives, the study provided a framework for assessing the potential risk of fire. Due to limited scope of the study, the framework was developed simply based on the ratio of the frequency of fire for a kind of feature and the average number of that kind of features per grid cell (frequency of fire-feature ratio). If more parameters were included in this model, more detail and comprehensive hazard assessment could be possible.

Distribution of different types of features over broad land use zones has been discussed and attempts were made to identify the impact of site characteristics on incidents of fire. The spatial pattern of fire locations has been investigated and the frequency of fire-feature ratio has been calculated to determine relationship of land use with incidents of fire. With the help of frequency of fire-feature ratio, fire proneness of the study area has been determined and a composite score of fire hazard proneness has been calculated. The composite score has been applied to prepare a fire hazard map and classify the area according to their hazard proneness. Attempt was also made to analyze the existing mitigation facilities including availability of different fire fighting equipment, role and effectiveness of Fire Service Personnel and people's participation in responding fire incidents.

6.2 Summary of Major Findings

The study reveals that non-slum residential land use has experienced a higher percentage of fire incidents. But commercial areas were found to have the most frequent fire incidents with 25 incidents of fire in only 12 locations. The study also shows that locations of fire incidents are distributed in a clustered pattern and electric short circuit was identified as the major cause of fires. The mean duration of fire in slums was found to be higher. This is due to the nature of building materials used in slums. It was found from the study that 29.60 percent of fires were minor, lasting for less than 15 minutes, and only 12.80 percent of fires were major incidents with more than 45 minutes' duration. While calculating the frequency of fire-feature ratio, it was found that shopping centres are highly vulnerable with a ratio of 0.1838. Filling stations were found to be in risk with the ratio of 0.50. It was found from the study that the prevalent notion that slums and garment factories are highly vulnerable-is not true in terms of frequency of fire. But the duration of fire is longer for slums. Both slums and garment factories have a low frequency of fire-feature ratio of 0.03016 and 0.0443 respectively. While calculating the composite score of fire hazard by the overlay of different data layers, it was found that due to accumulation of different uses of land for various purposes commercial land use is in risk. After classifying the composite score using a five-point ordinal scale it was found that only few cells (5 cells) in the commercial area are highly hazardous. Except these cells, other cells containing commercial areas are also obtained high score. Residential areas (both planned and mixed), slums and institutional areas fall within low hazardous zone and industrial areas are in moderately hazardous zone.

6.3 Recommendations/Policy Implication for Further Improvement

Marked improvement is necessary in both fire prevention and fire fighting. Fire prevention can be improved by strict enforcement of planning regulations to prevent hazardous land uses from locating in densely built up areas. The fact that electric short circuit is the major cause of fire may be due to old and faulty cabling and unauthorized power connections. Proper fire inspection and maintenance of electricity supply lines can reduce the hazard of fire. To improve the fire fighting aspect, indiscriminate filling up of water bodies must be prevented and adequate right-of-ways should be ensured. This is particularly important in the fringe areas where new developments are taking place. Public awareness campaigns, including fire drills, may be couducted. Also, careful planning of the number and locations of fire stations is needed

Following aspects should be considered for reducing fire hazard:

6.3.1 Fire Disaster Prevention Planning

The developed fire hazard map can be used to identify fire risk area and hazardous and incompatible land use in an area, which can help exploring corrective measures and undertaking both fire prevention and mitigation planning. The hazard map can also help in formulation of land use control and zoning plan.

6.3.2 Development of Fire Risk Management System

There is virtually no legislation specifically designed for disaster management. There exists a Famine Manual (1967), Drought Code (1980), Standing Order for Flood (1984), Standing Order for Cyclone (1985). These manuals, codes and orders provide instruction for the government agencies including the ministry to organise their work and priorities during and after disaster. They also provide specific tasks for every government body (Akther, 1998). But fire hazard did not get its due importance from the planners and policy makers

Department of Fire Service and Civil Defense has developed and is being directed by the "East Pakistan Fire Service Ordinance 1959". There has been no attempt to review this ordinance to reflect the changing circumstances over the decades. Even the provision of penalties made by the ordinance is not being enforced properly (Sayeeduzzaman, 1990). The ordinance, if not reviewed, should be enforced properly. This ordinance alone is not adequate to reduce the threat of fire hazard. A comprehensive risk management system should be developed like the United States Fire Administration (USFA). While developing a comprehensive risk management system it should be remembered that it is a dynamic system and not a fixed solution to fire hazard (USFA, 1996).

6.3.3 Enforcement of Building Code

Excellent provisions have been made for fire protection and safer buildings under the National Building Code 1993. Fire zones have also been defined in the code. The code is a system of risk management designed to provide socially acceptable level of risk for the public. It is implicitly balanced against cost. Since it is a system, it is possible to change components within the system and maintain the overall level of safety (Benjmin/Clarke Associates, 1984). But the code is not being following by the occupants of property and also is not being enforced properly by the enforcing authority. The proper enforcement of the code might reduce the possible risk of fire hazard.

6.3.4 Development of Land Information System (LIS)

An effective land information system should be developed which shall contain plot-to-plot structured-based data including function of a particular type of structure in a given land use. This will help to obtain current and updated data about the use of land in different areas and also help in preventing land from hazardous. Geographic Information System (GIS) could be used as an effective tool for developing an LIS.

6.3.5 Development of Land Policy for Disaster Mitigation

At present, there is no such land development legislation like " *The Town Planning Act of 1907*" of Sweden or the *Town & Country Planning Acts* of the UK to safeguard public interest (Huque, 1987). A detailed and comprehensive land development policy should be evolved, special consideration should be given to disaster management. The land policy should impose bar on filling up of water bodies, and ensure preservation of adequate open spaces as safer zones and so on, which shall help in mitigating various hazards including fire hazard A policy guideline for land use regulation and zoning, and sub-division law should be incorporated in the policy paper on land use and development policy. Necessary steps should be taken to define fire zones in hazardous areas.

6.3.6 Provision of Necessary Utilities and Services and Co-ordination among Different Agencies

Utilities and services that are necessary for fire fighting should be installed properly. For example water supply is the most crucial element for fire fighting. But currently adequate water is not available for fighting fire. During collecting data on fire incidents from the register of BFSCD, it was found that in many cases due to unavailability of adequate water for fire fighting, the fire engines had to go far away from the fire location for fire to fetch water, which contributed to the duration of fire in some cases. Provision has been made in the Town Improvement Act, 1953 for providing adequate water supply for public use. This implies that supply of adequate water should be made for all necessary purposes including fire fighting. But roadside water hydrants for fire fighting have not been installed by the concerned agency; even adequate head pressure for fire fighting is not available. So provision should be made for roadside water hydrants and adequate head pressure of water supply for fire fighting, particularly in highly hazard prone areas.

During the collection data from BFSCD it was also found from the register that in some cases of incidents of fire resulting from electric short circuit and gas line leakage, fire was controlled by disconnecting electricity and gas supply. Thus it seems that coordination among different utilities and services agencies with the fire service authority is also essential. These authorities also require awareness about the dangers of faulty and unauthorised connection. Coordination among these agencies should be institutionalised and should be an integral part of a risk management system.

6.4 Areas for Further Research

The study dealt with fire hazard mapping with a view to identify fire hazard prone areas. Although a methodology for fire hazard mapping has been developed for an urban area, there is still ample opportunity to develop it further. Duration of fire, human death and injury, fire damage, population density, density of structure, people's attitude and behaviour, accessibility, impact of fire incidents on weather condition and its seasonal variation can be incorporated in future research.

Organizational and operational risk management and, information management and institutional development for fire hazard management and development are other important areas of study, which can help in responding fire disaster (USFA, 1996). These fields are still unexplored by researchers in Bangladesh.

Optimum location of fire service station is a crucial factor for fire hazard response, which has not yet been determined. Travel time should be the most crucial factor to consider rather than physical distance in determining such locations. Because the travel time of fire engines may not be proportionate to the distance of the fire station from the location of fire, but may depend on other factors such as traffic conditions and the width of roads on the route taken.

6.5 Conclusion

The ultimate goal of fire hazard analysis is to develop a fire hazard implementation policy for reducing the impact of fire hazard and also to reduce private and public losses resulting from fire hazards, which is a responsibility of the policy makers. The development and implementation of fire hazard prevention policy generally involves the formulation and execution of fire prevention measures and management plan. This process may be thought of as a series of distinct but interconnected steps. These steps consist of:

- Identification of goal
- Assessment of problem
- Identification of alternative strategies
- Identification of criteria
- Evaluation of alternatives
- Selection of appropriate strategy
- Implementation of the selected strategy
- Operation and management

The various steps are part of a continuous process, with the output of each phase providing the input for the next phase. Finally, it is clear that hazard maps, which have been produced in this study, can play a major role in risk assessment and developing fire prevention plan.

While developing a fire hazard prevention plan, it must be borne in mind that wholesale replication of fire prevention and fire fighting strategies from other countries may not work. It is necessary to gauge the overall attitude of the people towards fire involving perception of fire hazards by people, planners, policy makers and the way these perceptions influence the fire hazard to identify culturally viable fire prevention procedure (Robson, 1988; Seley, 1979). More research is required in this end.

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Appendices

Annexure-A

URBAN AND REGIONAL PLANNING DEPARTMENT
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

SURVEY FORMAT FOR COLLECTING DATA FROM BANGLADESH FIRE SERVICE AND CIVIL DEFENSE ON INCIDENTS OF FIRE

SL. No.	Date of Fire Incident	Location of Fire Incident	Type of Element Under Fire	Time of Fire Call	Time of Controlling Fire	Time of Extinguishing Fire	Cause of Fire	Fire Damage

Annexure-B

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF URBAN AND REGIONAL PLANNING

FIRE HAZARD MODELLING IN DHAKA CITY BY USING GIS

For Research Only **Confidential**

A. 1. ID No.

2. Date of fire incident:

3. Identification:

4. Location:

5. Type of Structure

B. Land Use of the Point of Fire:

Residential	**Commercial**	**Industrial**	**Institutional**
11. Detached	21. Bank	31. Garments	41. Hospital/Clinic
12. Flat	22. Shop	32. Tannery	42. Religious Place
13. Apartment	23. Petrol Pump	33. Factory	43. School/ College
14. Public Quarter	24. Cinema Hall	34. Bakery	44. Public Building
15. Semi-pucca	25. Shopping Centre	35. Others (Specify)	45. Club
16. Kutcha	26. Workshop		46. Pump House
17. Slum	27. Wire house		47. Others (Specify)
18. Others (Specify)	28. Garage		
	29. Departmental Store		
	210. Restaurant		
	211. Kutcha Bazar		
	212. Others (specify)		

C. Source of fire:

1. Electric short-circuit
2. Gas line leakage
3. Cigarette
4. Kerosene/ Gas stove
5. Mosquito coil
6. Arson
7. Open lamp
8. Others (Specify):

D. Duration of fire (in minute):

E. Who extinguished the fire?

1. Owner/user/occupants of the property.
2. Neighbours/passers by.
3. Bangladesh Fire Service and Civil Defense (BFSCD).
4. BFSCD with the help of local people.

F. Which is the nearest fire station?

G. Performance of BFSCD:

1. Reached timely.
2. Reached after extinguishing the fire.
3. Did not reach the site of fire.

H. If FS reached the site of fire, how many vehicles were dispatched?

I. How was the fire extinguished?

1. With water,
2. With sand,
3. By disconnecting electric/gas supply
4. With extinguisher
5. With foam
6. Others (specify):

J. What was the hindrance to fire fighting?

1. No access, 2. Narrow access road, 3. Lack water, 4. Lack of sand, 5. Lack of knowledge of the victims, 6. Obstruction by the crowd.

K. Who reported the incident of fire to BFSCD?

1. Victim himself, 2. Neighbour, 3. General People, 4. Police,

5. Others (specify): ______________

L. How the incident of fire was reported to BFSCD?

1. Over telephone, 2. By messenger, 3. Over wireless, 4. Others

M. What facilities were available for fire Prevention?

1. Automatic Detection System
2. Fire Alarm
3. Self Extinguisher
4. Automatic Sprinkler System
5. Foam
6. Others (Specify)

N Was fire exit available?

1. Yes, 2. No.

O. How much did the incident of fire cause damage?

1. Amount (Tk.):
2. Percent of Property:

Signature of the Interviewer: ______________________

Date of Interview: ____________________

Annexure-C

LOGICAL FRAMEWORK FOR NEAREST NEIGHBOURHOOD ANALYSIS

Name: View SpatialNearestNeighbor

Title: Perform Spatial Nearest Neighbor Analysis

Topics: Analysis

Description: Create a new tool in a ViewDocGUI with this script as the Apply script. To use this you must have an active theme. Just drag a rectangle around the features you wish to conduct a spatial nearest neighbor analysis of. The wait cursor will appear and then a messagebox will tell you the R value and how many features were accounted for in the analyis. R values relate how clustered or dispersed points (or centroids of polygons and polylines) are within the rectangle you specified. An R value of 0 (zero), indicates an intensely clustered pattern, while an R value of 1 indicates a random distribution, and an R value of 2 (or higher) indicates strongly dispersed or organized pattern

```
' Requires: The active document must be a view, with an active feature theme
'
' Self.
'
' Returns


theView = av.GetActiveDoc
theTheme = theView.GetActiveThemes.Get(0)
theFTab = theTheme.GetFTab
theExts = theView.GetDisplay.ReturnUserRect
  xrect = theExts.GetWidth
  yrect = theExts.GetHeight
  area = xrect * yrect
  low = xrect * yrect
Shp = theFTab.FindField("Shape")
td = 0
n = 0
av.UseWaitCursor
For each rec in theFTab
  Val = theFTab.ReturnValue(Shp,rec)
  if (Val.Is(Point)) then
    xz = Val.GetX
```

```
  yz = Val.GetY
  if (theExts.Contains(Val).Not) then continue end
 elseif ((Val.Is(Polygon)) or (Val.Is(PolyLine))) then
  c = Val.ReturnCenter
  xz = c.GetX
  yz = c.GetY
  if (theExts.Contains(Val).Not) then continue end
 end
 n = n + 1
 For each z2 in theFTab
  Valn = theFTab.ReturnValue(Shp,z2)
  if (Valn.Is(Point)) then
   xn = Valn.GetX
   yn = Valn.GetY
   if (theExts.Contains(Valn).Not) then continue end
  elseif ((Valn.Is(Polygon)) or (Val.Is(PolyLine))) then
   c = Valn.ReturnCenter
   xn = c.GetX
   yn = c.GetY
   if (theExts.Contains(Valn).Not) then continue end
  end
  d = (((xz - xn) * (xz - xn)) + ((yz -yn ) * (yz - yn))).sqrt
  if (d > 0) then
   if (d < low) then
    low = d
   end
  end
 end
 td = td + low
end
Re = (1) / (2*((n/area).sqrt))
Ra = td / n
R = Ra / Re
theRect = GraphicShape.Make(theExts)
theRect.SetDisplay(theView.GetDisplay)
theRect.Draw
MsgBox.Info("The R value ="++R.AsString++"where n = "+n.AsString,"Result")
```

Annexure-D

TYPE OF LAND USE/USE OF STRUCTURE ACCORDING TO SAMPLE QUADRAT

Sl. No.	Quadrat No.	Type of Land Use/Use of Structure						
		Slum	Non-Slum	Shop	Shopping Centre	Others (Commercial)	Hospital/ Clinic	Others (Institutional)
1	10141	0	4	3	0	0	0	0
2	10066	0	0	0	0	0	0	1
3	10055	1	0	7	0	1	0	0
4	9952	1	0	7	0	0	0	1
5	9244	0	7	3	0	0	0	0
6	9063	0	0	0	0	0	1	0
7	9036	0	7	0	0	0	0	0
8	8736	0	9	0	0	0	0	0
9	8689	0	0	0	0	0	0	1
10	8667	0	7	0	0	0	0	0
11	8544	0	4	3	0	0	0	0
12	8210	0	0	0	0	0	0	1
13	7979	0	8	12	0	0	0	0
14	7470	0	12	0	0	0	0	0
15	7231	0	0	0	0	0	0	1
16	7031	0	0	0	0	0	0	1
17	6788	0	8	3	0	0	0	0
18	6696	0	3	12	0	0	0	0
19	6633	0	0	0	0	0	0	1
20	6554	0	5	3	0	0	0	0
21	6508	0	12	0	0	0	0	0
22	6423	0	5	0	0	0	0	0
23	6409	0	5	11	0	0	0	0
24	6323	0	0	0	0	0	0	1
25	6022	0	0	0	0	0	0	1
26	5773	0	6	0	0	3	0	0
27	5746	0	5	0	0	0	0	0
28	5646	0	3	0	1	0	0	0
29	5569	0	5	0	0	0	0	0
30	5533	0	4	5	0	0	0	0
31	5480	0	0	0	1	11	0	0
32	5458	0	6	0	0	0	0	0

Sl. No.	Quadrat No.	Type of Land Use/Use of Structure						
		Slum	Non-Slum	Shop	Shopping Centre	Others (Commercial)	Hospital/ Clinic	Otrhers (Institutional)
33	5413	1	4	14	0	0	0	0
34	5061	0	3	0	1	0	0	0
35	4594	0	2	14	0	0	0	0
36	4546	0	7	0	0	0	0	0
37	4167	0	0	0	0	0	0	0
38	4103	0	8	4	0	1	0	0
39	3958	0	1	13	0	1	0	0
40	3765	0	8	2	0	0	0	0
41	3696	0	5	0	0	0	0	0
42	2895	0	6	0	0	0	0	0
43	2722	0	4	0	0	0	0	1
44	2219	0	7	0	0	0	0	0
45	2094	0	9	0	0	0	0	0
46	1989	0	9	14	0	0	0	0
47	1920	0	8	0	0	0	0	0
48	1915	0	6	2	0	1	0	0
49	829	0	16	2	0	0	0	0
50	762	0	3	0	1	0	0	0

Annexure-E

STATISTICS ON DIFFERENT TYPES OF LAND USE/USE OF STRUCTURE OBTAINED FROM SAMPLE SURVEY

Statistics on shops

Code	Land Use	Total Grid	Sample Grid	Shops
1	Planned Residential Area	1805	17	46
2	Mixed Residential Area	2253	17	57
3	Commercial Area	124	2	0
4	Industrial Area	83	0	0
5	Institutional Area	1242	9	3
6	Slum	316	3	28
7	Recreational and Open Spaces	492	2	0
8	Water Body	71	0	0
9	Low Area	1078	0	0
	Total	**7464**	**50**	**134**

Statistics on Non slum

Code	Land Use	Total Grid	Sample Grid	Non Slum
1	Planned Residential Area	1805	17	100
2	Mixed Residential Area	2253	17	108
3	Commercial Area	124	2	9
4	Industrial Area	83	0	0
5	Institutional Area	1242	9	10
6	Slum	316	3	4
7	Recreational and Open Spaces	492	2	0
8	Water Body	71	0	0
9	Low Area	1078	0	0
	Total	**7464**	**50**	**231**

STATISTICS ON DIFFERENT TYPES OF LAND USE/USE OF STRUCTURE OBTAINED FROM SAMPLE SURVEY

Statistics on other Commercial

Code	Land Use	Total Grid	Sample Grid	Others (Commercial)
1	Planned Residential Area	1805	17	0
2	Mixed Residential Area	2253	17	14
3	Commercial Area	124	2	3
4	Industrial Area	83	0	0
5	Institutional Area	1242	9	0
6	Slum	316	3	1
7	Recreational and Open Spaces	492	2	0
8	Water Body	71	0	0
9	Low Area	1078	0	0
	Total	**7464**	**50**	**18**

Statistics on other Institutional

Code	Land Use	Total Grid	Sample Grid	Others (Institutional)
1	Planned Residential Area	1805	17	2
2	Mixed Residential Area	2253	17	0
3	Commercial Area	124	2	0
4	Industrial Area	83	0	0
5	Institutional Area	1242	9	6
6	Slum	316	3	1
7	Recreational and Open Spaces	492	2	1
8	Water Body	71	0	0
9	Low Area	1078	0	0
Total		**7464**	**50**	10

Statistics on Hospital and Clinic

Code	Land Use	Total Grid	Sample Grid	Hospital/Clinic
1	Planned Residential Area	1805	17	0
2	Mixed Residential Area	2253	17	0
3	Commercial Area	124	2	0
4	Industrial Area	83	0	0
5	Institutional Area	1242	9	1
6	Slum	316	3	0
7	Recreational and Open Spaces	492	2	0
8	Water Body	71	0	0
9	Low Area	1078	0	0
	Total	**7464**	**50**	**1**