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# Fire hazard categorization and risk assessment for Dhaka city in GIS framework

Md. Jobair B. Alam and George N. Baroi[1]

*Department of Civil Engineering*
*Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh*

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**Abstract**

Occurrence of fire incidences is a common phenomenon in Dhaka city, particularly in dry season. Fire break out in slums, garment factories and small manufacturing industries are regular news item during the season. Fire break outs cause loss of numerous lives and valuable properties in the city as well as other metropolitan areas of the country. With the increase of industrial establishments, mainly small industries, the number of fire incidences is increasing rapidly. Although there are a couple of fire stations in Dhaka City, an integrated framework of fire hazard management is non-existent. Such a framework, combined with information and communication system, has the potential to alleviate the damages and sufferings of the people. Also 'Fire hazard categorization' is vital for emergency planning in order to minimize loss of lives and property. Geocoded records of fire incidences and their characteristics help in understanding the spatial distribution of fire susceptibility and vulnerability as well as assist in the 'Allocation' and 'Mobilization' of dynamic resources. This paper presents an assessment of risk of fire hazards in Dhaka City in GIS framework in order to develop a methodology to generate fire hazard categories and risk mapping. It also examines the methodology for site selection for fire stations in a given region for effective management of dynamic resources. The area under Dhaka City Corporation (DCC) is categorized into different fire hazard zones according to the frequency of fire incidence. Tejgaon, Ramna and Postogola are found to be the most hazardous zone with above thirty fire incidences per year. It is observed that most of the fire occurs in the market and are caused by electrical problems. The paper also examines the application of computer based fire risk assessment system.



*Keywords*: Fire Hazard, Categorization, Risk, GIS.

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## 1. Introduction

Fire is one of the earliest innovations of civilization and an essential part of our existence on the earth. Still it is the name of a dreaded demon which burns everything

[1] Former student

into ashes when it gets out of control. Fire can cause widespread destruction within no time and is one of most feared scourge of modern civilization. Although fire hazards cannot be fully eliminated, corresponding risk can be minimized by better preparedness and well planned mitigation strategies developed on the basis of comprehensive analysis based on its spatial, temporal and causal pattern. It is vital that hazard levels be assessed in order to understand the spatiality of fire hazards and enable distribution of the optimum dynamic resources in a balanced manner (Gunther, 1981 and Dodge, 1996).

Table 1
Number of reported fire incidences in Dhaka city

| Incidence | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
| Fire Incident | 736 | 809 | 768 | 734 | 782 | 806 | 833 |
| Fire in Accident and Other Mishaps | 136 | 124 | 128 | 160 | 179 | 192 | 201 |
| Total | 872 | 933 | 896 | 894 | 961 | 998 | 1034 |

*(Source: BFSCD, 2001)*

Emergency services need current information to provide quick and adequate response. Such information include spatial details on land-use, functions of structures, access network, and availability of resources. To combat the menace of fire hazard it is required to integrate the spatial context and potential population exposure together with technical and engineering aspects (Rayner, 1992). Spatial context can be an important factor in determining the scale of potential harm but has often been neglected in setting of criteria or thresholds which determine levels of risk management process (Gordon et al., 2000). Recent perspectives on natural hazards also emphasize on the wider spatial and social context within which the effects are experienced. The concept of vulnerability has been particularly important, encompassing the physical relationship between hazards and communities at risk, accident preparedness and mitigation and the social geography of potentially affected populations (Blakie et al., 1994). In addition to the spatial characteristics, it is required to analyze the temporal and causal characteristics of fire hazards to reduce the danger.

The key objectives of the research, presented in this paper, are to analyse the nature of fire incidents by their type, spatial distribution, variation over time, and their relationship to the underlying social composition of the population involved. The results of the study will be beneficial for the planners and developers while designing the development activities. It will also assist in finding judicious locations for new fire stations in the city. The GIS framework will facilitate development of an integrated information system for fire hazard management and effective handling of fire incidences. The paper also presents an application of an integrated software to assess the level of fire hazard risk for buildings and industries as well as measure the quality of fire protection facilities.

## 2. Study area

The study area includes ninety wards of Dhaka city comprising 164.62 sq.km of area with a population of over seven million. Fire protection in the city is provided by Bangladesh Fire Service and Civil Defence (BFSCD), which operates from fourteen stations, with a compliment of about 300 professional fire-fighters. The fire service department handles over ten thousand emergency calls a year, which include rescue requests in addition to fire incidences.

## 3. Fire incidence database

Bangladesh Fire Service and Civil Defence (BFSCD) keeps record of all emergency incidents logged in their register. Each incident has the following key attributes:

- unique identification code
- time and date
- address / location
- incident type (fire, rescue, false alarm, etc)
- land-use /function type (house, hospital, office, etc)
- cause of incident (electrical fault, arson, cooking, etc)
- responsible fire station

The most significant component of the database is the information on type of incident which is categorized into five major groups namely, major fires, small fires, precautionary alarm calls, malicious false alarms, and special services (e.g., car accidents, flooding, etc).

The address information of fire incidence record in the register has been verified with fire station jurisdictional information before being coded into database. This information is incorporated into GIS as a point data structure. The incident attributes are also summarized to aerial units (fire station areas and wards) for subsequent analysis. The resulting GIS database of fire incidents, integrated with road network and land use information, facilitates development of Management Information System (MIS) for fire hazard handling.

## 4. Damages and casualties caused by fire incidents

In most of the cases, damages and casualties caused by fire hazard is not recorded properly in the register due to resource limitation. Considering the importance of the data, an assessment in this regard is done on the basis of information published in the newspaper. Out of 833 fire-incidents occurring in Dhaka City in 2001, as reported by BFSCD, only in 226 cases the amount of damages and number of casualties were reported in the newspaper. A total of 38 people died, 171 people were injured and properties worth about Taka 86 crores were damaged in these incidents. Adequate attention to collect such data is deemed necessary.

## 5. Patterns of fire incidents

For the purpose of designing fire hazard management system it is required to understand patterns of fire incidences across space and time, which would be evident from fire incident database. GIS framework is used in the analysis and visualization of the database. The study includes reported fire incidences occurring in seven years from 1995 to 2001, which is recorded in the register of fourteen fire stations.

### *5.1 Place of occurrence of fire incidents*

In the process of fire risk analysis, the first step is concerned with categorization of the place of occurrence. As shown in Fig. 1, fire incidents at markets ranks atop with 17 percent of the total incidents. It is followed by fire incidents at residential buildings and 'electricity and gas' installations with 15 and 14 percent, respectively.

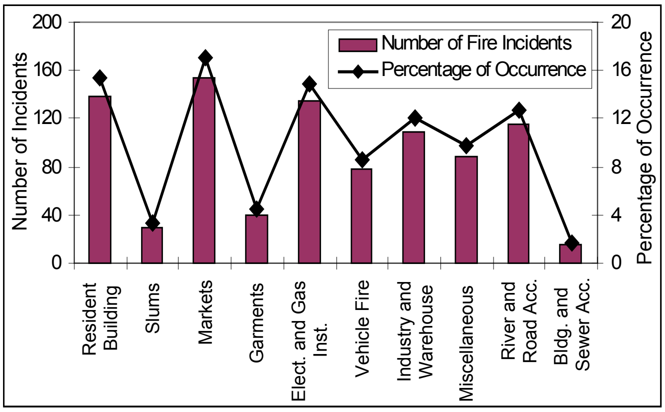


Fig. 1. Places of occurrence of fire incidents

## 5.2 *Spatial pattern*

On the basis of frequency of fire hazards, the city is categorized in five groups of hazard zones (Sayeeduzzaman, 1992). The distribution of fire hazards and zonal mapping are shown in Fig. 2. From the analysis, Tejgon industrial area, Fulbaria and Postogola wards are found to be most hazardous having more than thirty incidences per year. These areas are classified as highly hazardous area (Hazard Zone Type -1). Wards with fire incidence frequency in between twenty to thirty are considered as moderately hazardous area (Hazard Zone Type -2). Jatrabari, Sadrghat, Shakaribazar, Oize ghat, Simson road, New Market, Mirpur-1 and Cantonment restricted area are found to be moderately hazardous. Hazardous area (Hazard Zone Type -3), with fire incidence frequency between ten and twenty, mainly covers residential areas like Dhanmondi, Mohammadpur, Gulshan, Banani etc. Less and least hazardous zones (Hazard Zone Type -4 and Hazard Zone Type -5) include the peripheral area of city.

Fire incidence per square kilometer is the highest in the Hazard Zone Type -1 with 19 fire incidences per sq km per year, which is followed by Hazard Zone Type -2 with 8 fire incidences per sq km per year. On aggregate, forty-eight fire incidences occurred per ward in highly hazardous zones and twenty-five fire incidences in moderately hazardous zones. On the average four fire incidences occurred per sq km. From the analysis of spatial concentration of fire incidents, it is evident that there exists discrepancy in aerial distribution of fire stations. It is observed that the locations of fire stations are not commensurate with risk of fire incidences.

## 5.3 *Causal patterns*

Various sources of fire incidence can be divided into five categories and their distribution is shown in Figure 3. Out of the 670 fire incidences occurring in 2001, for 37 percent of the cases the cause remained unknown and under investigation. Maximum number of fire incidences in Dhaka Metropolitan Area (DMA) is caused by electrical faults, which accounted for 34 percent of the total incidences. Highest number of fire incidences caused by gas occurred in hazardous and less hazardous zone. For about 15 percent cases, fire incidences are caused by cigarettes, machine's heat, kitchen, candles and mosquito coils.

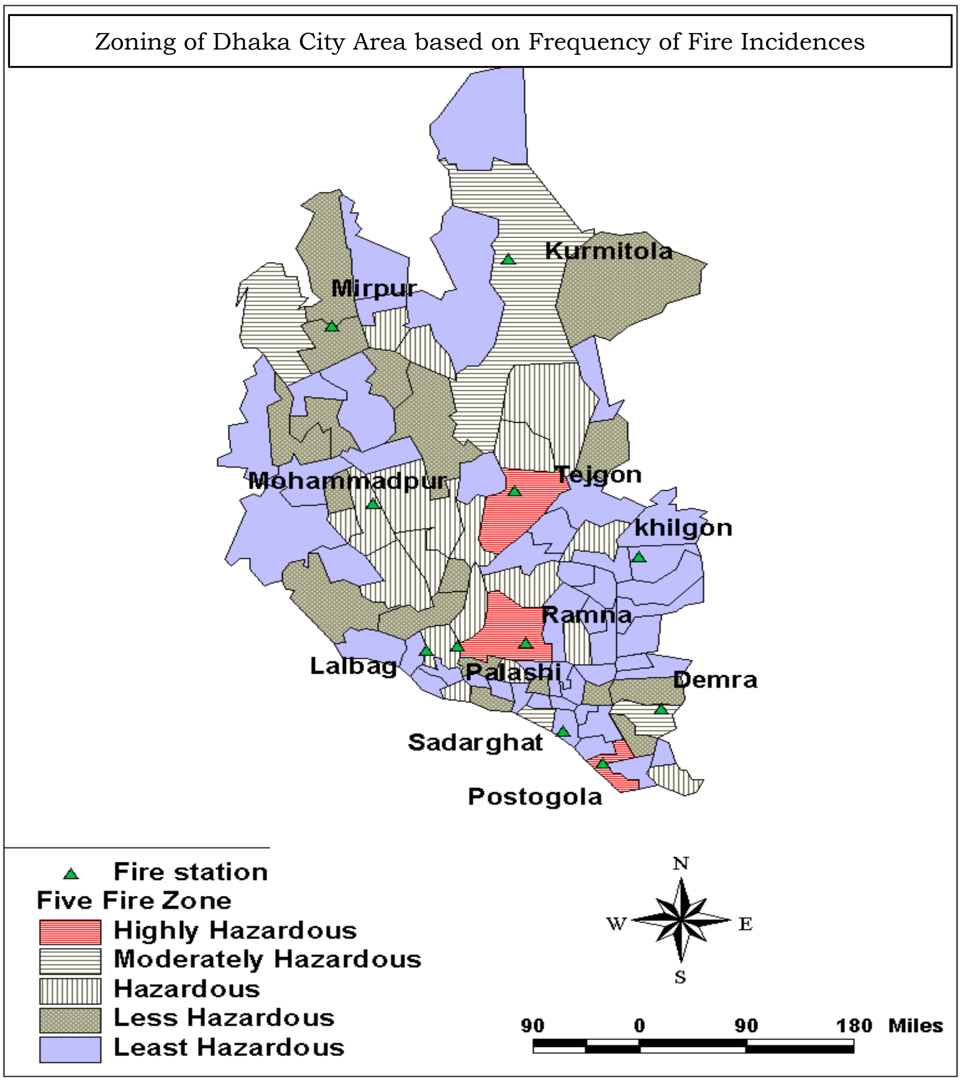


Fig. 2. Fire hazard zone mapping for Dhaka city

## *5.4 Temporal patterns*

The temporal distribution of fire incidents occurring in Dhaka city is shown in Figs. 4 and 5. It is observed that 34.5 percent of the total fire incidences occurred in the evening, between 6.00 PM and midnight and 29 percent of fire incidences occurred in the afternoon, between noon and 6.00 PM. Particularly in the highly hazardous areas, 70 percent of incidences occurred in the evening. From the observations it is evident that morning is less venerable than afternoon and night. Figure 5 presents monthly variation of fire incidents in the city. It is observed that the dry season from December to March is more vulnerable than the rest of the year. The average numbers of fire incidents during dry and wet seasons are 130 and 70, respectively.

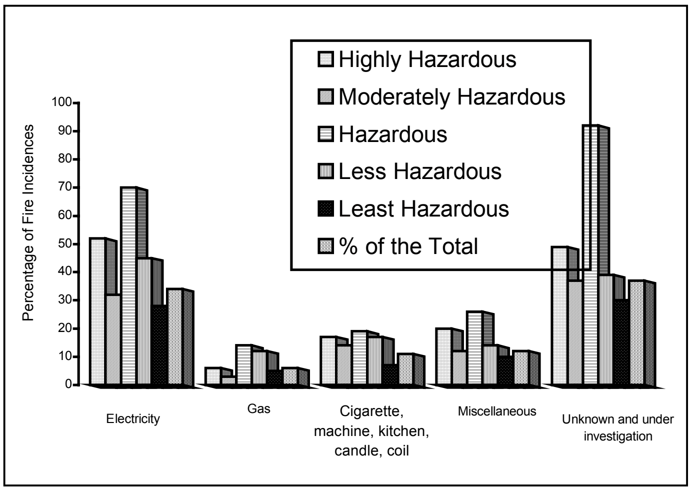


Fig. 3. Causal pattern of fire incidences in Dhaka city

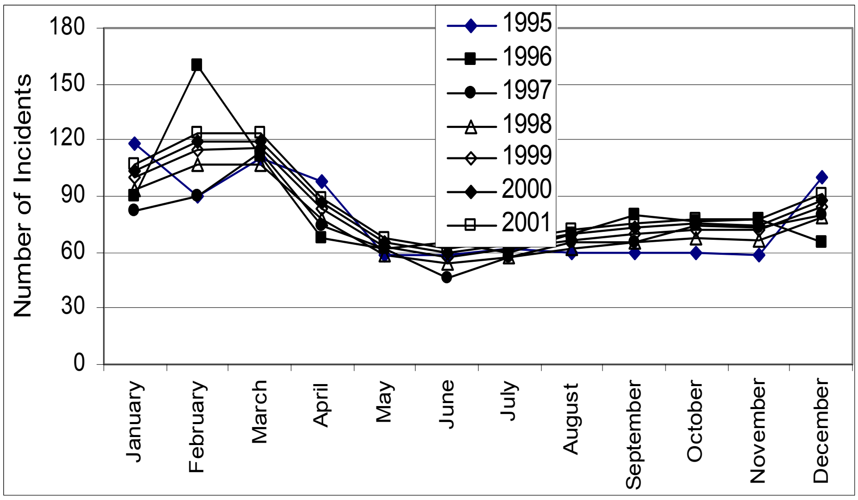


Fig. 4. Temporal pattern of fire incidences in Dhaka city

### 5.5 *Visualizing patterns in GIS framework*

Map animation is a visualization tool that goes beyond conventional static point mapping, avoiding potential large data loss when the time dimension of datasets is aggregated. The use of animation as a means of data presentation and visualization of information is increasing with the diffusion of 'multimedia' technology. Map animation techniques have been extensively applied in the social geography arena to analyze crime incidents, epidemiology and urban growth for example (Dorling and Openshaw, 1992; Opensaw, 1994; and Batty, 1995). A range of different map animations are generated from the fire incident space-time database, using a variety of temporal intervals. Also, such animations on the basis of causal factors of fire incidences help in identifying potential locations vulnerable to fire incidences. As shown in Fig. 1, using such tools vulnerable areas could be located and potential risk could be assessed. Also, these spatial databases can be integrated with road network database in GIS framework to identify the best possible routes and probable locations of necessary resources, required for fire extinguishing purpose.

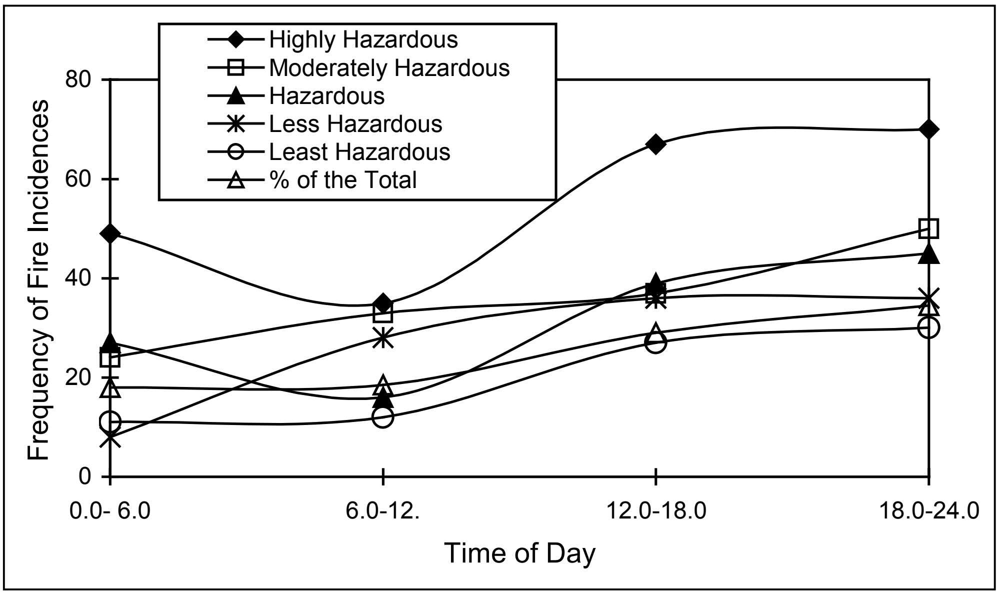


Fig. 5. Monthly variation of fire incidences in Dhaka city

## 6. Fire risk analysis

For the purpose of analyzing the risk of fire hazard an expert system is developed following the framework of 'Fire Risk Assessment Method for Engineering' as proposed by Erik (1992). It is found to be the most comprehensive, transparent and practical calculation method for fire risks in buildings and localities. It is a tool to help a fire protection engineer to define a sufficient and cost effective fire safety requirement for new or existing installations. Unlike building codes that are mostly meant to assure a safe escape or rescue for the occupants, the method also aims at protecting the building, its content and the activities in it. This method can easily be used to evaluate fire risks in existing situations, and to find out whether alternative designs have also comparable efficiencies. It estimates the fire risk in buildings for the property and the content, for the occupants and for the activities in it. A systematic evaluation of all major influence factors is given, and the final result is a set of values which provide objective measures of positive and negative aspects associated with fire hazard.

In the analysis Fire Risk R is defined as the quotient of the Potential Risk (P) by the Acceptance Level (A) and the Protection Level (D). The Protection Level D is defined as the product of the water supply factor W, the normal protection factor N, the special protection factor S and the fire resistance factor F.

The Potential Risk factor measures the probability of occurrence of fire accident and its extent in terms of destructive capability as well as expansion propensity. The Potential Risk is defined as the product of the fire load factor q, the spread factor i, the area factor g, the level factor e, the venting factor v, and the access factor z. The fire load factor q indicates how much can burn per area unit ($m^2$). In practice, the method provides monographs with reasonable estimates of the values of Qi (fire load immobile) and Qm (fire load mobile) based on building construction types and occupancy classification. The fire spread factor i indicates how easily a fire can spread through a building. It is calculated from the average dimension of the content m, the flame propagation class M, and the destruction temperature T. The area factor g indicates the horizontal influence of the fire. The factor g is calculated with the values of l, the theoretical length of the compartment, and of b, the equivalent width, expressed in meter. The length "l" of a compartment is the longest distance between the centers of two sides of the compartments' perimeter. The equivalent width "b" is the quotient of the total area of the compartment by the theoretical length. The level factor e indicates the vertical influence of the fire and is calculated from the level number E. The main access level has number E = 0. Levels above the access are numbered 1, 2, 3, etc. Levels below the access level are numbered -1, -2, -3, etc. The venting factor v indicates the influence of smoke and heat inside the building. It compares the venting capacity of the compartment with the sources of smoke. The access factor z indicates how difficult it is for outside help to get into the fire area.

The acceptance level reflects the fact that people can live with the threat of fire up to a certain level, as long as fire is an unlikely event, and as long as the consequences are not too irreversible. The Acceptance Level A is defined as the maximum value 1.6 minus the activation factor a, the evacuation time factor t, and the value factor c. The only way to define the activation factor a is to go through a review of possible fire sources, and to sum all relevant values, referring to the following types of fire sources: Main activities, secondary activities, process and room heating systems, electrical installations, presence of flammable gases, liquids and dusts. The evacuation time factor t is calculated with the dimensions of the compartment, the number of people, exit units and exit paths, and the mobility factor. Content factor c evaluates the possibility to replace the building and its content, and the monetary value. Environment factor r reflects the running speed of fire, and the dependency factor d measures how much a business can be touched by fire. The method provides estimate of Initial Risk from information about the level of protection that can already be obtained from the built-in safety measures, such as compartmentalization, risk separation, smoke venting, fire proofing, and gives a good guideline to choose an adequate fire protection system.

The protection levels are calculated with W, the water supply factor; N, the normal protection factor; S, the special protection factor; F, the fire resistance factor; U, the escape factor and Y, the salvage factor. Water supply factor W considers the type and capacity of water storage and distribution network. Normal protection factor N considers guard services, manual fire fighting, time delay of fire brigade intervention, personnel training. Special Protection factor S considers automatic detection, reliability of water supplies, automatic protection, and fire brigade force. Fire resistance factor F considers the structural elements, outside walls, ceiling or roof and inner walls. Escape factor U considers every measure that speeds up the evacuation or slows down the early development of fire. Salvage factor Y considers protection of critical items, and contingency planning.

On the basis of the analytical framework, software is applied to assist the planners, fire engineers and fire fighters. The interfaces of the software are shown in Figures 6 (a), (b) and (c). This is a user friendly software using Graphical User Interfaces (GUI) for ease of operation. It also provided automated reporting and visualization tools.

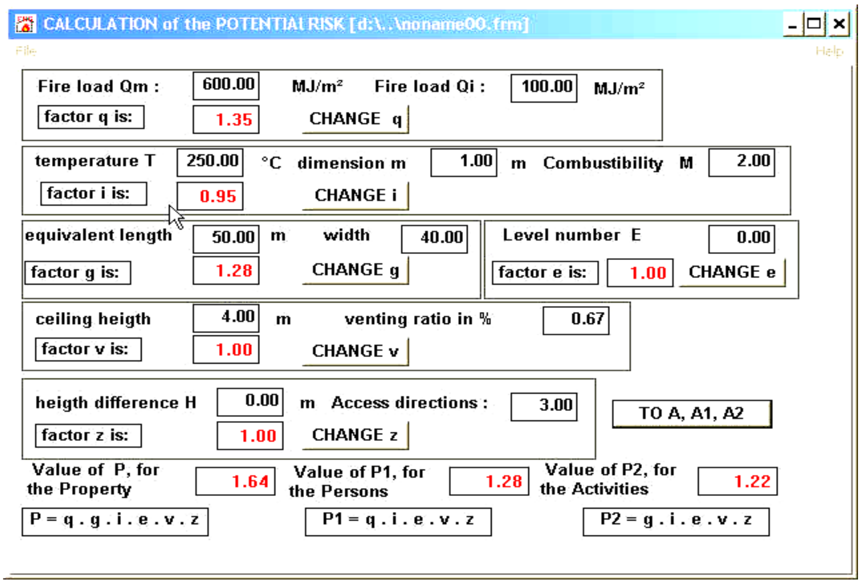


Fig. 6(a). Input Interface of 'Fire Hazard Assessment Software'

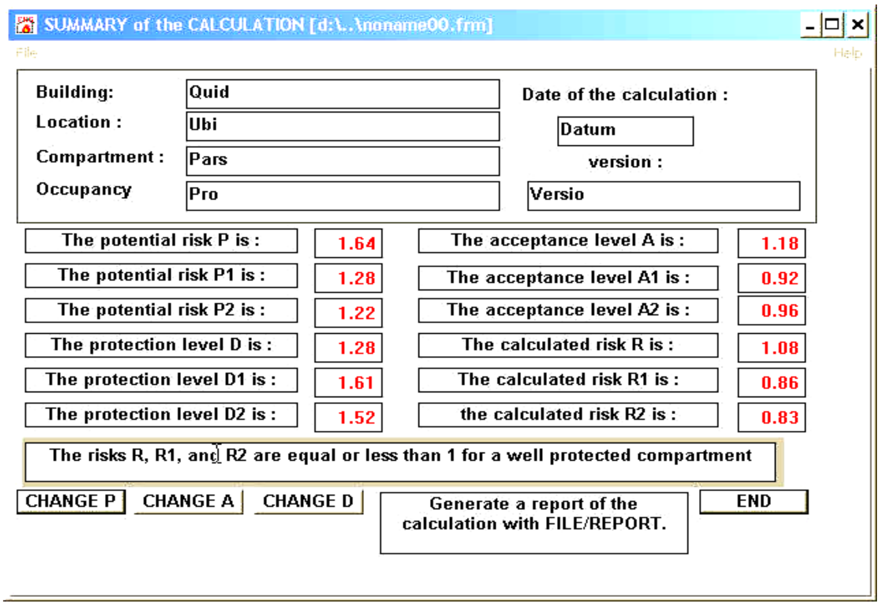


Fig. 6(b). Analytical interface of 'Fire Hazard Assessment Software'

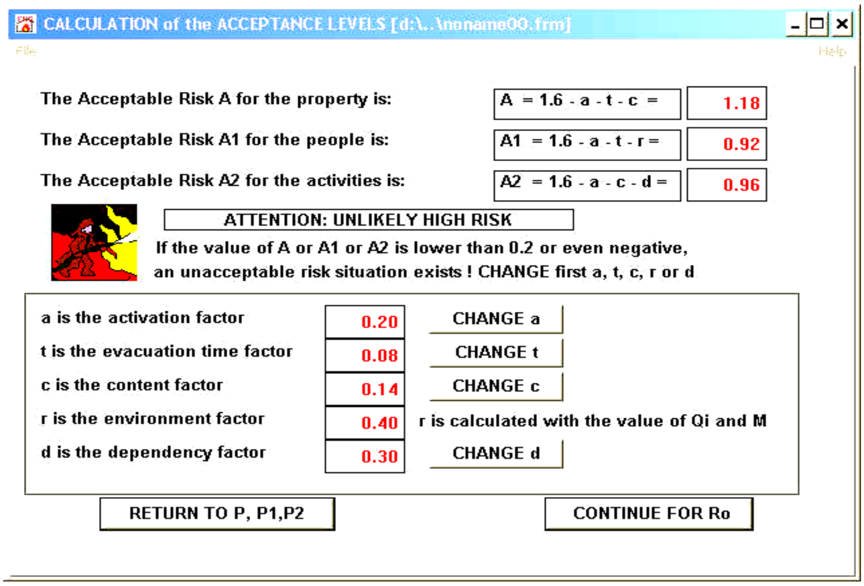


Fig. 6(c). Output interface of 'Fire Hazard Assessment Software'

## 7. Conclusions

Fire is an essential part of day to day life. But people often become unaware of its devastating nature. For the purpose of ensuring safety, it is required to develop awareness regarding the potential hazards of fire and take precautionary measures accordingly. This paper presented an overview of the characteristics of fire incidences occurring in Dhaka City. It is observed that the industrial areas are the most hazardous with respect to frequency of fire incidents. The results also suggest that most of the fire incidences occurred during afternoon and electrical fault is the most important cause fire incidences in Dhaka city. The analysis also reveals that even the most hazardous areas are not well covered by the fire stations. On the basis of the study, following recommendations are proposed to reduce the fire hazards in Dhaka.

- In highly hazardous areas, fire safety measures such as automatic sprinklers, warning systems, smoke detectors, fire extinguishers and hydrant should be made readily available.
- Hazard preparedness should be developed as a bottom-up approach, by giving due priority to the community level preparedness. Voluntary organizations like 'fire service crops' may be developed for each ward through incorporating local clubs and religious organization.
- Bangladesh Fire Service Ordinance should be publicized and enforced properly. Warehouses and workshops defined in the ordinance should be strictly enforced and segregated from residential area. Assessment of fire risk and protection level should be assessed for building construction which should be included in the approval process by agencies like RAJUK and DCC.
- In the Old Dhaka city, the road geometry is not suitable for the fire-fighting vehicles. The routes for fire-fighting vehicles in these areas should be earmarked. Suitable vehicles may also be arranged for the area.
- Adequate insurance policy should be developed.

- In many cases the causes of fire incidence remain unknown and take very long time to investigate. Expertise in this regard is required to be improved.

It is worthy to develop a Fire Hazard Management Cell under Disaster Management Bureau to help BFSCD with the objectives of promoting awareness regarding fire hazard prevention, providing guidelines, organizing training and developing an integrated Fire Hazard Management Information System.

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