CrossMark

Urban fire occurrences in the Dhaka Metropolitan Area

Tanjiba Rahman Tishi · Ishrat Islam

Abstract Fire, with its sudden appearance and destructive character, causes property losses and sometimes death and injury within a short time. High density of population and structures make the urban areas more vulnerable to fire hazard. In this context, fire incidents are very common in Dhaka city and the city is experiencing huge economic loss due to the increasing trend of fire incidents. These incidents are spread through different land use categories and the frequency of incidents also varies in these categories. This paper focuses on the distribution pattern of fire incidents of Dhaka Metropolitan Area according to different land use categories and structure types. The hot spots have been identified on the basis of density of fire occurrences using Kernel Density tool. The result of the research will help the policy maker in executing proper land use zoning as well as ensuring fire safety so that the loss due to fire incidents can be controlled.

Introduction

Fire, as a disastrous event, can have its origin either in natural or in human activities. It can occur almost anywhere where inflammable materials are present and can cause huge loss of human lives and properties if it is not controlled in due time (Haque 2001). The trend of urban fire is closely related to the level of urbanization of an area (Wang et al. 2011) and globally this urbanization is taking place rapidly. Urbanization is also taking place in Bangladesh very rapidly. Especially in Dhaka, the urbanization rate is very high. The urban population growth rate in the last decade was 3.73% (BBS 2011). Worldwide, this increased population has been linked with more frequent urban conflagrations. Likewise, there is an increasing trend of occurring fire incidents in Bangladesh with higher frequency in Greater Dhaka district (Dhaka, Gajipur, Munshigonj, Manikgonj, Narayangonj and Narsingdi) (Fig. 1). According to the statistics of Bangladesh Fire Service and Civil Defence (BFSCD) Directorate, the governing authority of Fire Stations, among the total reported fire incidences in Bangladesh, 18.17%, 15.36%, 15.96%, and 16.14% incidents were occurred in greater Dhaka district in the

T. Rahman Tishi · I. Islam
Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh
e-mail: ishratislam.buet@gmail.com

Present Address:
T. Rahman Tishi (✉)
Environment and Infrastructure Management Solution (EIMS) Limited, 126/3, Monipuripara, Tejgaon, Dhaka, Bangladesh
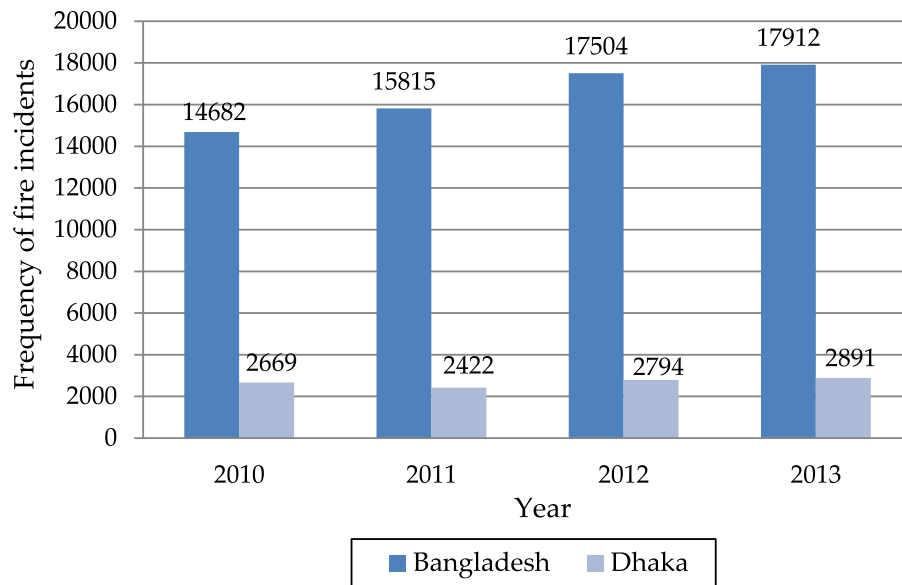e-mail: tanjiba@yahoo.com

Fig. 1 Yearly trend of fire incidents of Bangladesh and Greater Dhaka district. *Source*: Field data, BFSCD (2014)

year of 2010, 2011, 2012 and 2013 respectively (FSCD 2013).

For being the hub of all commercial and economic activities, Dhaka also faces huge economic losses due to these incidents (Table 1).

These fire incidents are spread in different land use categories (Haque 2001). To take proper initiatives to fight against fire it is important to identify the places of frequent fire incidents and to explore the land use features of those areas. The objective of the research is to explore the spatial distribution pattern of the fire incidents of Dhaka Metropolitan Area. In this context, the distribution of the fire incidents will be revealed according to land use categories as well as the use of structures. And the hotspot will be identified having higher frequency of incidents.

Table 1 Economic loss due to fire incidents in Greater Dhaka districts. *Source*: Field data, BFSCD (2014)

Year	No. of incidents	Loss (BDT, in million)
2010	2669	1470
2011	2422	960
2012	2794	2400
2013	2891	4070

Research on distribution of fire incidents

All over the world, so many research have been carried out on fire incidents specially to identify the geographical location of fire incidents. So that planning can be done carefully to mitigate the fire loss. This will also help the planners for setting up new fire stations in the unserved area which is experiencing fire incidents frequently.

In this regard, analyzing the historical pattern of fire incidents is important to identify the zone experiencing most fire incidents which will help to take necessary precaution against the fire incidents in those respective areas. Wing and Long (2015) examined spatial and temporal trends in large fire incidents (> 400 ha) in Oregon and Washington. The fire database containing over 1000 fire incidents over a 25-year time period (1984–2008) was compared to climate variables like average monthly maximum temperature, average monthly minimum temperature, average monthly dew point, and average monthly precipitation and the results showed an increasing trend in fire frequency, extent, magnitude and fire season duration. Different geospatial analytical techniques such as Nearest Neighbor analysis, quartic Kernel Density estimation and Quadrat analysis identified spatial patterning and hot spots of fire occurrence and size in the study area.

Parajuli et al. (2015) assessed forest fire magnitude, distribution, seasonality and risk zone in diverse geographical area of Nepal. They identified hotspot regions of fire in diverse regions of Nepal using Kernel Density model.

On the other hand, there are some research, where the location of fire stations have been assessed relating with the fire incidents. A research by Hacioglu (2010) had been carried out based on the spatial deficiencies of fire stations in urban areas which are important reasons of the fire losses. Mahmud and Indriasarin (2009), in their research present and discuss a new developed model to maximize total service area of a fixed number of facilities like fire station, ambulance etc. The objective of the study was to develop a facility location model in continuous demand region, with road accessibility considerations. This was performed by integrating travel time zone generated through road network analysis in GIS. Liu et al. (2006), in their research, deal with the effectiveness of the fire stations of Singapore in covering the transportation routes of hazardous materials (HAZMATs). The research presented an approach to suitably situating new fire stations, considering multiple objectives, using Geographic Information Systems (GIS) and an Ant algorithm (ANT).

In Bangladesh, research have been done on mostly fire hazard vulnerability of Dhaka City where study focused on yearly distribution and causes of fire incidents (Islam and Adri 2008). Haque (2001), explored fire hazard only in the service area of Mohammadpur fire station through fire hazard modeling. It identified the distribution pattern of fire incidents and the hazard proneness of the area by different broad land use categories like, planned residential area, mixed residential area, commercial area, institutional area, slum area and industrial area based on previous pattern of fire incidents. And finally a hazard map was prepared. Jahan et al. (2012) carried out a research on the older part of Dhaka where the fire risk index was identified for chemical shops and warehouses and then the shops and warehouses was classified according to the index.

And in this research, the distribution pattern as well as the hot spots of fire incidents of Dhaka Metropolitan Area has been identified based on historical database of the fire incidents.

Data and tool

Data of fire incidents are always listed in the record book of fire stations under the parameters of incident date, response time, location, cause of incident, name of serving station and amount of loss and recovery due to incident. The data on fire incidents for the year of 2011–2013 have been collected from that record book of fire stations. The fire incidents, occurred from the year 2011–2013, within a structure or land use are considered for this research. This data set did not include the fire incidents occurred in vehicles. As a whole, 2389 locations have been identified and the incidents have been classified according to different land use categories and use of structures at the location of fire incidents.

Then the hot spot having the frequent fire incidents have been identified using Kernel Density tool in GIS environment using Arc GIS 10.1. The Kernel Density tool calculates a magnitude per unit area from point features using a Kernel function to fit a smoothly tapered surface to each point. The surface value is highest at the location of the point and diminishes with increasing distance from the point, reaching zero at the search radius distance from the point. Wing and Long (2015), Parajuli et al. (2015) used Kernel Density model to identify the hot spots representing the density of fire incidents. Besides, a road accident hotspot map (Anderson 2009) and hot spots of crime incidents (Wing and Tynon 2006) was identified using Kernel Density estimation.

Distribution of fire incidents in DMA

Distribution of fire incidents according to the use of structure or location of fire incidents

Historically, fire incidents have been taking place in different buildings of different uses. The incidents observed in the study years have been classified in the following use categories which has been recorded in the log book of fire stations:

- Residential use
- Commercial use
- Industrial use
- Mixed use

- Public facilities (include school, college, hospital, mosque, madrasa, temple, public institutions etc.)
- Road (include utility line like gas line, electric line, manhole)
- Open space
- Building of under construction

From the analysis, it is evident that, the number of fire incidents is highest in residential use category; next higher occurrence is found in commercial use, and then in industrial use (Fig. 2).

In addition to frequency of incidents, it is important to identify the loss of property due to fire incidents in different categories of uses. Figure 3 shows the average loss of fire incidents at different use of the structures.

From the Fig. 3, it is clear that, industrial land use faces more economic loss due to fire incidents, as it experienced highest average loss of BDT 0.76 million among all the land use categories. The figure shows, in case of all residential uses (including non-slum and slum areas) the average loss of property is BDT 0.17 million. But, only in slum areas the observed average loss is BDT 1.279 million which is greater than the loss experienced in industrial land use. In Bangladesh, slum areas refer the heavily populated urban area characterized by substandard housing and squalor. And from the research, it has been found that, slum areas are experiencing moat economic loss due to fire incidents among all types of land uses.

Though the frequency of fire incidents is highest in residential land uses, the industrial land uses as well as the slum areas face more economic losses. In the industries, expensive machineries are used to produce goods. Beside, in some cases of industrial land uses, fire spread so rapidly due to explosive materials. So,

the fire causes huge economic loss within a short time in industrial land uses. On the other hand, in slum areas the density of dwelling structures are significantly high and the building material are so susceptible to fire that the fire spread very rapidly within the site. And sometimes result in a destruction of the whole area with a huge economic loss and often serious injuries and life loss of the inhabitants.

Distribution of fire incidents according to the type of structure

Along with the use of structure, another important aspect is the type of structures in which a fire starts. In Bangladesh, there is mostly three types of building based on construction material of the building:

1. *Pucca* structure: refers to dwellings that are designed to be solid and permanent and is built of substantial material such as stone, brick, cement, concrete, or timber.
2. *Semi-pucca*: structure of which either the roof or the walls but not both is made of *pucca* (solid or permanent) materials like burnt bricks, stone, cement, concrete or timber.
3. *Kutcha* structure: structure built with naturally occurring materials like sun burnt bricks or mud or bamboo which is not solid or permanent.

All types of structures are subjected to fire incidents for different reasons. If the incidents are classified according to these types of structure at the location of fire incidents the distribution can be depicted in Fig. 4.

From the Fig. 4, it is evident that, most of the incidents took place in *pucca* structures and then in utility lines. With the development of any urban area, generally the number of *pucca* structures increases. In

Fig. 2 Distribution of fire incidents at different use of structure or location (2011–2013). *Source*: Field data, BFSCD (2014)
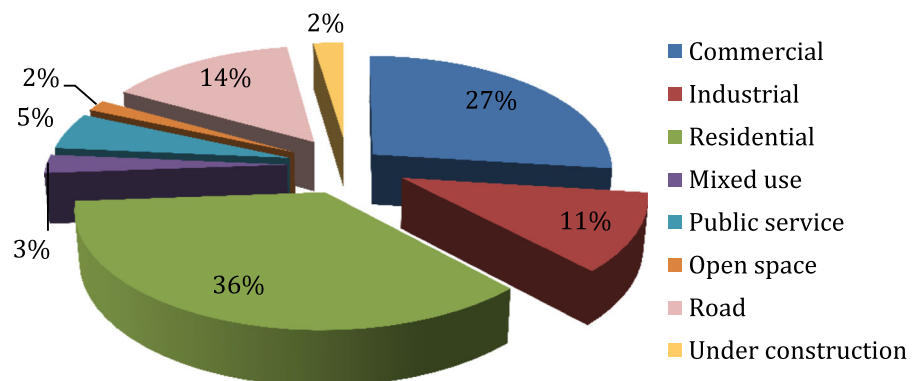
Fig. 3 Average loss of properties according to different use of structure or location (2011–2013). *Source*: Field data, BFSCD (2014)
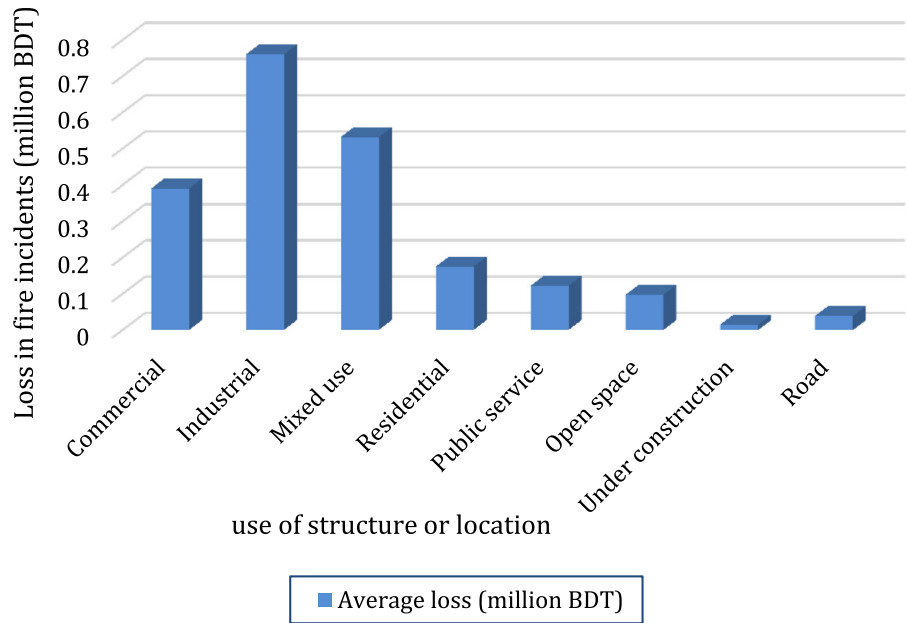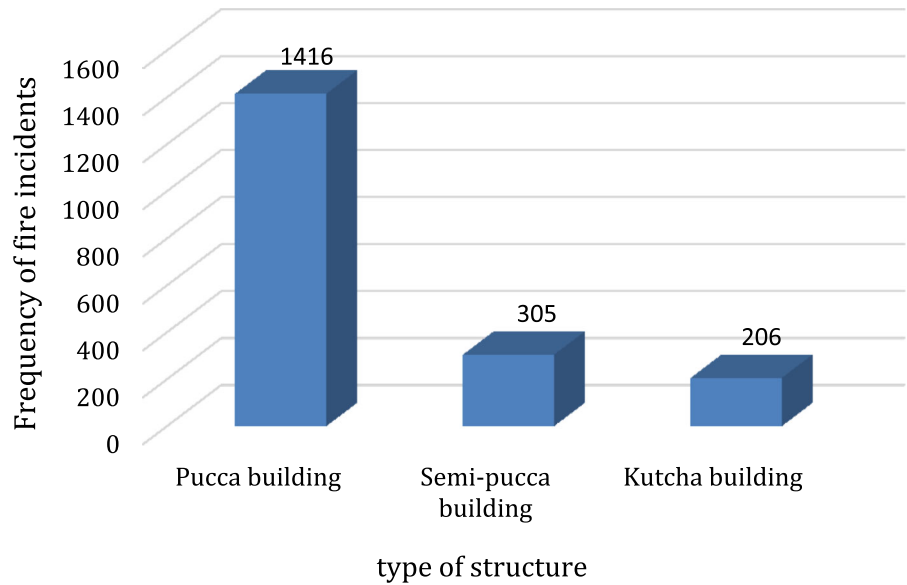

Fig. 4 Frequency of fire incidents according to different type of structures (2011–2013). *Source*: Field data, BFSCD (2014)

DMA, most of the structures are *pucca* (34%). These *pucca* structures are used for different purposes. So, the number and utility of *pucca* structure is higher than any other type. And this type of structure is experiencing most fire incidents from the year 2011 to 2013. Besides, short circuit in road side electric transmitter and electric wire is very common for Dhaka city. Though in most of the cases, the fire originated from road side electric installation is put off before spreading, but sometimes it may cause significant damage for the adjacent buildings. The leakage from the road side gas riser or gas line is another significant source of fire. And the fire originated from the gas source has to be handled in proper way to get rid of severe destruction.

From the recorded data, a number of fire sources have been identified and these sources are distributed

differently according to different type of structures it affected (Fig. 5).

From Fig. 5, it is clear that most fire incidents of every structure type are created from electric sources which include short circuits in electric line as well as in different electronic appliances like television, air condition and so on. Islam and Adri (2008) also found electric short circuit as the main cause of fire accidents in Dhaka city for every year of collected data (from 2001 to 2007). Electric short circuit results mainly from the loose connections, substandard wiring and overloading of the system and unconscious use of electrical appliances (Islam and Adri 2008).

In *pucca* structure, main two sources of fire are electric line and gas line, whereas in case of *kutcha* structure, in addition to electric short circuit 30% fire is originated from cigarette and stove. In slum areas, it is a common practice to have illegal electric lines installed with substandard wiring. Moreover, in slum areas, the stoves or burners are not set with proper precaution at appropriate location. The materials of *kutcha* structures are more susceptible to fire. So, in

kutcha structures, the fire spreads very rapidly and cause huge loss of property in a very short time. It is also evident from the aforementioned part, which states that, in slum areas the average loss due to fire incidents is highest. So, very special care is needed for *kutcha* structures specially in slum areas.

Identify the hot spots of fire incidents

Zone refers to an area or stretch of land having a particular characteristic, purpose, or use. A fire regime or zone can be defined by fire intensity, fire frequency, and the season of burn (Williams et al. 2001). In this research, from the distribution pattern of the fire incidents fire incidental zones have been identified which refers to similar intensity of fire incidents.

Using the Kernel Density tool in GIS environment, a map has been created having the raster cell size 100 m × 100 m to identify the density value of fire incidents per 0.01 km^2. Based on this density value of fire incidents, the areas of having fire incidents have
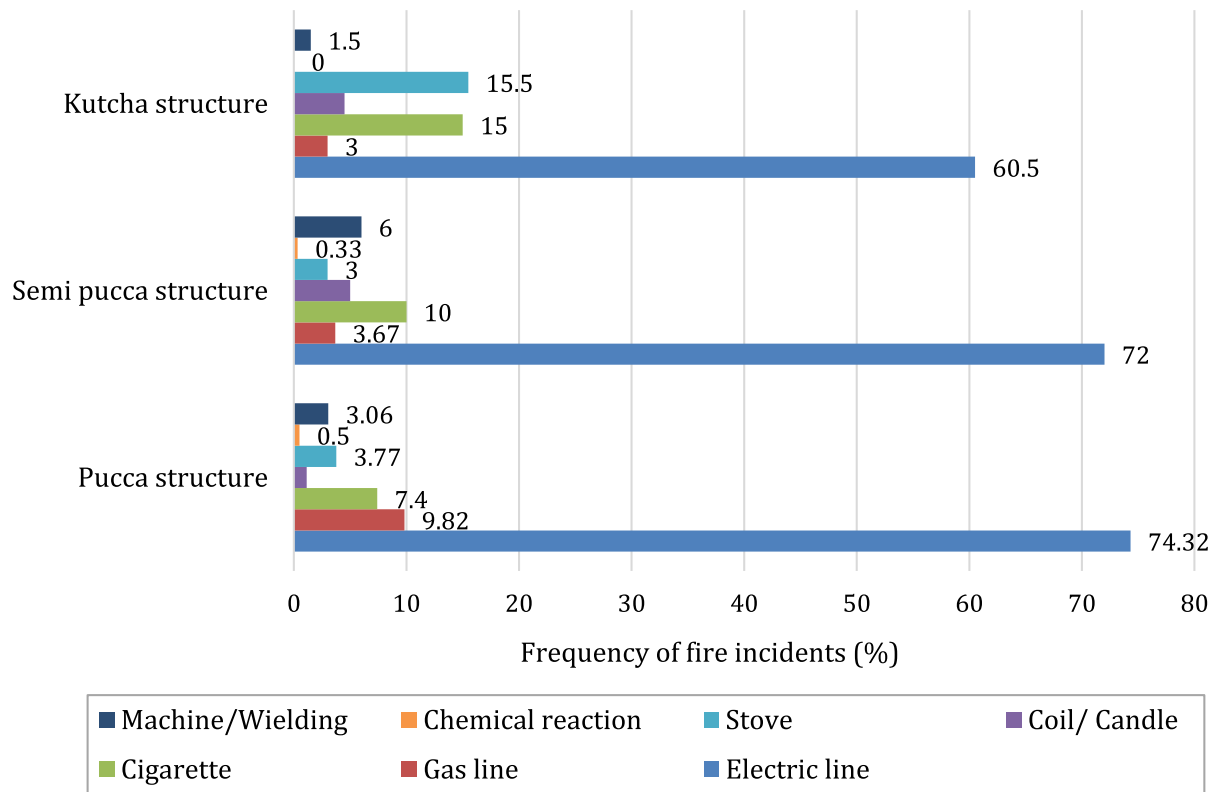

Fig. 5 Distribution of sources of fire incidents according to structure type. *Source*: Field data, BFSCD (2014)

been classified in 5 categories, through equal interval process which can be termed as:

1. Extremely high fire incidental zone
2. High fire incidental zone
3. Moderate fire incidental zone
4. Low fire incidental zone
5. Extremely low fire incidental zone

Then detail land use categories of these areas have been revealed. Rajdhani Unnayan Kartripakkha (RAJUK)—literally the Capital Development Authority of the Government of Bangladesh—is a Bangladeshi public agency responsible for coordinating urban development in Dhaka, Bangladesh. RAJUK has categorized the DMA area in some specified land use categories in the Detail Area Plan (DAP) of Dhaka. In this part of the research, the hotpot areas have been categorized in those land use categories following the map prepared by RAJUK. From the Fig. 6, the coverage area of these five types of zones has been calculated.

The areas of having the density value from 83 to 104 are classified as "Extremely high fire incidental zone" which covers an area of 0.2 km². And the hotspots are situated at Kotwali *Thana* and Bangshal *Thana* (Fig. 6). The area is mostly occupied with commercial (38.45%) and mixed (25.67%) land uses. And then the area is covered by residential area (20.55%). On the other hand, some important public services cover very low portion of this zone (4.85%). Among the public facilities there are Jagannath University, other schools and colleges, health facilities and some other government offices which can be considered as critical facilities and needed to take special care.

The area having the density value of fire incidents from 62 to 83 are classified as "High fire incidental zone" which covers an area of 0.92 km². These hotspots are located in Kotwali *Thana*, Bangshal *Thana*, Chakbazar *Thana*, Motijheel *Thana* and a small portion in Gulshan *Thana* (Fig. 6). In this category, the area is mostly covered by mixed use (24.75%) and then by commercial use (20.17%). Public services also cover a big portion (21.34%) of High fire incidental area. These facilities include schools, health facilities, mosques, banks, police stations and other government offices. So, public facilities should be given more attention to take prevention measures from fire incidents.

In "Moderate fire incidental zone" the density value of fire incidents ranges from 41 to 62 and its coverage area is 6.21 km². In this zone, besides the mixed use (16.18%) and commercial use (12.67%), residential uses occupy a notable portion of land (33.83%). The residential areas of this zone mostly located in Mirpur-10, west Dhanmondi, west Tejturi bazar, Tejkonipara, Malibag and Shantinagar. The public facilities like schools, colleges, hospitals, and other government public offices occupy 10.30% land of this zone.

In the "Low fire incidental zone" and "Extremely low fire incidental zone" the density of fire incidents ranges from 21 to 41 and 0.1 to 21 respectively. In these zones, residential use has been increased occupying 48.68% and 53.28% of respective zones, whereas the occupancy of other types of use has been decreased.

The significant land uses of these zones have been highlighted in a tabular format in Table 2.

The most notable findings from the detail land use categories of the above five fire incidental zones are that, in the "Extremely high fire incidental zone" 38.45% land is used for commercial purpose and 25.67% land is used for mixed purpose. And the residential area occupies 20.55%. On the other hand, in "Extremely low fire incidental zone" 53.28% land is used for residential purpose whereas 2.50% and 1.75% land is occupied with commercial purpose and mixed purpose respectively. So, areas of commercial and mixed use are most hazardous areas. And in residential area, though the frequency of incidents is highest but mostly residential areas are found in Low and Extremely low fire incidental zones.

Location of fire stations

In Dhaka Metropolitan Area, there are 12 fire stations. From the distribution of the fire stations (Fig. 7) it is clear, that the fire stations are more concentrated in south western part of DMA than the northern part. And compared with the distribution of fire incidents, it is found that, two stations are closely located near the Extremely high fire incidental zone. And others are located near the High fire incidental zone and the Moderate fire incidental zone. Though, near the Kurmitola fire station and the Palashi Barrak fire station the density of fire incidents is very low, they
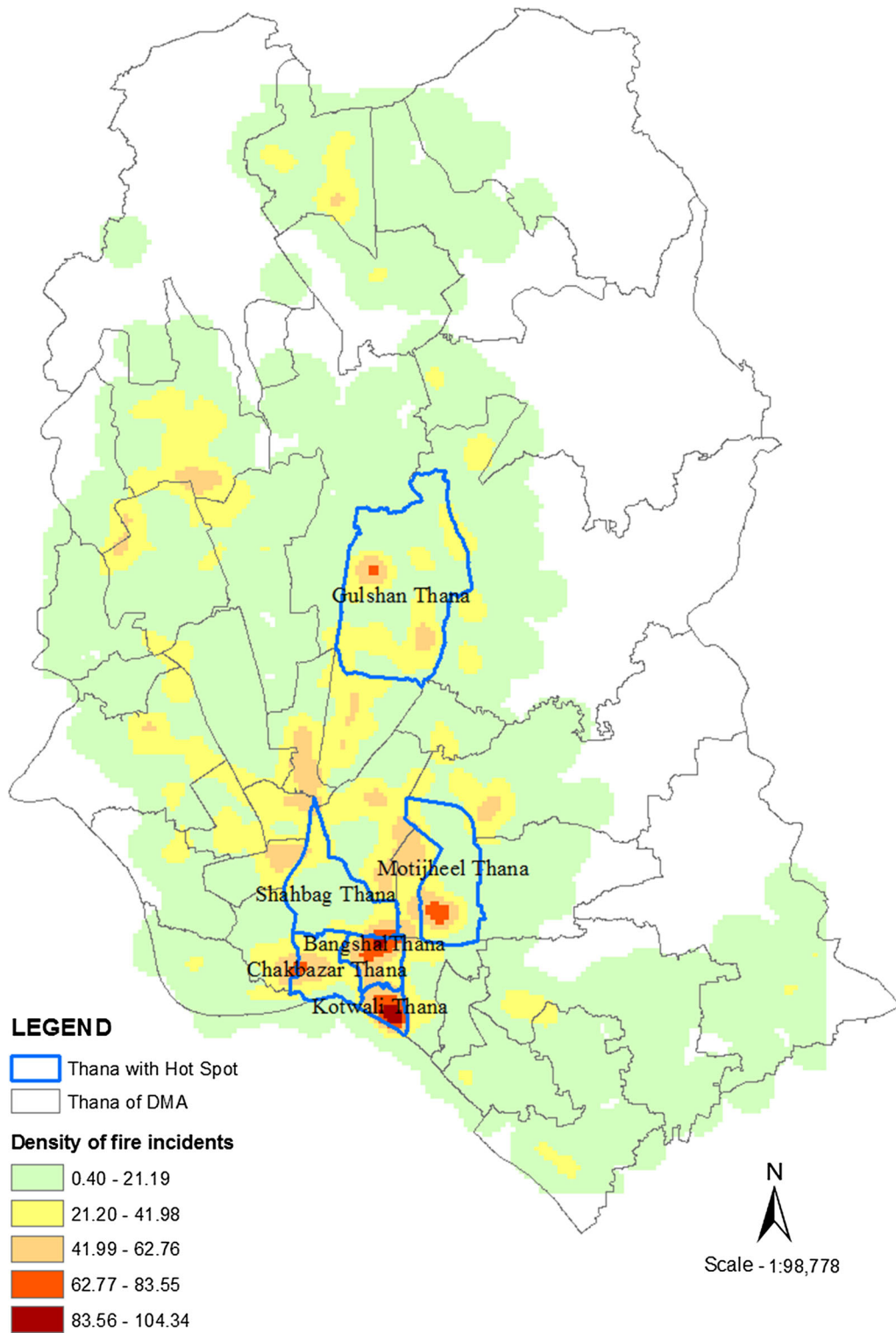
Fig. 6 Map of *thana*s containing the hot spots of fire incidents

Table 2 Land use categories of different fire incidental zone

No. of fire incidents (per .01 km²)	Total area (km²)	Land use category	Area (km²)	Percentage of total area
Extremely high fire incidental zone (83–104)	0.2	Commercial use	0.076915	38.46
		Mixed use	0.051358	25.68
		Residential use	0.041092	20.55
		Public service	0.009693	4.85
High fire incidental zone (62–83)	0.92	Commercial use	0.185559	20.17
		Industrial use	0.005233	0.57
		Mixed use	0.227730	24.75
		Residential use	0.119955	13.04
		Public service	0.196305	21.34
Moderate fire incidental zone (41–62)	6.21	Commercial use	0.781450	12.67
		Industrial use	0.122736	1.99
		Mixed use	0.998337	16.18
		Residential use	2.086167	33.83
		Public service	0.635546	10.30
Low fire incidental zone (21–41)	30.01	Commercial use	2.027561	6.78
		Industrial use	1.174042	3.92
		Mixed use	2.143989	7.16
		Residential use	14.557974	48.68
		Public service	3.494563	11.68
Extremely low fire incidental zone (01–21)	147.82	Commercial use	3.701180	2.50
		Industrial use	3.533868	2.39
		Mixed use	2.600816	1.75
		Residential use	78.767184	53.28
		Public service	8.087379	5.47

have been designed to serve the Cantonment area and the University area. On the other hand, in *Uttara thana* (north of DMA), though the intensity of incident is relatively higher, there is no station nearby the *thana*.

Result and conclusion

From the analysis of distribution pattern of fire incidents it is found that frequency of incidents is highest in residential land use category (36%). And the observed economic loss due to fire incidents is higher in slum areas (average loss is BDT 1.279 million) and in industrial land use category (average loss is BDT 0.76 million). So, special care must be taken for the development of slum areas. At the same, attention should be given in designing any industry so that proper fire-fighting precautions are taken properly.

Moreover, the highest density of the incidents (ranges from 83 to 104 incidents per 0.01 km².) are concentrated mostly in areas of commercial use (38.46%) and mixed use (25.68%). So, mostly the commercial and mixed use areas are more vulnerable to fire incidents. In this regard, land use zoning is very much important. Occupancy class of any building in a particular zone should always be maintained. According to Bangladesh National Building Code, 2014, without prior permission from the authorities having jurisdiction no change shall be made in the type of occupancy or use of any building that would place it in a different occupancy group or in a different subdivision of the same occupancy group. So, in case of giving permission for mixed occupancy hazard proneness of fire incidents should be considered efficiently. Hazardous occupancy (J) shall not be allowed as
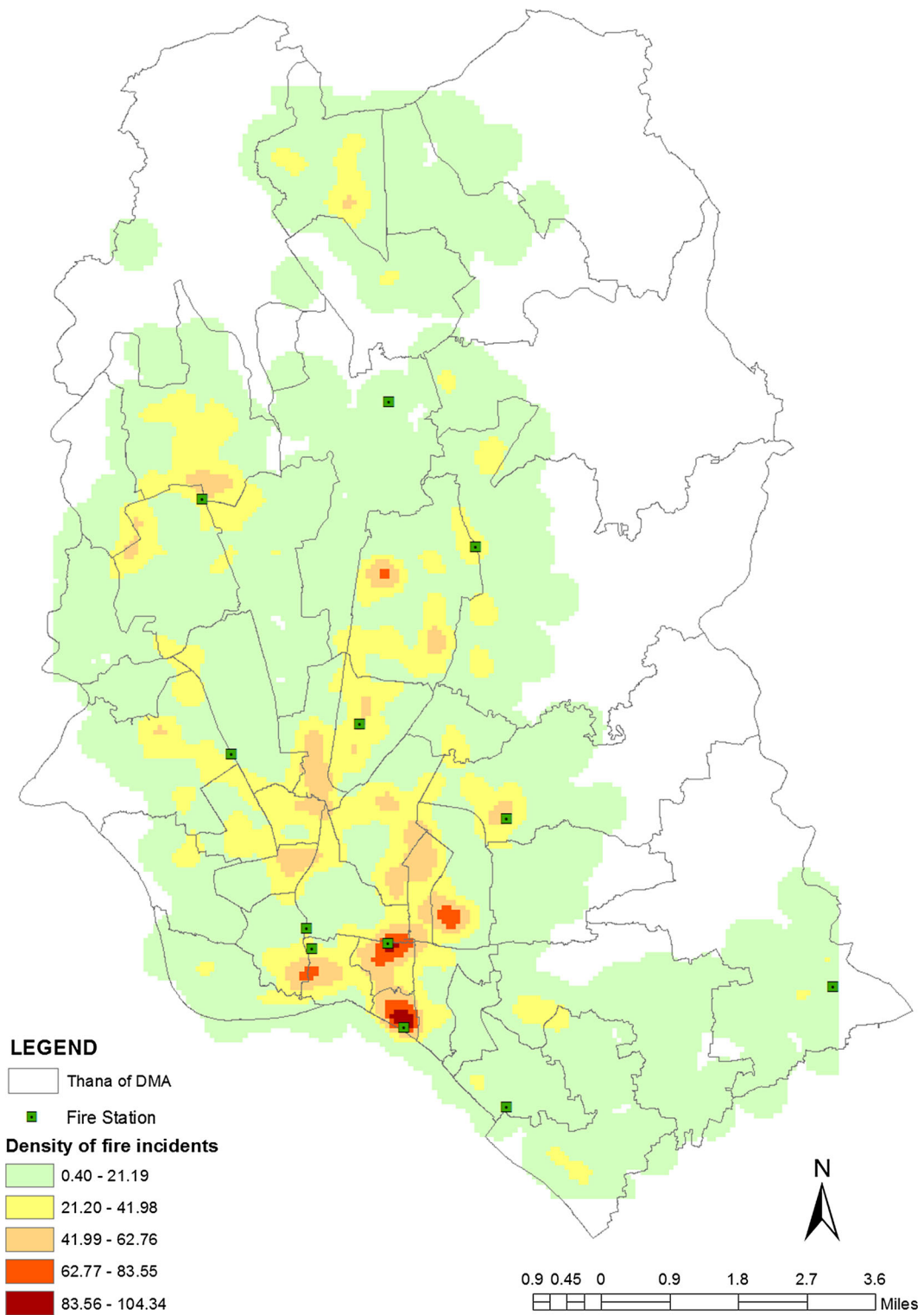
LEGEND

☐ Thana of DMA

▪ Fire Station

Density of fire incidents

☐ 0.40 - 21.19

☐ 21.20 - 41.98

☐ 41.99 - 62.76

☐ 62.77 - 83.55

☐ 83.56 - 104.34

N

0.9 0.45 0   0.9   1.8   2.7   3.6

Miles

Fig. 7 Map of fire stations with the hot spots of fire incidents

mixed or separated occupancy with any other occupancy classification as per provisions of the code.

So, if proper initiatives are taken the occurrence of fire incidents can be diminished at a certain level to save national asset. And to mitigate the fire loss, carefully planning is needed for setting up new fire stations with optimum capacity at appropriate location considering the trend of fire incidents to meet the increasing demand of fire safety.

Human and animal rights The research does not directly involve the any human or animal participants.

References

Anderson, T. (2009). Kernel Density estimation and K-means clustering to profile road accident hotspots. *Accident Analysis and Prevention, 41*(3), 359–364.

Bangladesh Fire Service and Civil Defence (BFSCD). (2014). Record book.

BBS. (2011). *Population and housing census 2011, community report: Dhaka.* Bangladesh Bureau of Statistics, Statistics and Informatics Division. Ministry of Planning, Government of Bangladesh, Dhaka.

FSCD Directorate. (2013) Stakeholder's workshop on finalizing strategic management plan. Fire Service and Civil Defense Directorate, Ministry of home affairs, Bangladesh.

Hacıoğlu, Ç. (2010). *Spatial requirements of fire stations in urban areas: A case study of Ankara.* M.Sc. thesis in Urban Design, Department of City and Regional Planning, Middle East Technical University, Turkey.

Haque, Q. M. F. (2001). *Fire hazard modeling in Dhaka city using GIS.* MURP thesis, Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology.

Islam, Md. M., & Adri, N. (2008, June). Fire hazard management of Dhaka City: Addressing issues relating to institutional capacity and public perception. *Jahangirnagar Planning Review*, 6, 57–67. Retrieved from https://www.academia.edu/24603228/Fire_Hazard_Management_of_Dhaka_City_Addressing_Issues_Relating_to_Institutional_Capacity_and_Public_Perception

Jahan, N., Islam, S., & Hossain, Md. I. (2012). *Developing fire risk index for chemical warehouse of old Dhaka.* BURP thesis, Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology.

Liu, N., Huang, B., & Chandramouli, M. (2006). Optimal siting of fire stations using GIS and ANT algorithm. *Journal of Computing in Civil Engineering, ASCE, 20*(5), 361–369.

Mahmud, A. R., & Indriasarin, V. (2009). Facility location models development to maximize total service area. *Theoretical and Empirical Researches in Urban Management*, Special Number 1S. April, 2009. Retrieved from https://core.ac.uk/download/pdf/6451137.pdf.

Parajuli, A., Chand, D. B., Rayamajhi, B., Khanal, R., Baral, S., Malla, Y., & Poudel, S. (2015, September). *Spatial and temporal distribution of forest fires in Nepal. XIV World Forestry Congress, Durban, South Africa*. Retrieved from www.forestrynepal.org/images/publications/wfc2015_forest firenepal.pdf. On November, 2015.

Wang, J. H., Sun, J. H., Lo, S. M., Gao, L. J., & Yuen, R. K. K. (2011). Statistical analysis on the temporal-spatial characteristics of urban fires under typical urbanization features. *Procedia Engineering, 11,* 437–444.

Williams, A. A. J., Karoly, D. J., & Tapper, N. (2001). The sensitivity of Australian fire danger to climate change. *Climatic Change, 49,* 171–191.

Wing, M. G., & Long, J. (2015, January). A 25-year history of spatial and temporal trends in wildfire activity in Oregon and Washington, USA. *Modern Applied Science, 9*(3). Retrieved from http://ccsenet.org/journal/index.php/mas/article/viewFile/44150/24047. On November, 2015.

Wing, M. G. & Tynon, J. (2006, September). Crime mapping and spatial analysis in national forests. *Journal of Forestry, 104*(6), 293–298. Retrieved from https://pdfs.semanticscholar.org/4f2c/d75e5ba5b1ba9c6f8e9d10a8cb3dcdbb3a25.pdf