

Fire Risk Analysis Using Geospatial Approach and Mitigation Measures for South-West Delhi

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Abstract—

One of the major challenge from unplanned growth in the cities is the fire incidents posing a serious threat to life and property. Delhi, the capital city of India, has seen unplanned growth of colonies resulting in a serious concern for the relevant agencies. This paper investigates the relation between potential causes of fire incidents during 2013-2016 in South-West Delhi Division of Delhi Fire Services as part of risk analysis using the data about fire stations & their jurisdictions, incidents of fire, water reservoirs available, landuse and population data along with the divisional & sub-divisional boundaries of South-West Delhi division under Delhi Fire Service. Statistical and Geospatial tools have been used together to perform the risk analysis. The analysis reveals that difference in actual occupancy and defined landuse as a part of unplanned growth of settlements is found to be the main reason behind the major fire incidents. The suggested mitigation measures focus on legal, policy, physical & technological aspects and highlight the need to bring the systemic changes with changing scenario of demographics and infrastructure to accommodate more aspects of ground reality.

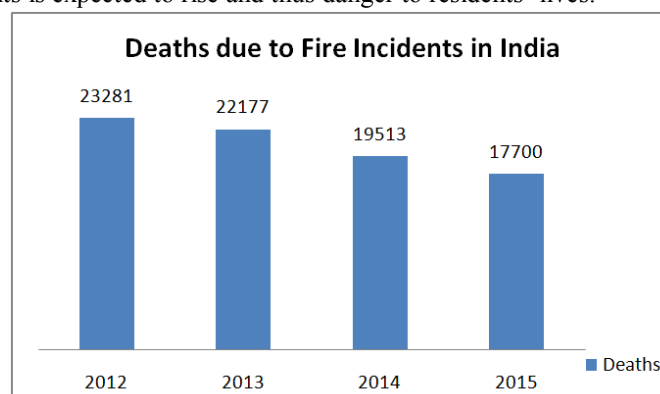
Keywords— Fire, Risk Analysis, Delhi, Geospatial, Mitigation, Landuse, Unplanned Growth

I. INTRODUCTION

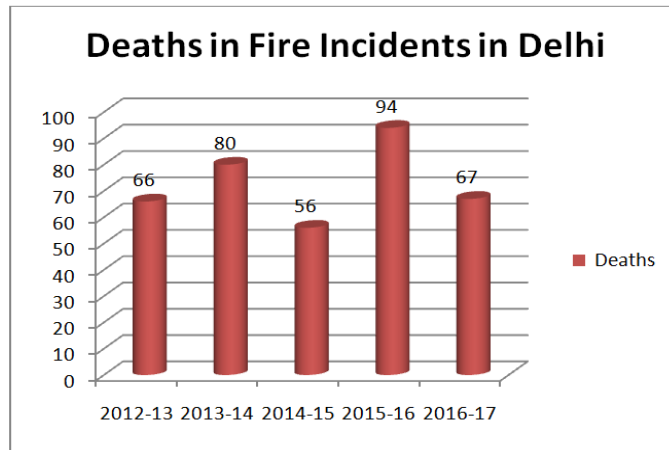
Cities are considered as engines of economic growth [1]. Increased urbanization is a global trend which has expanded the cities and thus demands for urban infrastructure, such as in China and India. Accordingly large cities are experiencing increase in population density, more traffic on roads, congested buildings and higher load on energy facilities [2]. This expansion requires proper planning and its implementation so as to ensure the good quality of city life [3]. Unfortunately, in less developed countries and developing countries such as India, the unplanned growth has taken place in cities. These cities have become over-populated and over-crowded partly as a result of the increase in population over the decades and partly as a result of migration [4], [5]. Migration is an individual as well as societal need which happens due to several socio-economic reasons. Such unplanned growth brings new challenges for the planners, decision makers and service providers. Among different types of disasters, fire constitutes a significant threat to life and property in urban and rural areas [6]. A challenge, common for all such cities in developing countries, is the fire incidents. Occurrence of disaster like urban fires pose a significant threat to life and globally results each year in high number of deaths with high occurrence at home [7].

Delhi is the capital of India and is a metropolitan city. It has seen significant growth in terms of infrastructure and population in recent decades, accompanied by unplanned growth of unauthorized colonies, expansion of existing colonies and vertical growth of existing buildings. Due to unplanned settlements, management of urban Delhi is a serious concern for the relevant agencies [8].

All this has created a problem of increased fire incidences due to various reasons. As shown in figure 1a, such fire incidents have caused approx. 70,000 deaths in India during the period of 2012-15. As per Figure 1b, during the period of 2012-13 and 2016-17, total 363 deaths have occurred due to fire incidents [21]. With the passage of time, the number and intensity of these incidents is expected to rise and thus danger to residents' lives.



(a)



(b)

Figure 1 (a): Deaths in Fire Incidents in India, Source: National Crime Record Bureau, India 2012, 2013, 2014 and 2015;
 (b): Deaths in Fire Incidents in Delhi, Source: Delhi Fire Service

Spatial nature of such incidents and the associated parameters/indicators, make it essential to use tools that can capture the spatial heterogeneity of the cause and impact. Local variations could be captured now much more easily with the advancement of spatial science based GIS and Remote Sensing technologies. These technologies can integrate spatial and non-spatial data to perform spatial analysis [9].

With this background, this paper focuses to investigate the relation between various potential causes of fire incidents in South-West Delhi Division of Delhi Fire Services as part of risk analysis. Further, based on this analysis, mitigation measures are suggested.

II. MATERIALS AND METHODS

For the purpose of this study, spatial and non-spatial data has been collected for the fire stations & their jurisdictions, incidents of fire, water reservoirs available, landuse data, population data along with the divisional & sub-divisional boundaries of South-West Delhi division under Delhi Fire Services and municipal ward boundaries.

The figure 2 shows the logical flow diagram for the study. The data collected has been utilized for the analysis of relation between fire incidents and the studied parameters.

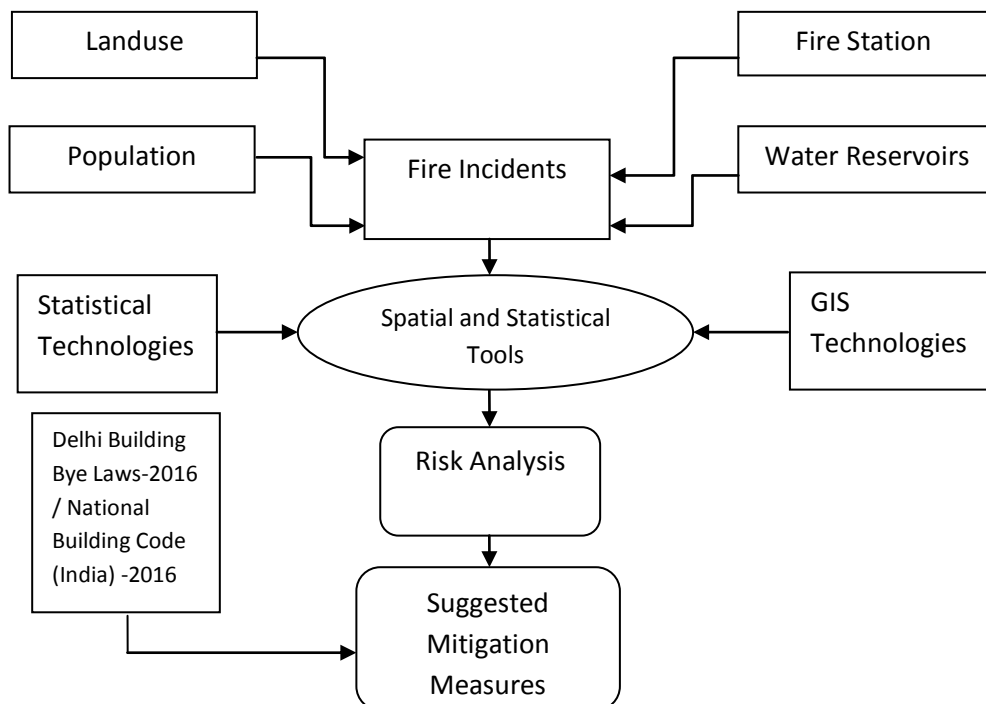


Figure 2: Conceptual framework for fire risk analysis and mitigation

Major fire incidents have been categorized and further analyzed as a result of landuse/landcover and population factors. Using these datasets as layers in a geospatial environment enables to generate various analytical maps for performing risk analysis. Water reservoirs and the fire stations are the resources available as counter measures to deal with fire incidents. Delhi Building Bye Laws-2016 / National Building Code (India) -2016 have been referred to identify the potential mitigation measures along with the interpreted results of Risk analysis.

III. RESULTS

Usage of GIS technologies allows digitally interacting with the relevant data of spatial and non-spatial nature with enough flexibility to visualize the results of various spatial tools for overlay and other queries to provide vulnerability of the studied area towards fire incidents [10]. Using the attribute data further in tabular format allows seeing the trends and linkages between the parameters. This data used in a statistical manner reveals the cause and impact relations [9].

Figure 3 shows sub-divisional boundaries along with fire stations in South-West division of Delhi Fire Service. Figure 4 shows the major fires and water reservoirs available. It shows that water reservoirs are available within the Jurisdiction of the South-West Division as well as outside of it. However, due to inadequate water supply from these reservoirs in the area, availability of enough water for firefighting purposes cannot be ensured. This results in replenishment of fire tenders from far areas decreasing the effectiveness of fire fighting operations. Figure 4 depicts that severe category fire incident locations of year 2014 are well within the service area coverage of the respective stations inside the subdivision as well as in proximity of the other stations in other subdivisions. This highlights the presence of responding capacity as counter measures. However, it shows clearly a vast area under a single fire station jurisdiction in Janakpuri subdivision. This can be explained with the expected lower level of population in this area due to its rural background. To deal with the changing landuse of urbanizing Delhi-NCR and thus changing scenario of demographics, Delhi Fire Service has upgraded a temporary fire post set up in rural area as a new fire station (Khera Dabar) under jurisdiction of Janakpuri Sub Division (shown in Figure 3 as proposed fire station). This has improved the response time and thus effectiveness of fire service interventions in this area.

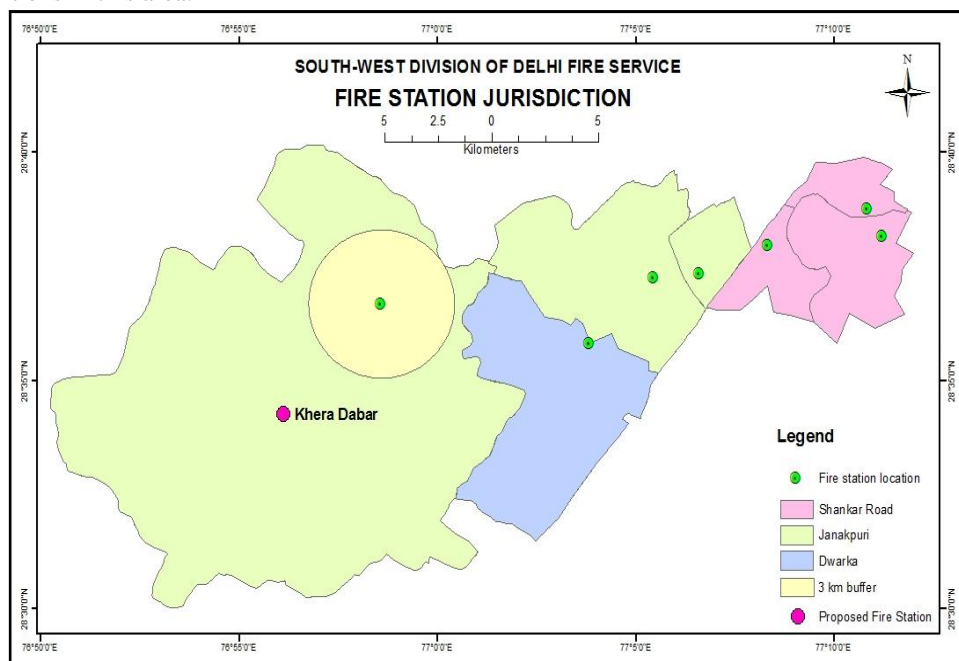


Figure 3: Map of Jurisdictions of Fire Stations in South-West Division, Delhi

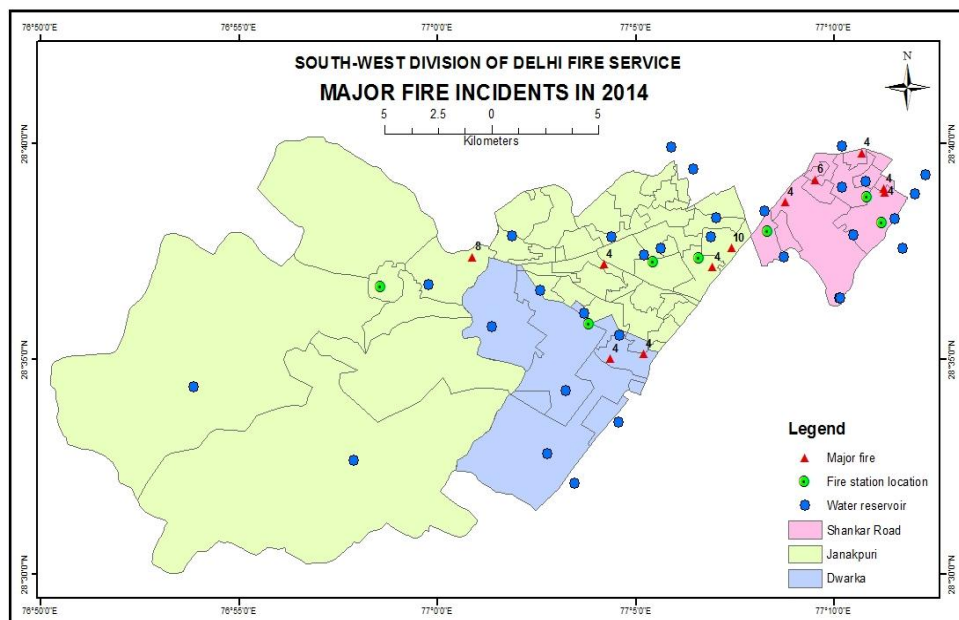


Figure 4: Map of South-West Division of Delhi Fire Service, Delhi

It can be seen from figure 5 that between 2013 to 2016, highest number of severe category fire incidents have happened in landuse designated as 'Residential' under all the categories except category 10. Highest number of incidents of category 10 has occurred in landuse designated as 'Commercial'. Figure 6 shows the overlay of severe category fire incidents location with landuse/landcover data in GIS Software. Figure 7 shows that population density has no significant correlation between incidents and population density except that no measurable incident has occurred in the categories of 4, 6 and 8 in the areas having population density more than 50,000 per square km. This indicates that population density has no relation with the major fire incidents in Delhi.

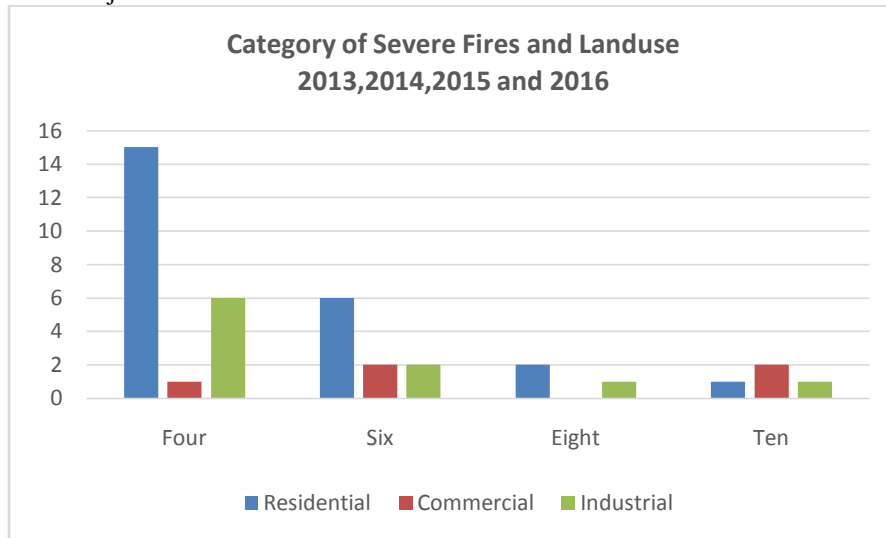


Figure 5: Relation Between severe Fire Categories and Landuse between 2013 to 2016

Table 1 shows the number of fire tenders required for each fire category.

Table 1 Fire tenders required as per fire category

Fire Category	No. of Fire Tenders Required
4	6 or >
6	10 or >
8	16 or >
10	22 or >
12	28 or >

For the fire incident of category four, 6 or more water tenders are required; category six requires 10 or more tenders; category 8 requires 16 or more tenders and for category ten, 22 or more fire tenders are required.

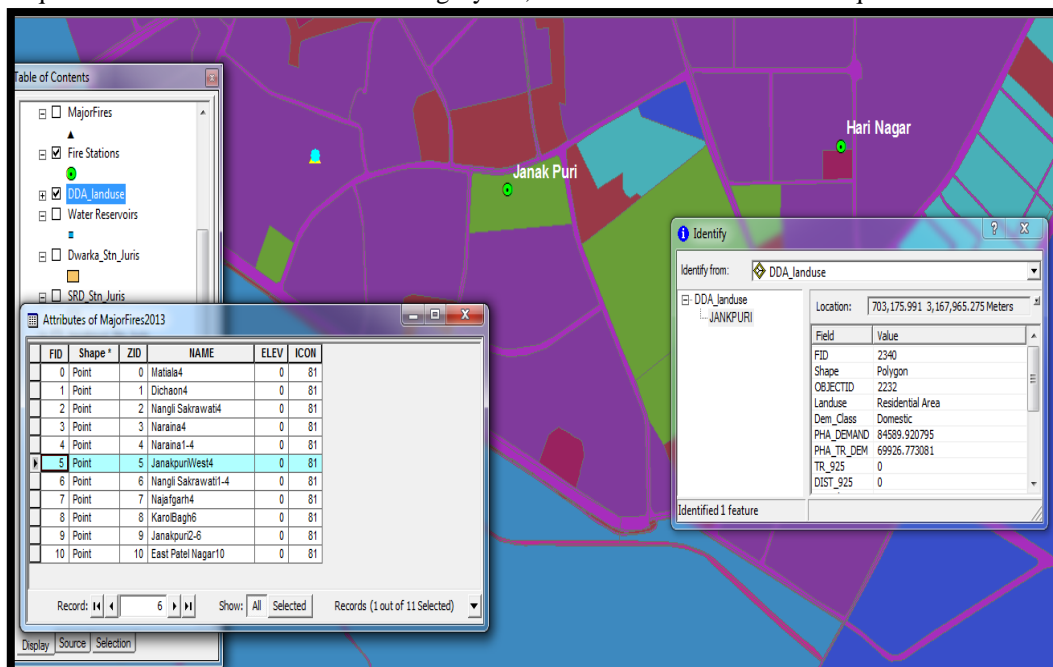


Figure 6: Overlay of big category fire incidents location with landuse/landcover

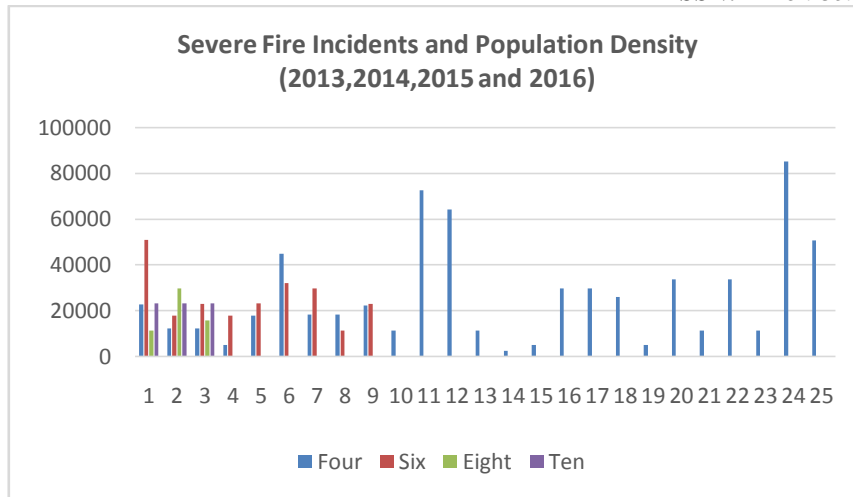


Figure 7: Relation Between Severe Fire Categories and Population Density between 2013 to 2016

Table 2 shows the area covered under three landuse categories in each subdivision. Table 2 has been analyzed for the relation of severe fire incidents with coverage area of particular landuse. Highest number of such incidents has occurred in ‘Residential’ designated landuse. However, this high occurrence could be related to the high percentage of total area covered by Residential landuse in all the subdivisions. Further, it has been found that the occupancy of the premises of some of the severe incident places was contrary to the designated landuse. In fact, some residential habitats were found to have factories as the actual occupancy.

Table 2: Percentage of total area covered by commercial, industrial and residential landuse in each subdivision

Sub-division	Commercial	Industrial	Residential
Shanker Road	0.1	6.3	19
Dwarka	3.9	0.4	35.4
Janakpuri	1.71	1.55	38.3

This linkage was further explored by analyzing the data on total fire incidents for colonies inside the particular ward. For this purpose, as a sample, top five areas according to fire incidents in each subdivision have been selected for the year 2014 and 2015. For each of these areas, the fire incidents have been categorized as electricity originated and non-electricity originated. Based on the materials involved such as in electric origin (Electric Pole wire, Overhead wire, Underground cable, Transformer Cable, Electric Meter Board, Electrical Wire, Cooler/ac) and in non-electric origin (In-House Article, LPG, Waste Material, Vehicles, Tree/Grass and others) which caught fire and resulted in fire incidents have been analyzed. The analysis of fire incidents in South- West Division in Delhi for the year 2014 reveals that an approximate 42% of the fire incidents are under the electrical category and an approximate 58 % of the fire incidents are under non-electrical category. This could be the result of faults in electric meter board, wiring, operating equipment for commercial purposes producing heavy load more than the allocated capacity of network lines and transformers, use of sub-standard electrical fittings, poor maintenance or illegal connections taken directly from the electric distribution lines/poles etc. Under non-electrical category, most common materials catching fire and resulting in fire incidents are identified as in-house articles-21%, vehicle fire-11%, waste material fire-10 % and LPG related fire incidents-9 %.

There is a worldwide trend of migration of people from rural to urban areas and this migration leads to the growth of unauthorized residential colonies particularly in rural area of a metropolitan city. Later, civic services are extended / provided to these unauthorized colonies by the local bodies / government and declaring them as regularized.

IV. MITIGATION MEASURES

Based on the above analysis about risk of fire incidents, the following mitigation measures are suggested:

A. Strict implementation of laws

Government of India has notified “Unified Building Bye Laws for Delhi” on 2nd March 2016, which shall be applicable to all building activities in urban villages/rural villages, unauthorized regularized colonies and for special areas. But these bye-laws are enforced from the date notified and cannot be enforced on buildings constructed prior to the enactment of these bye-laws. Earlier Building Bye Laws, Delhi -1983 was in force. Parallel bye-laws for the existing buildings may be framed and implemented through regulations.

B. Awareness about fire safety

Fire safety awareness programmes should be conducted regularly by fire department across the city for different occupancies especially in high fire risk prone areas like Jhuggi clusters and un-authorized colonies. Special workshops on fire safety for school teachers and Resident Welfare Organizations (residence and market etc) should be conducted.

C. Road network improvement and dedicated lanes for fire tender

Road network has a direct connection with the response time of fire services in case of an incident. This makes it imperative to devote this infrastructure a special status for fire services. Colonies having limited or narrow approach roads can be identified and small fire tenders built on small vehicle chassis can be used.

D. Strengthening of electrical infrastructure for distribution with strict enforcement

Electricity based fire incidents are quite common and thus improvement in electricity supply and distribution infrastructure is required. Community Awareness programmes for electrical fire safety can be organized in cooperation with electricity distribution companies.

E. Setting up new sub-fire stations accommodating new infrastructure developments and population distribution

Considering changes in infrastructure development and population distribution over a period, setting up new sub-fire stations or upgrading the existing sub-fire stations will be required. Such infrastructure could have a direct impact on losses occurring due to fire events. Master Plan Delhi 2021 (MPD-2021) has a provision of a Fire Post at every 3 kilometer and a Fire Station at every 7 kilometer distance. It also has a provision of Disaster Management Centre and Fire Training Institute/college.

F. Use of latest technology equipment by Fire Department

Latest technology such as water mist has brought much advantageous equipment for firefighting purposes, where large fires can be extinguished by using limited quantity of extinguishing material like water and foam. Such equipment can be easily carried by fire fighter or on the small fire vehicles like motorbike.

G. Use of geo-spatial technologies

Geospatial technologies can contribute in planning for fire services. In addition to giving an idea of landuse/landcover in the jurisdiction area, it can help in generating optimum routes, service area as per the time and distance, asset management. Using Global Positioning System, responders can plan response route in advance as well as get the updates about the live traffic situation. This can drastically cut down the response time and losses. Live Images/Videos from fire fighters cameras and fire fighting vehicles at fire ground connected with fire control room can make a significant difference. Images or videos from Drones or if possible, satellite images in real time, may contribute.

H. Fire safety regulations as integral part of urban planning

With increased population, infrastructure and resulting congestion, modern cities need to prepare for increased fire risks. Delhi Fire Service Rules - 2010 under Delhi Fire Service Act, 2007 have been framed and notified, making mandatory for certain classes of occupancies to incorporate minimum standards for fire prevention safety such as access to building, arrangement of exits, fire compartmentation, smoke management system and fire protection systems etc. Such standards should be included in urban planning.

I. Arrangement of Dedicated Underground Water Reservoirs

In the areas of higher fire risk, it is imperative to have dedicated underground water reservoirs for replenishment of fire tenders in time. Locations for such dedicated reservoirs should be identified based on fire risk analysis. Alternatively, water bousers/water carriers having large capacity of water shall be provided in adequate numbers in such areas.

V. DISCUSSION

The results highlight the importance of planned growth in an urban scenario so as to mitigate the risk to physical assets of community, government and private sector. Unplanned growth makes it easy to avoid the strict implementation of landuse laws. Such growth could create hazardous situation in case of fire and Delhi has a long history of such fires. The comparison of major fire incidents in these areas proves this fact that actual occupancy could be different from the permitted or defined landuse and thus could lead to the disasters.

Unplanned growth also leads to the development of congested colonies, markets and other buildings which subsequently result in overburdening the transportation and electrical networks. Many times, the overburdening of electrical networks result in fire incidents. The increased infrastructure development in unplanned manner creates pressure on the fire service department. The increased traffic on transportation network can lead to slow response by the fire tenders. All this contributes to the overall risk for the population and infrastructure in the area from fire hazards.

The suggested mitigation measures highlight the need to update the fire safety regulations with changing scenario as well as to accommodate more aspects of ground reality. Fire safety guidelines while developing new colonies should be implemented strictly. In the existing colonies, especially unauthorized, redevelopment should take place in a manner to implement fire safety guidelines properly. Enforcement of landuse plan is a critical step towards reducing the fire risk.

ACKNOWLEDGEMENT

Authors of the paper acknowledge the contribution from Mr. A. K. Sharma, Former Director, Delhi Fire Service in the form of his valuable comments.

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