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Anthropogenic Hazard in The Urban Area: A Geographical Assessment for Management of Fire Risk in Kolkata Munical Corporation (KMC)

Sandip Ghosh[1]* and Ashis Kumar Sen[2]

Abstract : *Fire is one of the most important hazard, often causing massive damage to life and properties but it can be managed and preventive measures can be taken to avoid large scale devastations. Anthropogenic hazards are usually very common in urban areas, particularly if such areas are unplanned and congested without having proper fire safety. In the Kolkata Municipal Corporation (KMC) of West Bengal, the present study area, the density of settlements has been increasing mainly because of the number of houses and infrastructures located within adjacent areas are increasing making it prone to urban fires. The present study involves investigation of the nature of fire hazards in the KMC area, including their geographical and seasonal distribution, frequencies and magnitudes, damages and control. The major focus is on the scope for use of geo-spatial technologies in assessment of fire hazards in the KMC area. Emphasis has been given on the risk factors of the fire hazards over time and space, identification of probable fire hazard zones and their specific categorization, and effective networking of the nearest fire stations and other fire fighting strategies. The research attempts to address the specific issues of different land use sector including industries, market, residential, slum and hospitals area through application of Global Positioning System (GPS), Remote Sensing (RS) and Geographical Information System (GIS) for preparation of Urban fire assessment plan.*

Key words: *Anthropogenic hazards, Risk factors, Geographical Fire Assessment*

Introduction of Kolkata city and its population problems:

Urban fire is one of the most common and dangerous man- made hazards, often causing massive damage to life and properties, which is manageable by taking preventive measures. It occurs frequently, particularly if the urban layouts are unplanned and congested, the man-land ratio is usually very high, and the nature of land use and land cover (LULC) permits fire to spread quickly, especially in the unplanned towns and cities**.** The Kolkata Metropolitan Corporation (KMC) area is historically old, congested and had emerged as an unplanned city due to haphazard

1 *Guest Lecturer, Kshudiram Bose Central College, Kolkata*

* *Corresponding author Email ID: sandipghosh.85@gmail.com*

2 *Retd. Associate Professor, WBES, Presidency College& Former Founder Head, Department of Geography, Aliah University, Kolkata*

settlement from the era of colonial period. The urban fire preventive measures responsible for the planning and implementation of urban fire prevention strategies are based on integration of fire protection systems with various other disciplines such as conservation of nature, riparian zone management, aesthetics, etc. (Tang, 2012). In Kolkata, the different land use forms a complex mosaic in the landscape and subsequently creates varying degrees of fire hazards in the region, particularly in the high-density areas. Fire prone zones of the KMC area have increased dramatically in many areas, and the past five years have witnessed a substantial increase in the number of fires and area burnt, causing loss of millions of rupees due to property damage, and even loss of lives. Kolkata is the pioneering city in India in terms of industrializations (Mukherjee et al., 2018), the most important city of the country in the sense of national economy, polity and culture (Sen, 2015), characterized by large number of migrants (Basu, and Sil 2000), contains major groups of water bodies (Rudra, 2014). Due to growth of population the land use pattern, with the shrinkage of water bodies and increase of residential, commercial as well as industrial and institutional areas (Chatterjee et al., 2006). For fire management, it is very important to have clear knowledge about the physical structure of the city to reach quickly to the fire victim places to reduce the loss of lives and properties. This is significant as Kolkata, the present study area, is historically old, congested and had emerged as an unplanned city ***(***Sikdar and Sahu, 2009***)*** due to haphazard settlement from the colonial time beings**.** The Kolkata metropolitan city is divided into two clear segments (a) the older section of the city, spreading over the central and northern parts and (b) the built-up areas, constituting southern and western periphery (Dhar, 2013). These two areas therefore have two distinct types of characters. The former section is characterized by poor urban infrastructure, close in proximity to the CBD whiles the latter, followed by the 'outer crescent of the city', exhibits planned urban development in the form of purely residential built up area (Dhar, 2013). In addition, it seems difficult for the quickest arrival at the fire victim places in the Kolkata, because the road space is very congested and vehicular density (500 vehicles /km) is also very high leading to high traffic congestion in the major roads (Chakrabarty et al., 2009).

Anthropogenic hazards in the Kolkata City:

Acknowledging the importance of Kolkata urban fire, the Fire Safety Journal (Elsevier) has published a special issue (Vol. 62: November, 2013) on spatial-analytic approach in urban fire management. Preventive measures against fire hazard in KMC are better suited than the post-hazard rescue and rehabilitation. Damages by urban fire can be drastically reduced if the provisions are made using geo-spatial technology at various levels of pre and post fire hazard scenario. The technology can be effectively used to combat and forecast urban fire, as this has both spatial and temporal dimensions. Geomatics**,** the new technological support of these days,

may be immensely beneficial for management of the fire hazard to a great extent (Murali and Vijayalakshmi, 2014). The system is capable of helping the managers of urban fire to take the best decision against real time fire incidents. Such an approach can be considered in view of the existing fire hazard in Kolkata. The traditional methods of fire prevention are still operative in the city; and unless this is upgraded using the modern geo-spatial technology, the problem will definitely continue.

Fire hazard proneness in Kolkata:

The present study involves investigation of the nature of fire hazards in Kolkata Municipal Corporation (KMC) area including its geographical and seasonal distribution, frequencies and magnitudes, damages and their control. It also includes a critical analysis of the existing fire prevention mechanisms under the control of the various agencies operating in the KMC area, and to find out in the deficiencies, if any. The exercises have definite focus on the scope for use of geo-spatial technologies in mitigation of fire hazards in the KMC area. Emphasis has been given on the risk factors of the fire hazards over time and space, identification of probable fire hazard zones and their specific categorization, identification of the best preventive measures including sources of water and other materials for fire fighting, location and effective networking of the nearest fire stations and other fire fighting strategies. The problem attempts to address the specific issues of Fire Management System (FMS) through application of Global Positioning System (GPS), Remote Sensing (RS) and Geographical Information System (GIS) for preparation of fire management plan.

Literatures on Geography of fire hazards are somehow very limited. However, a number of studies, mainly by the scholars of other disciplines, have been done on the hazard and disasters in the different parts of the world, i.e. (i) the Federal Emergency Management Agency (FEMA), the USA (1999) has prepared a comprehensive profile of the urban fire problem in the United States of America, (ii) Vliegher and Basigos (1995) have prepared fire hazard modeling using remote sensing and GIS with a case study in Greece, (iii) Lentile et al (2006) have used remote sensing technique in assessment of fire hazard as an effective technology with the assertion that it has great potential for scientists and managers seeking to map, predict and assess the ecological effects of fire, (iv) Melesse *et al* (2007) have discussed about the remote sensing sensors that can be applied for environmental resources mapping and modeling, (v) Picotte and Robertson (2010) have attempted to test the accuracy of remote sensing technology in forest fire damages, (vi) Ghosh Dastidar (2012) has discussed in detail the AMRI hospital fire tragedy of December 9, 2011, while Paul and Ghosh (2014) have analyzed the fire incident of AMRI hospital, which was a very shocking incident for the people of Kolkata.

In general, there is an individual fire extinguishing system in almost every apartment, hospital, industry and other installations against small fires at the nascent

stage. But, unfortunately there is major infrastructural lacking and communication gap between fire events and their management especially for the large scale fires. In many cases it is noticed that the department of fire and emergency services is not properly informed. Sometimes narrow roads do not permit to enter the big fire engines, and very often fire fighters have to fetch water from distant places.

But most of the papers have emphasized on the Vulnerability Analysis of fire hazard taking different indicators. Surprisingly, the already existing literature as mentioned above have overlooked some major aspects of the fire management, i.e., identification of the fire, selection of the shortest route through which fire engine can reach the victim place with a minimum time, selection the suitable extinguisher based on fire type etc which are the major aspects of the present research work. In addition, the present work also aims at identifying quickest response to fire management.

The Study Area

The KMC is located at 22^0 82'N of latitudes and $88^0$20'E of longitudes (Fig. 1) and is one of the oldest urban centers developed by the British. The city was not developed in a planned way, so is has a complex character which has resulted in a number of human and environmental problems including fire hazard. Kolkata (formerly known as Calcutta) is the capital of West Bengal, and is one of India's oldest urban areas. Historically, the city was the trading and commercial capital of India. It is located on the eastern side of the river Hooghly.

It is the third largest urban agglomeration and the fourth largest city in India. Kolkata Municipal Corporation (KMC) is the city's local authority to provide the basic services and amenities for the citizens such as supply of drinking water, sewerage, drainage, solid waste management, fire and safety management, maintenance of roads, street lighting, slum development works etc. The city is divided into 144 administrative wards that are grouped into 15 boroughs. As per the2011 census data, the city has an area of 185 square km and a population of 4.48 million, with a population density of 24,252 per square km.

Objectives and Methods Adopted for of the Study:

The main aim of the present study is to provide a methodological assessment for preparation of a fire hazard management plan for the KMC area using geo-spatial techniques. However, it includes the following specific objectives: (a) identification of fire risk prone locations in KMC area, (b) finding out the factors responsible for fire hazards in the area and (c) preparation of GIS based models for effective real time fire assessment practices for the city.

The study area in urban fire hazard research has been used with respect to the logical method statistically to assess the nature of old maps, data collection,

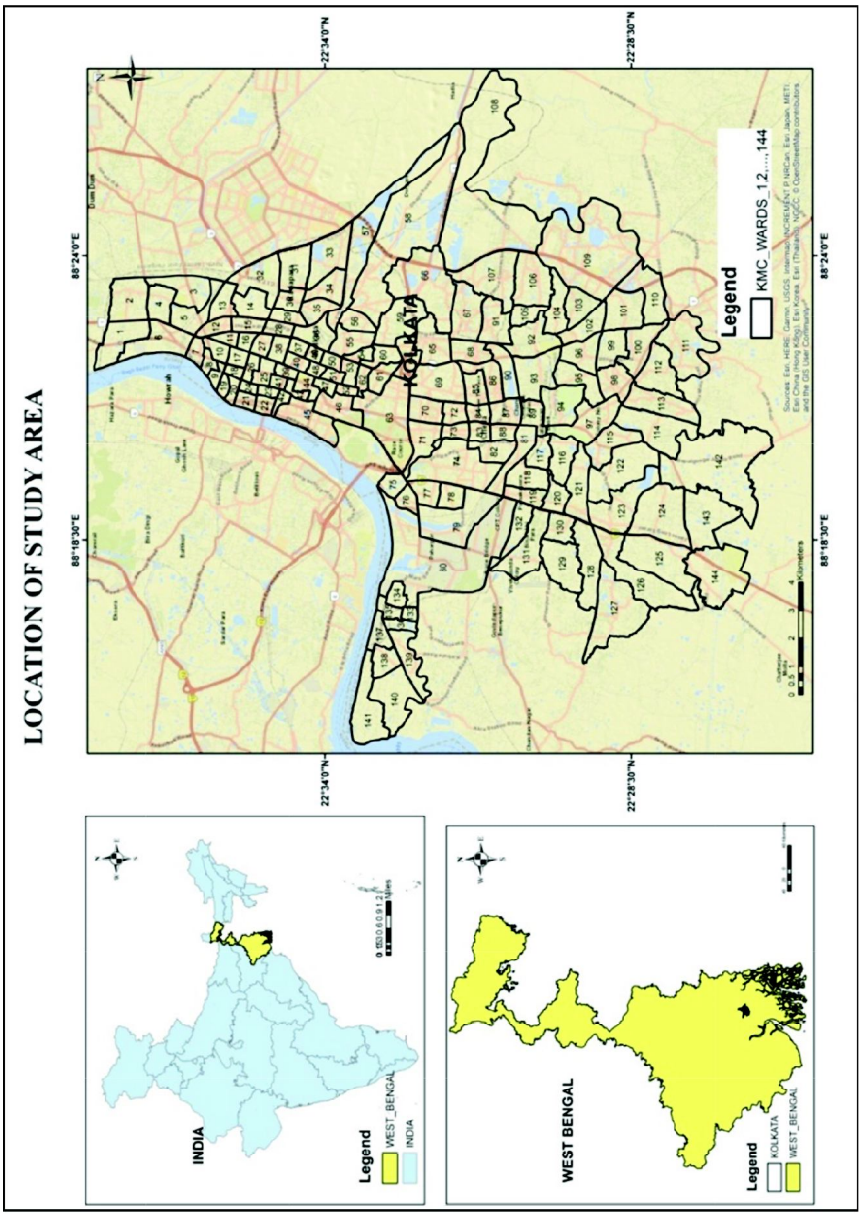

Fig. 1: Location of the Study Area

data analysis and data interpretation are properly done and geospatial data are also corrected through ground truth verification During the field survey different types of primary data concerning the fire hazards of Kolkata Municipal Corporation region have been collected. Spatial data sources include Topographical sheet (73 B/6 and 73 B/5), ward maps (1:50,000), Calcutta Plate 33 (1:100,000), Satellite imagery Data used for Analysis:

Apart from primary data, secondary data have been also collected along with the field survey: In this research, GIS Map based fire hazard and risk analysis is one of the main application of this assignment to undertake hazard and risk analysis, various GIS layers and other associated thematic maps have been created for each of the wards of KMC that form the basis for risk ranking of base units (wards).

Table 1: Materials and Methods of Data Base

S. No.	Data Type	Resolution	Sources	Year	Data Format
1	LANDSAT- (MSS, TM, ETM+	15m/30m	USGS	2016	Raster
2	IRS- (LISS-III + PAN, LISS-IV, IRS-P5 PAN AFT+ IRS P6 L4MX)	2.5m/5.6m	NRSC	2001-2014	Raster
3	Geo Eye	0.5m	Google Earth	2005-2017	Raster

How fire hazards are influenced the Grow of a city: Administrative Setup of the Study Area

Mukherjee et al (2018) have observed that Kolkata happened to be one of the most growing mega city in a developing country, which is facing rising pressures on water environmental provisions due to the rapid population growth and urbanization and resultant governance and infrastructural issues .Within the municipal limits of Kolkata, the fastest growth has occurred in relatively less accessible low-lying, poorly drained areas located in Borough VII (Ward no. 56, 57, 58, 59, 63, 64, 65, 66, 67) and XI (ward no. 103, 104, 110, 111, 112, 113 ,114) to XV (Ward no.56-67). Ghosh (2018) has used the urban growth that took place subsequently, thus, could not follow any expected relationship with the existing landform pattern of Kolkata. Chaterjee et al (2006) has discussed in detail the growth of population the land use pattern been changed with the shrinkage of water bodies and with the increase of residential, commercial as well as industrial and institutional area. Chakraborty et al (2009) have used the lands are either predominantly low

lying, swampy and immediately flooded by the monsoon rains each year or encroached land of railways, canal banks, even dry canal beds, garbage disposal areas and the like. The Kolkata Municipal Corporation Kolkata (KMC) has prepared a physical structure of the city to reach quickly to the fire victim places and in close proximity to water bodies. It is not only very expensive to make these areas suitable to a point where decent urban development can take place, it also became highly difficult and expensive for the Kolkata Municipal Corporation to extend all basic utility and services to these areas.

Ramachandra *et al*, (2006) have discussed the unplanned urbanization results in sprawled regions within and outside of the city centers; these areas usually lack basic infrastructure such as treated water supply, sanitation, and electricity .Borough (I-XV)wise land use pattern shows that Borough No. II (75.34%), Borough No.III (75.26%) and Borough No. XIV (82.09%) have the high percentages of land under residential category. On the other hand Borough No. (23.51%) and Borough No. VII (21.05%) have the lowest percentages of land under residential category. The maximum commercial utilization of land is in Borough No. IV (20.9%), Borough No. (39.35%) and VI (17.69). The predominant land use for Borough Nos. V (15.45%), Borough No. VI (11.72%) and Borough No. IX (10.75%) is for institutional purpose. The maximum open spaces fall in Borough No. VII (49.5%) and Borough No. XII (34.11%). Borough Nos. VII (15.5%) and Borough No. XII (19.68%) have the maximum land use under water bodies. Borough Nos. II, IV, V, VII and IX have the maximum utilization of space for roads and transportation (Fig. 4.1).

Geographically Kolkata is found to have its urban primacy with the vast hinterland due to the economic and cultural dominance over the large area of the eastern part India (Haque, 2013) resulting in influx of huge population, and as a consequence Kolkata has become the biggest city in India till the census year of 1981 but its physical configuration and urban services have not been able to support and survive that ever going influx of migration (Haque, 2013).

The nature of dynamics of population has been changed in the study area, which reveals the total population of KMC in the census year of 2001 was estimated as 4,572,876 people, out of which 54.67% (2500040) were male and the rest of 45.33% were females. Within the Municipal Corporation boundary 73.96% people were literate (76.99% for male, and 70.29% for female). It is also found that 37.56% were considered as workers, out of which 1451548 people were male workers and 266186 people were female workers. The decadal growth rate in the study area had been found to be varying. During the period of 1831 to 1840, the population had increased remarkably, estimated as more than 93%, whereas the period from 1850 to 1866 showed decline population growth with (-)14.11%. Afterwards it varied but the trend was somehow increasing till 2001, and then declined in 2011.

Table 4.1: Borough wise General Land Use pattern of Kolkata city (Fig. in %)

Boro No.	% share of total population	Area (in sq. km)	Residen-tial	Commer-cial	Indus-trial	Institu-tional	Open Space	Water body	Roads and transport
I	7.12	9.57	67.52	1.9	8.04	5.06	5.88	1.95	9.65
II	5.18	3.27	75.34	6.35	0.3	1.8	4.3	0.9	11.01
III	7.48	9.43	75.26	3.68	7.85	1.45	2.23	1.78	7.75
IV	6.08	3.35	60.14	20.9	2.09	3.1	1.23	0	12.54
V	5.74	5.33	23.51	39.35	0	15.45	7.76	2.3	11.63
VI	6.86	5.56	50.29	17.69	6.8	11.72	4.5	0.01	8.99
VII	9.32	25.89	21.05	5.75	1.2	2.5	49.5	15.5	4.5
VIII	8.22	8.75	63.52	3.5	0.9	4.85	7.9	6.5	12.83
IX	7.97	19.42	35.1	3.5	11.85	10.75	14.85	8.45	15.95
X	8.90	15.71	73.01	4.5	1.77	4.97	8.77	0.72	6.26
XI	4.40	12.91	71.01	1.95	1.43	1.27	9.4	9.77	5.17
XII	4.86	24.82	36.84	1.63	1.47	0.24	34.11	19.68	6.03
XIII	5.40	12.85	72.19	3.3	5.68	1.02	3.31	4.58	9.92
XIV	6.47	19.18	82.09	3.6	0.38	1.56	1.5	3.61	7.26
XV	6.01	8.96	59.57	10.25	7.95	0.12	13.85	4.8	3.46
Total/Avg.		**185**	**57. 76**	**8. 5**	**3. 85**	**4.39**	**11. 27**	**5. 37**	**8. 86**

Source: Census of India, (2011)

The process of urbanization in India is a result of the India's Industrial Revolution (Bose, 1965). Though India is less urbanized, it contains the second largest urban population in the world. In the case of West Bengal, the process of urbanization has been largely mono-centric, characterized by the dominance of Kolkata (Sengupta, 1966) and here, the rate of urbanization has always been slightly greater compare to national average. But the case of Kolkata is quite different than the other metropolis of India. In the early phase of twentieth century Kolkata had leading position among the India's three 'Presidency Cities' (Haque, 2013). Gradually in 1960s Kolkata became a 'premature' metropolis and absorbed the ti.de of in-migration from different parts of country and from Bangladesh (previously East Pakistan) (Berry, 1969; Bose, 1965).

Two decades back, Kolkata has lost the nation's leading position and has become the second largest city in India. In West Bengal after the independent of

country, the process of urbanization is totally controlled by the external forces, through the relative stagnation of industrial job opportunities, political process of franchise and high population pressure. (Haque, 2013) has analyzed the process of urbanization in West Bengal during the post-independent period. During the time of independence, West Bengal had greater rate of urbanization compared to the Indian average rate. At that time Calcutta controlled the total urbanization scenario in West Bengal, i.e. Calcutta was mono-centric urban center. The main feature of urbanization in West Bengal was high degree of spatial concentration dominated by Calcutta city. But during the pre-independence period the process of urbanization in West Bengal was totally controlled by the exogenous factors (Sengupta, 1966). During the post-independent decades slower rate of urbanization was found in West Bengal. From the demographic viewpoint it was clear that the slower rate of urbanization showed the declined nature of urban growth with lower rate of intra-state rural-urban migration and relatively higher growth rate of rural population. Industrial stagnation with its multiplier effects on job opportunities in the early 1960s was also one of the causes for this urban declination. After 1960s, the decade of 1970s showed 6.95 percent increased rate of urbanization, but during 1981 to 1991 it again declined (Haque, 2013).

Table 5.1: List of Industry and Chemical Fires in KMC area (2006-2018)

YEAR	A(Type)	B(Type)	C(Type)	D(Type)	K(Type)	No. WARD
2006	A	-	C	-	-	37,65,34,32,32,62
2007	A	B	C	-	-	25,35,64,62,32,61
2008	A	B	C	D		107,58,34,13,6,51,43,65,34,62
2009	A	-	C	-	K	32,61,60,56,61,65,34,7
2010	-	-	-	-	-	-
2011	-	-	-	-	-	-
2012	A	-	C	-	-	58,45,66,40,62,81,62,60,32
2013	-	B	-	D	-	27,21,64
2014	-	-	-	-	-	-
2015	-	-	C	-	-	-
2016	A	-	-	-	-	62
2017	A	-	-	-	-	25,27
2018	-	-	-	-	K	2

Source: Prepared by the researcher

Details on the sectors wise impact of Fire hazards in the Kolkata city:

Industry and Chemical Fires (2006-2018):

The process of urbanization is accompanied by rapid industrialization and such development is marked by a significant progress of chemical industries within the metropolitan urban complex of KMC.

The predominant chemical industries (3.85%) around the city are ceramic kiln, boiler, foundry, rolling mills, acid fumes, tannery, etc. majority of which is concentrated in the northern side of the city. Incidentally, there were a total of 47 industrial fires taken place during the above-mentioned period. Total numbers of industrial fires in the KMC during 2006- 2018 were 46 (26.28% of the total). Industrial fires mostly occurred in ward no. 32, followed by ward no. 62 (39.04%) and ward nos. 34 (8.69%), 65 (6.52%) 61 (6.52%), 64 (4.34%), 60 (4.34%), and 27 (4.34%).

Fire incidents in Residential area and slum area (2006-2018)

The city has witnessed 30 residential fires during the above period with the main fire types of A (18), B (6), C (10), and K (1). The total residential area, including slum areas, of the KMC area is 57.76%. The residential fires (with the share of the total in parenthesis) mostly occurred at ward no. 32 (16.66%), 34 (10%), 35 (6.66%), 62 (6.66%), and 60 (13.33%) as shown by the following table (Table No.5.7).

Table 5.2: Fire incidents in Residential area and slum area (2006-2018):

YEAR	A (Type)	B (Type)	C (Type)	D (Type)	K (Type)	WARD (No.)
2006	A	B	C	-	-	32,34,57,31,35
2007	A	B	-	-	-	10,62
2008	A	-	C	-	-	33,56,60
2009	A	-	-	-	-	-
2010	-	B	C	-	-	60,35
2011	-	-	-	-	-	-
2012	A	-	-	-	-	60,62,34,32,32,60
2013	A	B	-	-	-	6,88,71
2014	A	-	-	-	-	63
2015	A	B	C		K	34,38,56,32,4,54
2016	-	-	C	-	-	86
2017	-	-	C	-	-	32
2018	-	-	C	-	-	60

Source: Prepared by the researcher

Fire in Hospitals:

The fire events took place in only four hospitals (2.28% of the total), and it had a great impact on the society. The victim hospitals included SSKM Hospital (Ward No. 93) with A-type fire in 2012; Amri Hospital (Ward No. 66) with A -type fire in 2011; Chittaranjan Cancer Hospital (Ward No. 85) with C- type fire in 2014, and Kolkata Medical Collage and Hospital (Ward No. 39) with C- type fire in 2018.Within the KMC area there are about 62 well known hospitals where thousands of patients and their companions used to go for treatment. Unfortunately these important places are also not secured from the standpoint of fire event as the city has experienced different life threatening fire events in hospitals during the recent past.

Fires in Market Areas and Shopping Complexes in KMC area (2006-2018):

The market area and shopping complexes are mostly vulnerable because in market area people are seldom aware about fire-safety process and a market usually maintains the minimum fire safety norms. The important markets in the KMC area

Table 5.3: Fires in Market and Shopping Complexes Areas (2006-2018)

YEAR	A(Type)	B(Type)	C(Type)	D(Type)	K(Type)	WARD No.
2006	A	-	-	-	-	32,82,62,66,32,11,78
2007	A	-	-	-	-	6,78,32
2008	A	B	C	-	-	27,32,106,15,34,40,25,32
2009	A	-	C	-	-	32,73,32
2010	-	-	-	-	-	-
2011	-	-	-	-	-	-
2012	A	B	C	-	-	22,102,62,15,33,34,60,19, 34,55,125,65,69,53,27,57, 2,54,32,7,137,136,90,7
2013	A	B	C	D	-	27,26,26,64,44,37,128,2, 62,100,65,38,15,108,2,6, 9,16,18,19,51
2014	-	-	-	-	-	-
2015	A	-	-	-	-	61,94,34
2016	-	-	-	-	-	-
2017	-	-	-	-	-	-
2018	A	B	-	-	-	25,27

Source: Prepared by the researcher

are: Sir Gurudas Market (Ward No. 30), Sir Charles Allen Market (Ward No. 18), Ultadanga Municipal Market (Ward No.13) , Manton Super Market (Ward No. 130), Bakultala Market (Ward No. 128), Santoshpur Municipal Market (Ward No. 106), Ramlal Municipal Market (Ward No. 106), Kalitala Bansdroni Municipal Market (Ward No. 113), Gorfa Municipal Market(Ward No. 59) , Jiban Mohan Ghosh (Ward No. 112), Baba Haat (Ward No. 138), Jabbar Haat (Ward No. 138), Binod Chamaria & Brothers (Ward No. no.42), Ganesh Properties Pvt.Ltd. (Ward No. 43), Bangur Charitable Trust (Ward No. 43), Kolay Properties Pvt. Ltd. (Ward No. 50), Charu market (Ward No. 89), New Market (Ward No. 46), Gariahat Market (Ward No. 68), Maniktala Market (Ward No.15) etc.

A Brief Case Study:

Bagree Market:

The Case study has been made on this fire event and can be summed up as follows:

- Bagree market, one of the biggest and busiest retail and wholesale market of Kolkata in close proximity to the Writer's Building and the Reserve Bank of India as well as just few meters from Nandaram market, where a fire damaged nearly 100 houses. The fire started at 2:30 am, People who stayed in the market rushed out to save their lives. Ultimately the fire was brought under control after 3 days, i.e., 18th September, 2018 (Photograph 5.6 - A, B, C, D and E).
- According to observation it revealed that the shops were affected by inflammable materials as mentioned above and the fire extended rapidly from the ground floor up to fifth floor with continuing damages at every floor.
- 30 fire engines were engaged into service to retrieve the situation into normalcy at this age-old building with narrow space to cover and to rescue the people and goods. Due to endless task of the fire brigade, no loss of human life was reported though two members of the rescue team were affected by minor injuries.
- Remarks of the Municipal Authorities: During the course of events, authorities of Kolkata Municipal Authority informed that the market authority was warned about the improper installation of fire safety measures and necessary precautions to be taken to prevent fire.
- The matter was subsequently take by Kolkata Police for necessary investigation from video footage of CCTV Cameras and other possible clues.
- As regards the limitation of the fire controlling measures, it was revealed that all the 24 overhead water tanks were empty of water for the last six

months and the fire brigade team could not handle the situation promptly due to lack of water.

- Finally it can be concluded from the cases study that Inadequate number of fire-extinguishers, non-availability of water, absence of pumping stations, narrow and extremely congested road and passage for the fire brigade machine, unplanned construction of building, improper and poor maintenance of the building, obsolete electrical wiring due to old and partly demolishing structures of the building, unauthorised hooking for electricity for the footpath dwellers and business men and last but not the least the lack of environmental awareness among the local people and inhabitants and carelessness of the business men about the possibility of fire should be taken into consideration for future management and planning of fire.

Methods, Analysis and Discussion

A General Overview of Vulnerability of Fire Hazards over Space and Time:

From the above study and research, a general overview of vulnerability of fire hazard over space and time for KMC area can be drawn as follows:

- Width of the road including road density, road frequency and road width.
- Availability of water for fire preventive measures.
- Proximity of fire stations to the water pumping stations and other natural and man-made water bodies.
- Determination of shortest path from fire station to fire victim places.
- Determination of alternative route when traffic is very high.
- Fire feeding materials used in building (including slums).
- Short circuit or illegal hooking.
- Illegal storage of gas cylinder, diesel, motor oil, and wooden furniture.
- Unauthorized chemical industries (paper and plastic materials).
- Breaking of the guidelines issued by Fire Safety and Emergency Department.
- Spark from the kitchen open stove used for cooking in improper places.
- Electrical components including loose wiring, computers, etc.
- Environmental awareness and cleanliness to prevent any further fire incidence as far as possible.

Computation of the value of response time through calibration:

Finally, the value of response time of fire engine and accessories to the fire

victim places should be calibrated (Banerjee, D. 2018.) after Haupt and Haupt (1997) as expressed by the following equation:

$$T = r0 + K \times r$$

where T = response time of the fire station,
r = distance (kilometers);
r0 (minutes) = operational readiness time
(the time taken for the fire engines to leave
the fire station upon receiving the call),
and K = traffic impedance factor.

For the present purpose, computations of the value of response time through calibration are calculated with respect to three fire events, viz., BAGREE MARKET, AMRI and STEPHEN COURT.

For example, the above formula can be applied with respect to the incident of Bagree (Market Photograph-7.3) Fire (14th September, 2018 in ward number 27) where the value of r = 0.65 m; r0 = 7 m and K = 15m.

Putting the values, we get $T = (7+15) \times 0.65 = 14.3m$

Putting the values, we get

- Applying the same equation, AMRI (December 9, 2011, ward No. 93).

  AMRI: r = 0.74 km; ro = 6 m; k = 20 m;T = (6+20)*0.74 = 19.24

- In case of STEPHEN COURT (23 March, 2010, ward no.60 the value of r = 0.48; ro is 5 m and k = 10 m and hence T= (5+10)*0.48 = 7.2

Generalizing the above equation, it can be suggested that greater the value of T is directly proportional to the extent of damage and the importance of the above equation lies in the fact that T factor should be reduced in order to minimize the fire hazard and therefore the formula is considered as an effective tool for any systematic planning and management of fire hazard.

Planing and Management of a Kolkata City to over come the problems:

Any planning and management of hazards should examine the infrastructural parameters and for the assessment of fire hazard, seven parameters are selected such as (1) Fire Extinguisher; (2) Stair condition; (3) Emergency Exit; (4) Water Tank; (5) Electrical Cable; (6) CCTV; and (7) Condition or quality of Building. For the present purpose, four different sectors of LULC have been selected for primary survey for three consecutive years (2016 – 2018) on the basis of stratified random

sampling and the survey reports have been assessed and evaluated on the basis of observation, deduction and statistical inferences.

Review of the Primary Survey:

For the collection of primary data, a questionnaire has been prepared first and data has been selected on the basis of stratified random sample and nominal scale has been selected to make a thorough review and intra-class comparison (Primary Survey). Here, three consecutive years i.e., 2016, 2017 and 2018 years are taken into consideration. Subsequently, a frequency of nominal data has been prepared on the basic of primary survey as shown by the following tables:

Table 7.1: Fire Extinguishing Parameters: the KMC Area

Parameters	Hospital	Industries	Market	Residential
Sample size (N)	159	113	92	58
1. Fire extinguisher	155	97	68	48
2. Stairs condition (Free)	123	102	92	58
3. Emergency exit	110	98	92	55
4. Water tank	76	89	62	47
5. Electric Cab	116	111	87	58
6. CCTV	130	93	60	55
7. Condition of the buildings	159	113	80	57

Primary Survey: 2016-18

From the above table it clearly appears that Hospitals are most favorably placed as they enjoy the maximum number of amenities. Industrial areas come next in position and followed by market and residential areas. Thus it can be conjectured that emphasis for the creation of more amenities and infra-structural facilities should be given to market and residential areas. During the course of survey, it has been further observed that the people are lacking in general about the basic amenities and preventive and precautionary measures as compared to hospitals and industrial areas which are better planned with respect to fire incident and can tackle the situation with the available infrastructures. This observation is well reflected in the following figure (Fig. 7.1).

Comparative Assessment between Different Sectors With Respect to Infra-Structural Facilities for Fire:

In order make a comparative study among different LULC as generated from satellite imagery through RS and GIS techniques with the help of software(ERDAS,

Arc GIS, Global Mapper etc.), a composite bar diagram is prepared and shown in Fig.No.1.8.

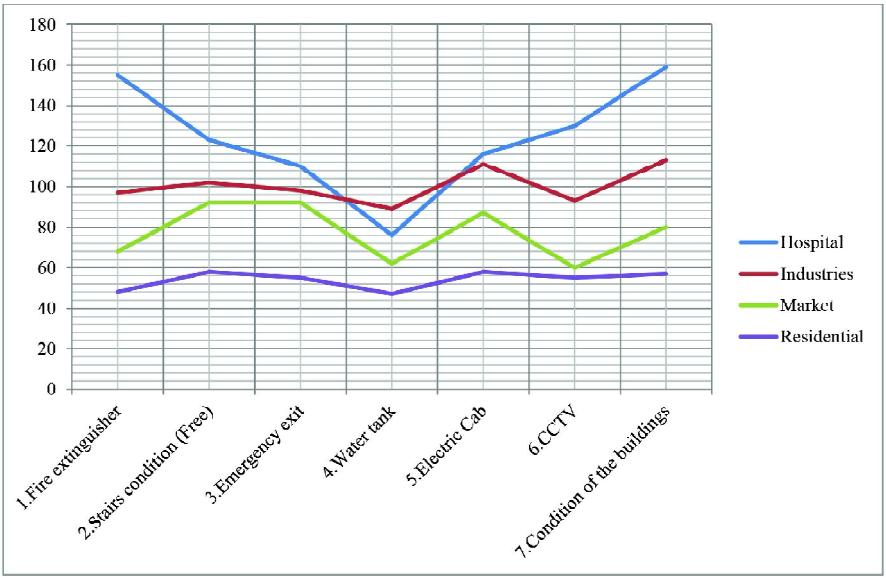

Fig.7.1: Fire Extinguishing Parameters: KMC Area (2016 to 2018).

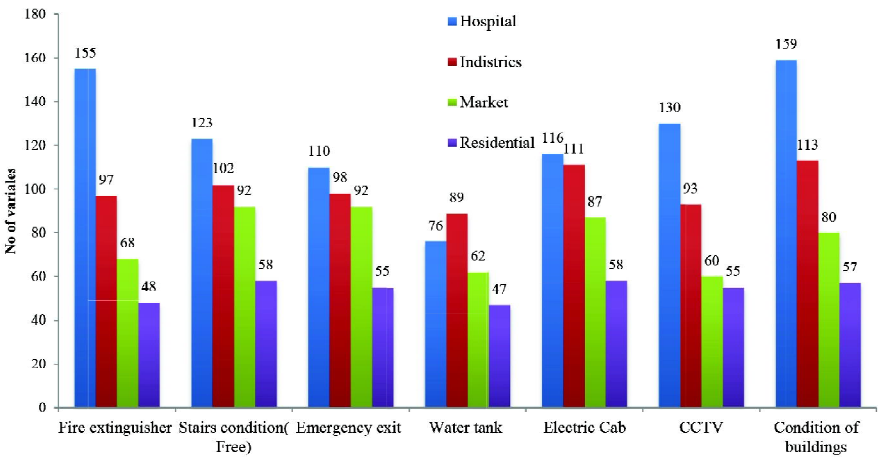

Fig.7.2: Scenario of Fire Extinguishing Parameters in different Sector: KMC (2016 to 2018).

In addition, sector-wise fire-controlling amenities are also highlighted to assess the relative position of different sectors. Obviously, hospital undoubtedly enjoys the maximum number of amenities followed by industry, residential and market as evident from figure Nos. 4, 5, 6 & 7.

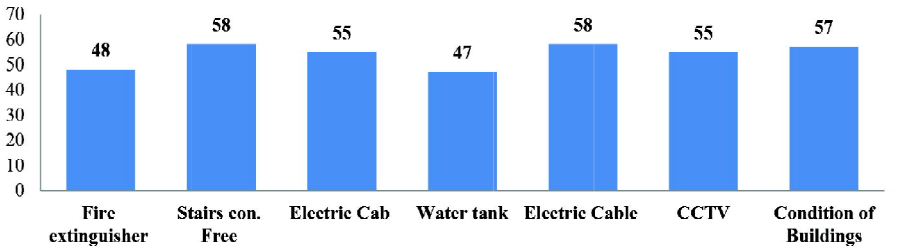

Fig.7.3: Fire Extinguishing Parameters in Residential sector: KMC Area (2016 to 2018).

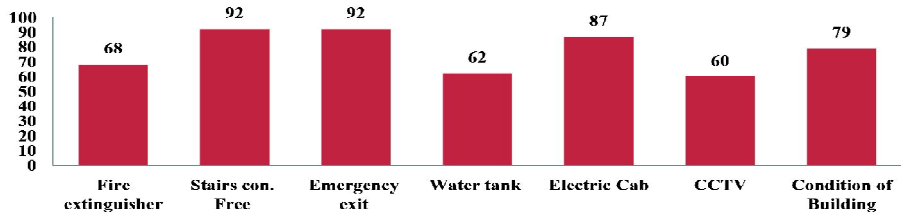

Fig.7.4: Fire Extinguishing Parameters in Market sector: KMC Area (2016 to 2018).

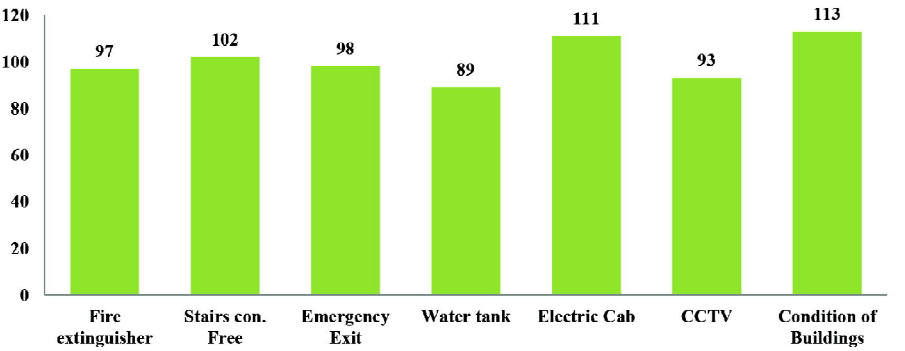

Fig.7.5: Fire Extinguishing Parameters in Industrial sector: KMC Area (2016 to 2018).

Application of ANOVA:

Analysis of variance is the standard parametric test of difference between three or more samples. Like other parametric tests, however, it is often used in situations where the rather rigid assumptions of such tests cannot be justified. ANOVA can only be applied to data measured on an interval scale. Through ANOVA technique one can investigate any number of factors which influence the dependent variables. Accordingly one way, two way and multivariate ANOVA may be employed.

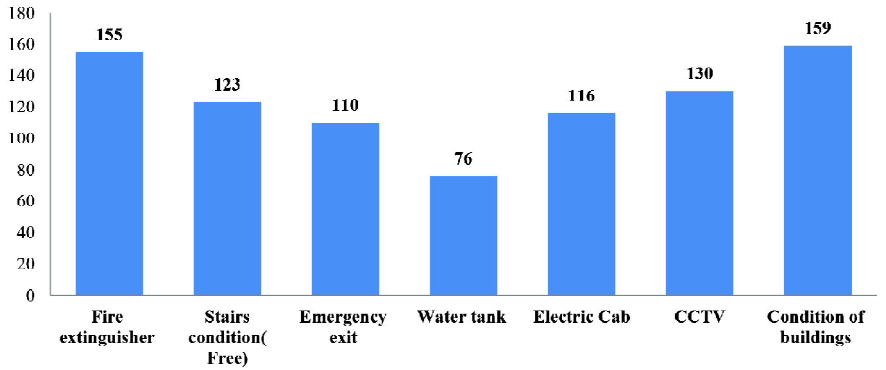

Fig.7.6: Fire Extinguishing Parameters in Hospital sector: KMC Area (2016 to 2018).

The basic principle of ANOVA is to test the differences among the means of populations by examining the amount of variation between samples relative to the amount of variation within the samples. The steps involved in computing one-way ANOVA are as follows:

Step – 1: Calculate the mean of each sample, i.e., for k samples.

$$\bar{X}_i = \bar{X}_1, \bar{X}_2, ... \bar{X}_k$$

Step – 2: Mean of the sample means:

$$\bar{\bar{X}} = \frac{\bar{X}_1 + \bar{X}_2 + ... \bar{X}_k}{k}$$

Step – 3: sum Square for variance between the samples, i.e., SS between:

$$\text{SS between} = n_i\left(\bar{X}_1 - \bar{\bar{X}}\right)^2 + n_2\left(\bar{X}_2 - \bar{\bar{X}}\right)^2 + ...n_k\left(\bar{X}_k - \bar{\bar{X}}\right)^2$$

Step – 4: The Variance or Mean Square between samples (i.e., MS between):

$$\text{MS between} = \frac{\text{SS between}}{k-1} \quad \text{where k = Number of samples}$$

$$\text{Step-5: SS within} = \sum\left(X_1 - \bar{X}_1\right)^2 + \sum\left(X_2 - \bar{X}_2\right)^2 + ...\sum\left(X_k - \bar{X}_k\right)^2$$

Step-6: The variance or mean square within samples (i.e., MS within):

$$\text{MS within} = \frac{\text{SS within}}{(n-k)}$$

Step – 7: Finally, F Ratio may be calculated:

$$F = \frac{MS\,between}{MS\,within}$$

On the basis of above equations, One-way ANOVA with respect to each different sectors (Hospital, Residential, Market and industrial) are calculated and their computed and tabulated values are analyzed and assessed as shown by the following tables:

Table 7.2: Single Factor ANNOVA Analysis for Industries:

Source of Variation	S S	df	MS	F	P-value	F crit
Between Groups	8.345865	6	1.390977	2.234364	0.039248	2.121715
Within Groups	244.0351	392	0.622538			
Total	252.381	398				

Table 7.3: Single Factor ANNOVA Analysis for market:

Source of Variation	S S	df	MS	F	P-value	F crit
Between Groups	24.02976	6	4.00496	10.635	negligible	2.126169
Within Groups	123.8958	329	0.376583			
Total	147.9256	335				

Table 7.4: Single Factor ANNOVA Analysis for Residential and slums:

Source of Variation	S S	df	MS	F	P-value	F crit
Between Groups	4.129032	6	0.688172	0.873635	0.515107	2.141943
Within Groups	165.4194	210	0.787711			
Total	169.5484	216				

Table 7.5: Single Factor ANNOVA Analysis for Hospitals:

Source of Variation	S S	df	MS	F_{cal}	P-value	F_{crit}
Between Groups	82.53202	6	13.75534	27.10772	0.00	2.121307043
Within Groups	202.4655	399	0.507432			
Total	284.9975	405				

Table 7.6: Final Inference and summing up:

Sectors	Computed Value	Tabulated Value	Remarks
Hospital	27.10772	2.121307043	H_0 is rejected
Residential	0.873635	2.141943	**H_0 is accepted**
Market	10.635	2.126169	H_0 is rejected
Industry	2.234364	2.121715	**H_0 is almost rejected**

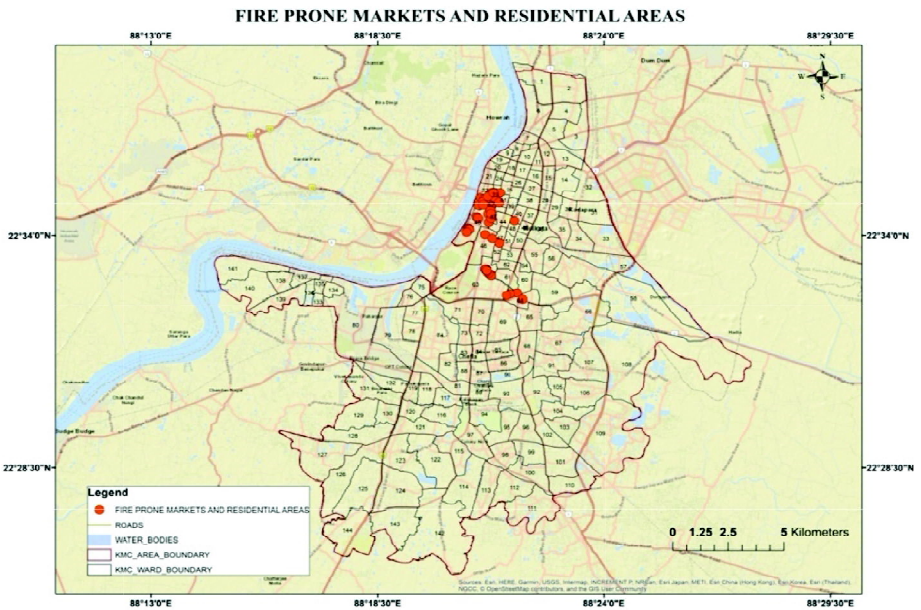

Plate: 2

From the above table it appears that Hospital is not vulnerable to fire events while the other three sectors i.e., Market, Residential and industrial areas are vulnerable and in Particular market areas appear to be the most vulnerable to fire incidents due to a lack of basic infrastructure and maintenance for fire events. It is to be mentioned further that number of fire events are comparatively less in hospitals due to better infra-structure as evident from the fact that only 4 fire incidents occurred in hospitals during a span of 2006 to 2018. On the contrary, Market areas are most vulnerable since 65 number of fire events occurred between 2006 to 2018.Industrial areas are next to market (55 number of fire events during 2006 – 2018 and followed by residential and slum areas (49 fire events between 2006 – 2018) .

Relation between LULC and Category of Fires:

For further assessment of fire hazard, it is now required to find out the degree of association between different sectors and categories of fire as shown by the following table: 8.

Table 7.7: Relation between LULC and Category of Fires

Sector(LULC)	Category of Fire (Type)					
	A (Type)	B (Type)	C (Type)	D (Type)	K (Type)	
Hospital	2	0	2	0	0	**4**
Residential	23	10	13	1	2	**49**
Market	34	20	10	1	0	**65**
Industrial	33	5	11	5	1	**55**
	92	**35**	**36**	**7**	**3**	**173**

Different Categories of fire (A, B, C, D and K) are shown with respect to different sectors (Hospital, Residential, Market and Industrial) and for numerical and statistical assessment between Rows and columns; Two-way ANOVA (Analysis of variance) is applied. In fact,

The basic principle of ANOVA is to test the differences among the means of populations by examining the amount of variation between samples relative to the amount of variation within the samples.

Here, two way ANOVA techniques are used when the data are classified on the basis of two factors. Therefore, we have to calculate the sum of the squares for total variance and for variance between two different categories of one factor as also variance between types of the other factor.

Sum of the squares of deviations between columns (Different Categories of Fire):

$$\text{SS between columns} = \sum \frac{T_j^2}{n_j} - \frac{T^2}{n}$$

Sum of the squares of deviations between rows (Different sectors of LULC):

$$\text{SS between rows} = \sum \frac{T_i^2}{n_i} - \frac{T^2}{n}$$

Calculation of SS between columns and SS between rows is to be determined.

Sum of the squares of deviations for residual (SS residual) may be calculated as:

$$\text{SS residual} = \sum X^2_{ij} - \frac{T^2}{n} - \left\{ \left(\sum \frac{T_j^2}{n_j} - \frac{T^2}{n} \right) + \sum \frac{T_i^2}{n_i} - \frac{T^2}{n} \right\}$$

= SS total – (SS between columns + Ss between rows)

Degrees of Freedom (df) for Total Variance:

$$\left(\sum n_j \times \sum n_i \right) - 1$$

where n_j and n_i = Number of columns and rows respectively

Degrees of Freedom (df) for Variance between columns:

$$\sum n_j - 1$$

= (number of columns – 1)

Degrees of Freedom (df) for Variance between rows:

$$\sum n_i - 1$$

= (number of rows – 1)

Degrees of Freedom (df) for residual Variance:

$$\left(\sum n_j - 1 \times \right) \left(\sum n_i - 1 \right)$$

where n_j and n_i = Number fo columns and rosws respectively

On the basis of above steps the following table is prepared:

Table 7.7: ANOVA (Two-Way without replication)

ANOVA (Two-Way without replication, i.e., SRSWOR)						
Source of Variation	**S S**	**Df**	**MS**	**F**	**P-value**	**F crit**
Rows	436.95	3.00	145.65	3.29	0.06	3.29
Columns	1264.30	4.00	316.08	7.14	0.00	3.26
Error	531.30	12.00	44.27			
Total	2232.55	19				

The computed F = 3.29 and is equal to the tabulated value of 3.29; hence we accept the null hypothesis, i.e., the variation of fire event is not caused by different

categories of fire. On the other hand, between rows computed F 7.14 is greater than the tabulated value of 3.26. Thus we accept the alternative hypothesis, i.e., the variation in fire events is caused by the different sectors of LULC in KMC area.

Conclusion: Findings and Recommendations:

Findings:

The research questions and hypothesis put forward in the preceding chapters have been examined with suitable quantitative, qualitative, statistical and numerical analysis along with the spatio-temporal characteristics in the study area from 2006 to 2018. The inferences and findings are derived through data collection, data processing and finally data interpretation. The major findings are summed up as follows:

Fire prone areas (F.F: 1-4/y to 10-13/y) are mainly concentrated in the central, northern, eastern and western part of the KMC although the fire stations are mostly located in these regions. The major reasons are justified by the following observations:

a. Concentration of market areas (having weak or inactive fire preventing system).
b. Location of CBD (Cosmopolitan urban character).
c. Narrow and congested roads and lanes (transport system) and blockage of passages due to unauthorized construction.
d. Lack of protective electric system in market area.
e. Lack of perception and awareness among the local people about fire management systems.
f. Presence of unplanned slum areas aggravates the spreading of fire.
g. Rapid urbanization and industrialization of the ‘pre-mature’ metropolis.
h. Inadequate and uneven distribution fire station.
i. Obsolete Electric and transmission systems in some of the wards of KMC.

Less fire prone areas (F.F:0/y) is concentrated in south and western part of the KMC area and a few fire stations are located in this area.

A Disaster Preparedness Management Plan:

A disaster preparedness plan should be clear, realistic, flexible, and easy to use and it must be covered during every stage of disaster management cycle. Identification of vulnerable area and section of appropriate measures should be the

first steps of disaster preparedness. Identification of the fire victim place can be done through GPS. The response to fire disaster demands a quick rescue operation as soon as possible. And time is a very important factor to control the fire impact. So the duration of the gap between a fire event and its rescue operation is very crucial. Moreover, the response to fire disaster is a systematic damage assessment process, to restore the utilities.

Deductions and Recommendations:

On the basis of history of fire hazards from 2006 – 2018, t- values should be computed and compared with the present-day location of fire service stations with respect to places of fire incidence. Besides, index of vulnerability analysis, analysis of Variance (ANOVA), and analysis of selected case studies, the proposed fire station sites for Kolkata are:

- Near Belaghata Bus Stand area
- Jamindar Para Near Nanigopal Roy Choudhary Avenue Road
- Topsia Near Park Circus Connecter Road
- North Pubanchal Near Kalikapur Road
- Taratala Beside Tarata Main Road

Finally for implementation of the above-mentioned proposed sites based on shortest and alternative routes as well as from the factor analysis and estimation of standard score values, the following recommendations are made:

a. Kolkata is the third largest municipal corporation in India with a population of over 4.48 million (Census 2011) and a population density of 24252 per sq km. The area under the Kolkata Municipal Corporation (KMC) spans 185 sq. km which consists of 144 wards that are grouped into 15 boroughs. These figures have been used for estimating the gaps in the number of fire stations that need to be functional and number of water tenders that need to be procured to meet the requirements. As per the S.F.A.C norms, the working out of the requirement is as under (1 fire station per 10 sq km):- 185 sq. kms/10 = 19 Fire Stations Thus total fire stations for Kolkata city works out to 19 fire stations. But, currently only 14 fire stations are functional. So, there is an additional requirement for 5 fire stations in KMC area. There is a budget allocation for these new power stations.

b. Considering the population of Kolkata city there is also a visible need for installation of water tenders. According to S.F.A.C., a population of 4.48 million requires more than 90 water tenders and presently Kolkata has only 51 water tenders. Therefore 39 water tenders are immediately required for safe water supply system at the time of fire incidents.

c. Hospitals and other medical institutions should be well-equipped with Burn units in order to ameliorate the fire hazards in the hospitals.

d. Automatic smoke vents should be provided especially for basements and enclosed parts of the building.

e. Automatic fire detection and fire alarm systems are essential to detect heat, smoke, fumes and flames to be installed in all appropriate points in all floor of the building.

f. Pre-alert fire preventing system through Radio Coverage Frequency Message (RCFM) using GPS for every traffic signal.

Conclusions

The present research work is a modest attempt to investigate the nature of fire hazard in the Kolkata Municipal Corporation (KMC) area including its geographical and seasonal distribution, frequencies and magnitude, its risk factors, identification of problems and their control. The work is expected to provide the guidelines for future activities towards fire management in other megacity as well as within the Kolkata Municipal Corporation to avoid the fire accidents in the buildings the passive way of safety design, life safety provisions and the active way of fixing fire fighting appurtenances in the building cannot assure full safety. Number of variables responsible in the fire phenomenon of the buildings is to be identified and assessed as fire hazard and proper action-oriented management programmes should be taken. The prospect of geo-spatial technology in identification of fire-prone zones and taking preventive measures against fire hazards has been found to be quite immense, as discussed in the previous chapters.

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