



## Case Study

# Exploring the effects of environmental factors, population density and occupancy on fire incidents – a case study of South-West Division of Delhi, India

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Available online at: [www.isca.in](http://www.isca.in), [www.isca.me](http://www.isca.me)

Received 30<sup>th</sup> November 2017, revised 28<sup>th</sup> February 2018, accepted 15<sup>th</sup> March 2018

## Abstract

*Due to rapid increase in population, the fire and other emergency incidents has increased significantly in Delhi. The number of fatalities and injuries in fire and emergency incidents has been increased by 68% and 53% respectively since 2001. This paper investigates the causal factors for large number of fire incidents and their association with environmental factors like weather conditions, population density and different types of occupancies. Statistical analysis of the study revealed that there is a positive association between day temperature and fire incidents numbers in a day, whereas day humidity has a negative relationship with day fire incidents. Population density is not found to be significantly associated with number of fire occurrences. Fire incidents in low rise private dwellings and apartment houses, under residential occupancy, account for the highest number of incidents i.e. about 38 % of total fire incidents. Approximately more than 50 % fatalities and injuries in fire incidents are found to have occurred in low rise residential occupancy buildings. The timings of fire incidents of about 50 % of total fatalities in these residential occupancy occurred between 00:00 hrs to 06:00 hrs and the number of total injuries of about 35% were between 18:00 hrs to 24:00 hrs.*

**Keywords:** Low rise, residential fires, fire risk, life safety and fire prevention.

## Introduction

Delhi has witnessed an increase of 21.20% in its population since 2001 census<sup>1</sup> but the number of fire and other emergency incidents in Delhi has increased by 52% during the same period. The resultant number of fatalities and injuries in fire and emergency incidents has also been increased by 68% and 53% approximately since 2001. Delhi Fire Service received 27089 fire and other emergency incident calls during the year 2015/16 in which 339 persons died and 2099 civilians got injured<sup>2</sup>. Building fires, especially in unapproved and unauthorized residential areas, remain a critical concern as most of the fires occur in one or two private dwellings buildings and apartment houses under residential occupancy, resulting in direct property damage, civilian deaths and civilian injuries. From the records of Delhi Fire Service for the period 2010-11 to 2015-16, it has been learnt that every year about 14529 to 15735 fire incidents are happening in Delhi, out of which 32% to 35% fire incidents have happened in one or two private dwellings or apartment houses having height below fifteen meters (i.e. low rise) residential occupancies (Sub-division A-2 and A-4), as shown in Figure-1. It has been noticed that noticeable number of fatalities and injuries has occurred during fire incidents in Delhi, as shown in Figure-2.

In urban areas, assessment of fire risk is an important process through which fire hazards can be characterized for increased understanding of the probabilities of fire and unwanted consequence that may result from the fires. Many studies have been conducted around the world to ascertain the relationship of fire incidents with socio economic, environmental conditions and other factors. It has been found that socioeconomic and environment factors of the communities are the primary determinants of fire loss<sup>3</sup>. Jing in China analyzed six years fire incidents data, temporal, spatial and causal, to understand the fire characteristics and the elements affecting the fire risk<sup>4</sup>. But in an another study, it was found that there was a strong negative relationship between income and fire rates i.e. as income rose, fire rate dropped significantly<sup>5</sup>. It has been demonstrated that amongst five types of fire i.e. malicious fire alarms, residential buildings, secondary (outdoor), vehicle and suspicious fires, the risk of fire greatly increased during holidays and weekends<sup>6</sup>. Residential fire incidents are the principal cause of death from thermal injury for New Zealand children<sup>7</sup> and in adults<sup>8</sup>. Majority of these studies are conducted in other countries, however, due to geographical, cultural and economic differences their suitability in Indian context particularly in a metropolitan city like Delhi needs to be studied.

There has been a comparative lack of study into the relationship between large number of fire incidents with weather condition, population and occupancy in any metropolitan city of India.

**Study area:** Delhi is located between latitude 28° 24' N grid to 28° 53' N and longitude 76° 50' E to 77° 20' E with a total area of 1483 sq. km. It has maximum length of 51.9 km and maximum width of 48.48 km. Altitude of Delhi varies between 213 and 305 meters above the sea level. For the purpose of this study, South-West (S-W) fire division, Delhi Fire Service has been selected. South-West Division has three sub-divisions and seven fire stations under its jurisdiction as shown in Figure-3.

### Materials and methods

For the purpose of this study, fire incidents data of fire stations under the jurisdiction of S-W division, Delhi Fire Service has been collected from the available records and website of Delhi Fire Service. A survey of the area under jurisdiction of South-West division was conducted and experts in field of fire services were consulted. Different tables from analysis point of view were formulated and compiled data was used in the tables for analysis. The Figure-5 shows the logical flow diagram for the study. The data has been collected and is utilized for the analysis of relation between fire incidents and temperature and Humidity, population per square kilometer and occupancy.

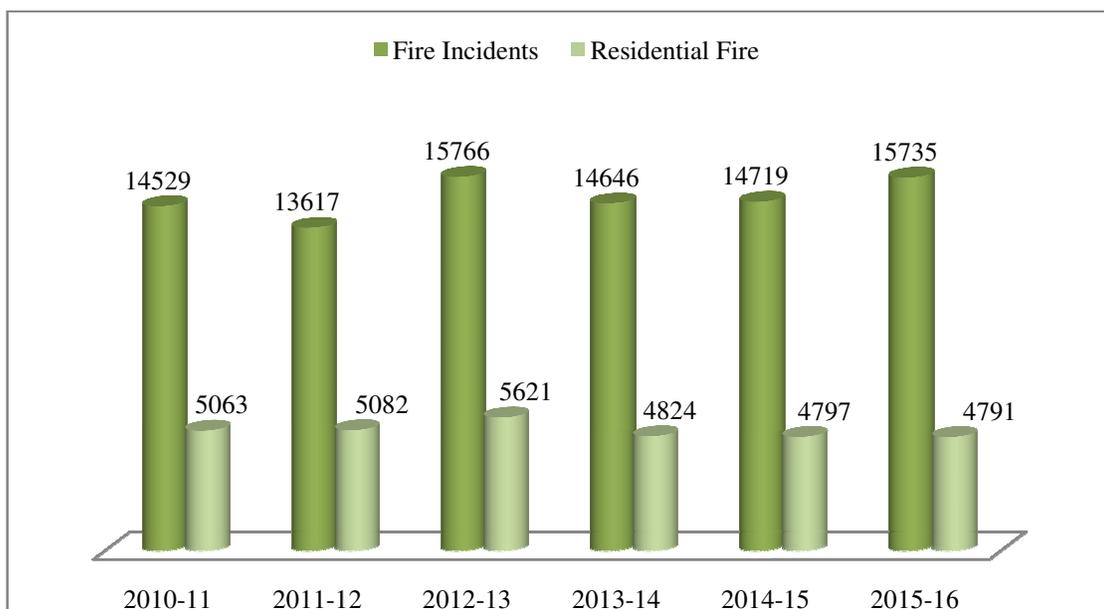


Figure-1: Fire Incidents and Residential fire incidents in Delhi<sup>2</sup>.

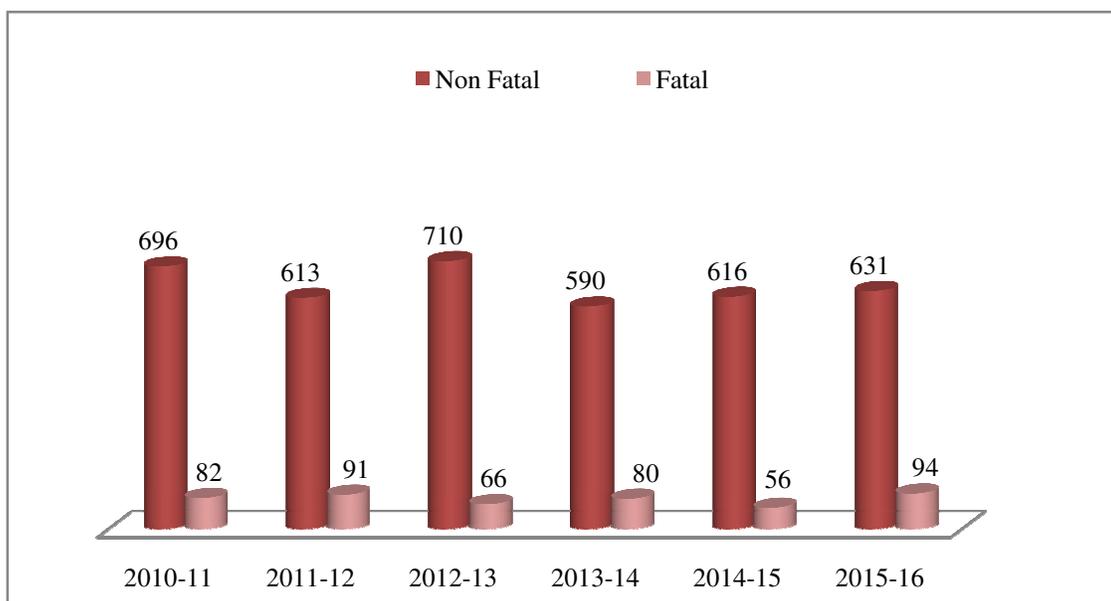
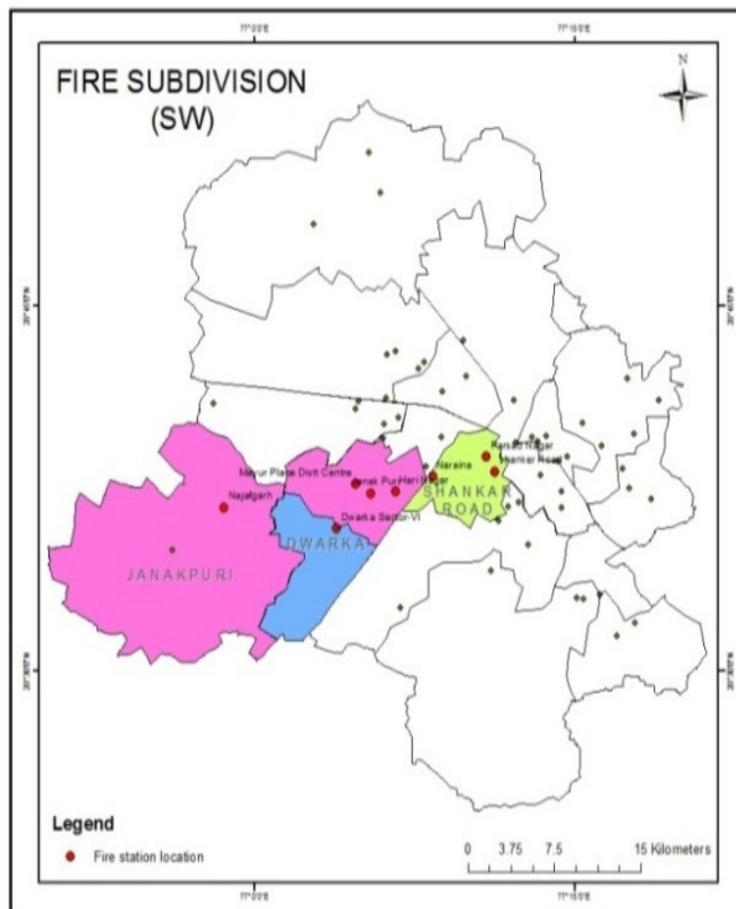
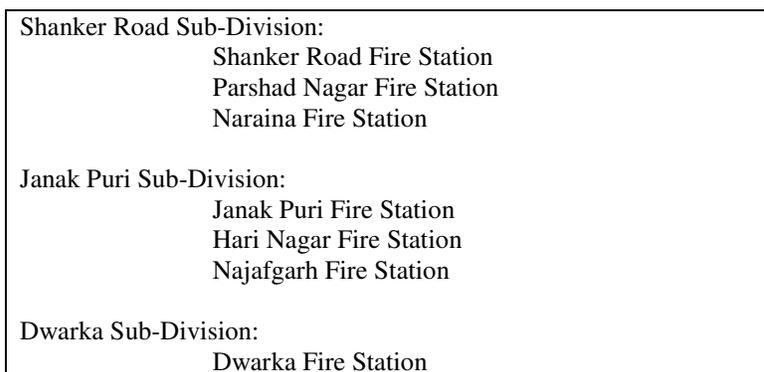


Figure-2: Fatal and Non Fatal in fire incidents<sup>2</sup>.



**Figure-3:** South-West Division of Delhi Fire Service<sup>2</sup>.



**Figure-4:** Sub Divisions and Fire stations under South-West Division<sup>2</sup>.

## Results and discussion

The month wise data of fire outbreak incidents under S-W division were recorded over a period of twelve months for the year 2013 to 2016 and total number of fire incidents per month in percentage has been calculated. Fire outbreaks in the month of May are found to be the highest (16.18%) and lowest in the month of February (5.21%). The vast difference in the fire incidents during different months of the year suggests association of weather conditions i.e. temperature and humidity

on fire incidents in the study area. This may be due to the effect of peak summer season during the month of May in Delhi. The sudden drop in the number of fire incidents in July and August indicates the association of humidity as this is the rainy season in Delhi. The number of fire incidents also goes up from 6.64% in the month of September to 8.38% in November, which may be due to festival season in Delhi. Figure-6 presented below shows the similar pattern over a period of four years except a slight variation in the year 2014.

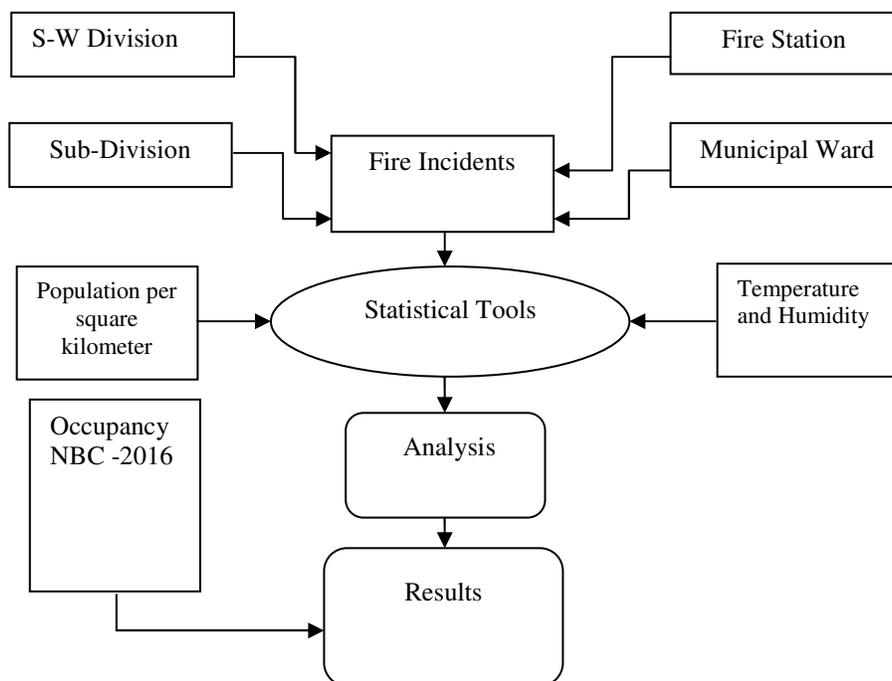


Figure-5: Conceptual framework for study.

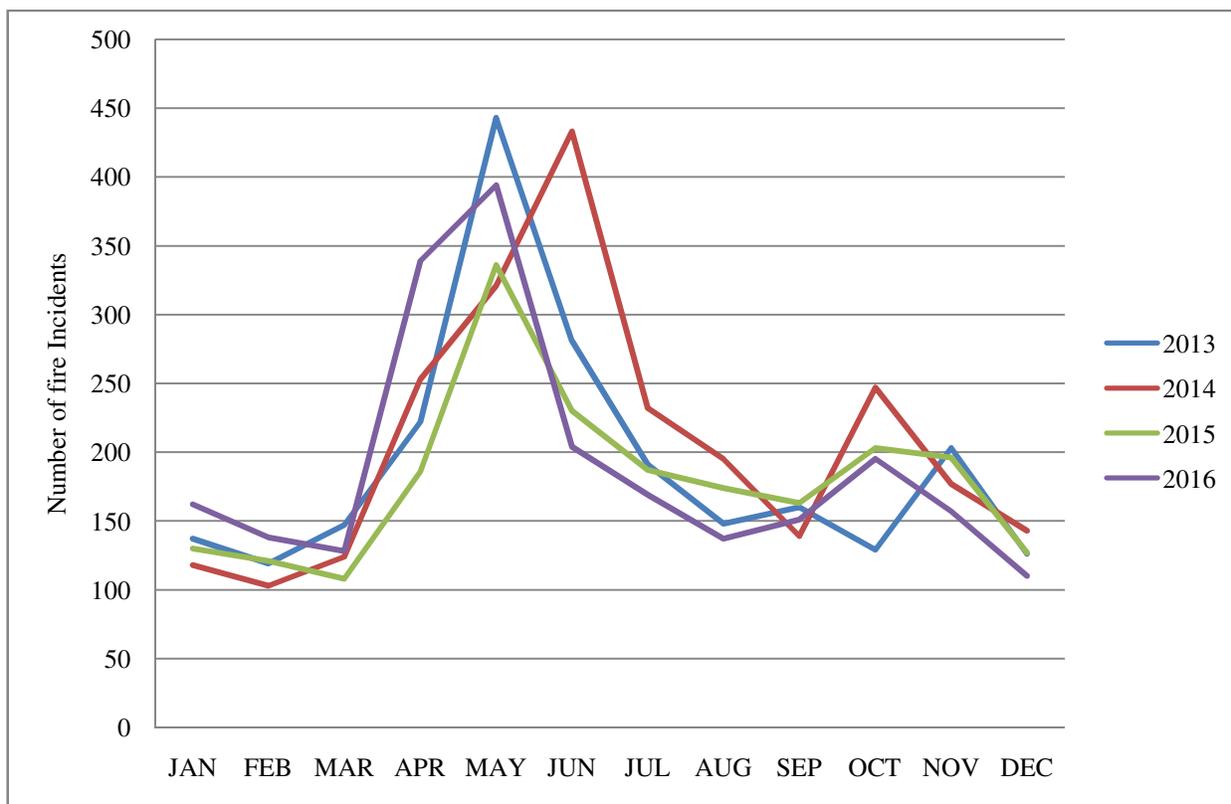


Figure-6: Month wise Fire Incidents in S-W Division of Delhi<sup>2</sup>.

To test the association of temperature and humidity on number of fire incidents, day wise fire incidents under jurisdiction of seven fire stations of S-W division for the year 2014 were

recorded along with day wise maximum temperature and maximum humidity in Delhi<sup>9</sup>. The results of regression analysis are presented in Table-1.

**Table-1:** Regression analysis (Effect of Temperature and Humidity on Fire Incidents)<sup>2,9</sup>.

Model		Coefficients				
		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Constant	12.087	2.625		4.604	.000
	Temperature	.155	.042	.229	3.713	.000
	Humidity	-.123	.019	-.403	-6.549	.000

a. Dependent Variable: Fire Incidents.

We tested assumption related to linearity, independent of error term and multicollinearity and found that sample data meet assumptions well. Further result shows that

$$\text{Fire Incidents} = 12.087 + 0.155 (\text{Temp}) + (- 0.123) \text{Humidity}$$

$$\text{Number of fire incidents} = 0.229 (\text{Temp}) + (- 0.403) \text{Humidity}$$

A value of  $R^2 = 0.348$  indicate that model explain 34.8 variation in dependent variable by independent variable.

Statistical analysis of the fire incidents data revealed that there is a positive association between day temperature and day wise fire incidents, whereas the day humidity has a negative relationship with day fire incidents in the study area.

Further for the purpose of testing the effect of population per square kilometre (population density) on fire incidents, the fire incidents for the year 2014, under S-W division were segregated as per municipal ward boundaries. A correlation test was conducted and it was found that there was no significant relationship between population density and number of fire incidents. Result of correlation study is presented below:

$$r (48) = -0.282, p = 0.052$$

The ward wise population density is not found to be significantly associated with fire incidents occurrence.

**Occupancy wise breakup of fire incidents:** This data used in statistical manner can disclose the pattern of fire incidents in different types of buildings. Fire incidents, for the year 2013 to 2016, under S-W division were recorded as per different occupancies prescribed in National Building Code (NBC) of India<sup>10</sup> - 2016, Part-VI (Fire and Life safety).

As per NBC, buildings have been classified according to use or the character of occupancy in one of the following groups based on their uses as shown in Table-2 and residential buildings (Group-A) include any building in which sleeping accommodation is provided for normal residential purposes with or without cooking or dining or both facilities, except any building classified under Group C are shown in Table-3.

**Table-2:** Classifications of occupancies<sup>10</sup>.

Group	Occupancy
Group - A	Residential
Group - B	Educational
Group - C	Institutional
Group - D	Assembly
Group - E	Business
Group - F	Mercantile
Group - G	Industrial
Group - H	Storage
Group - J	Hazardous

**Table-3:** Sub division of residential occupancy (Group-A)<sup>10</sup>.

Sub Division	Buildings
A-1	Lodging and rooming houses
A-2	One or two private dwellings
A-3	Dormitories
A-4	Apartment houses
A-5	Hotels
A-6	Starred hotels

Two categories i.e. Jhuggi (temporary hutments) and Non-structural fires have also been found to be associated with fire incidents and therefore fire incidents in these two categories have also been analyzed. The data of fire incidents has been graphically plotted for all occupancies as per NBC, Jhuggi

(hutments) and non structural fire incidents like fires on road/open area/fields etc. A significant number of fire incidents (47.53%) were found to be under Non-Structural fires. Amongst the nine different occupancies, as per NBC, residential occupancy was found to have highest number of fire outbreak incidents (38.75%), followed by mercantile occupancy (6.36%) and Business occupancy (2.34%). Figure-7 below shows the

occupancy wise distribution of fire incidents in S-W division of Delhi.

**Deaths and injuries during fire incidents:** Fire incidents data under S-W division for the years 2013 to 2016 has been analyzed further to find the number of injuries and fatalities and the results are shown in Figure-8 and Figure-9.

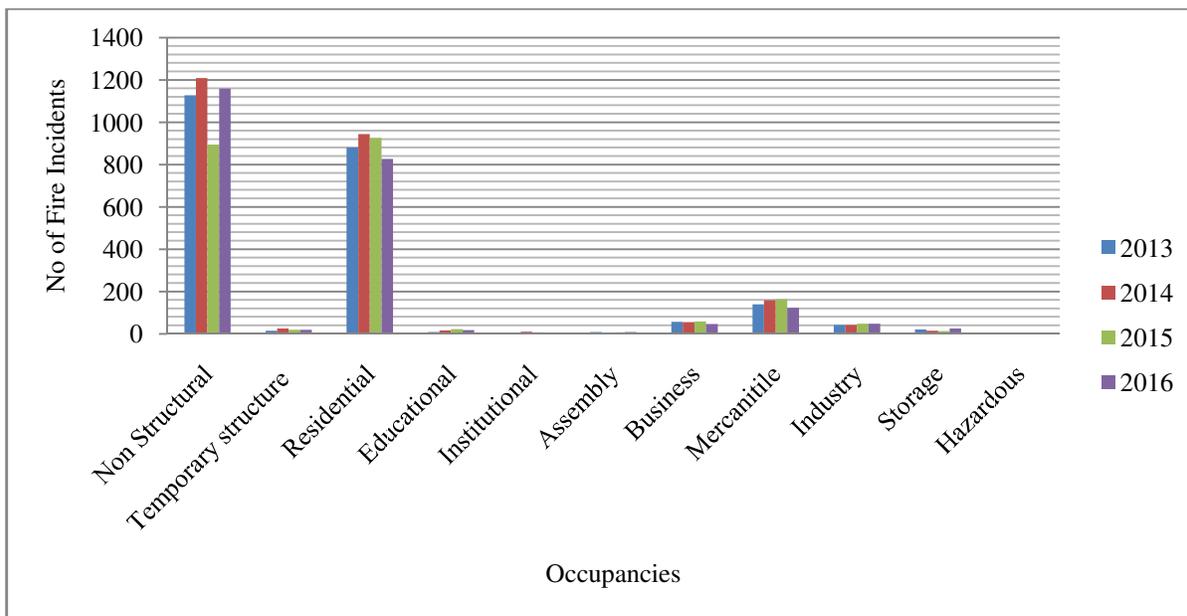


Figure-7: Occupancy wise distribution of fire incidents, S-W Division -2013 to 2016<sup>2</sup>.

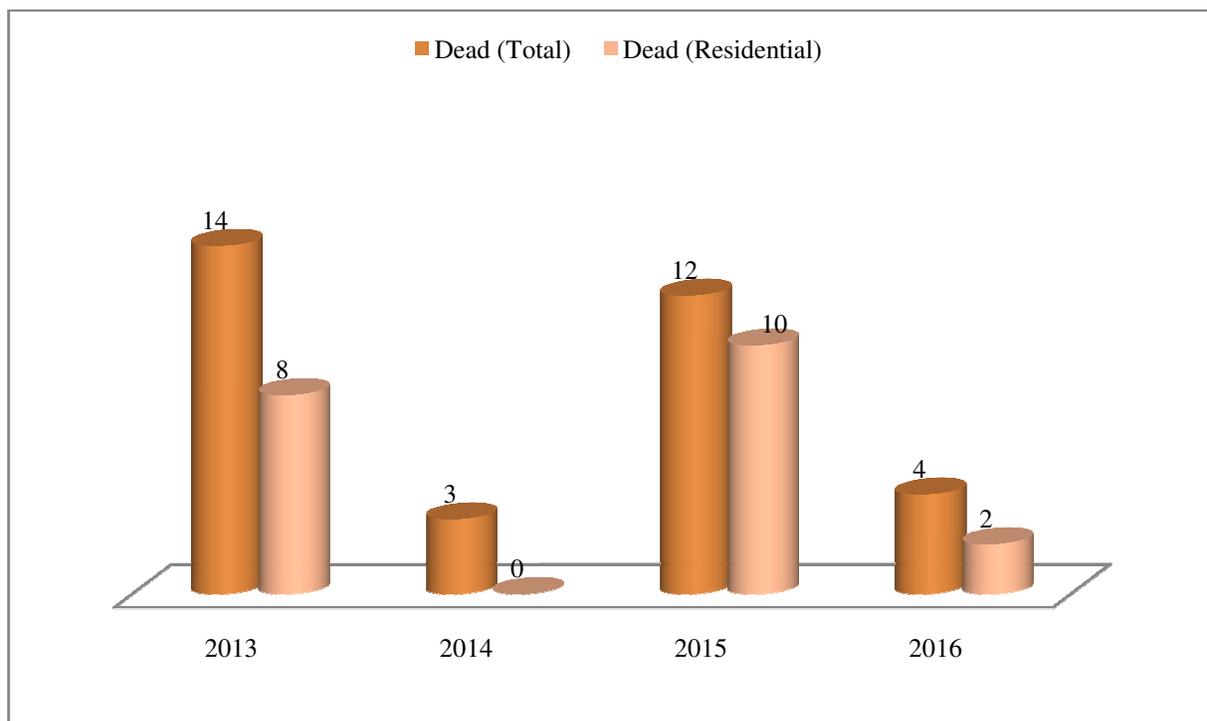
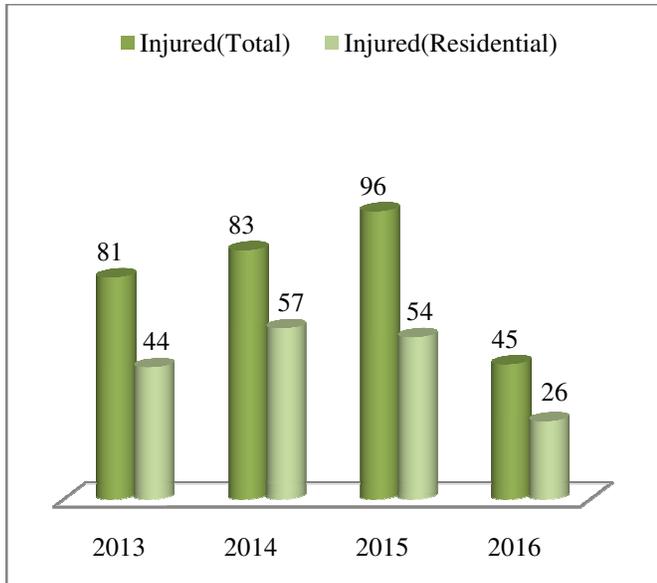


Figure-8: Total deaths and deaths in residential fire incidents in S-W Division, Delhi<sup>2</sup>.

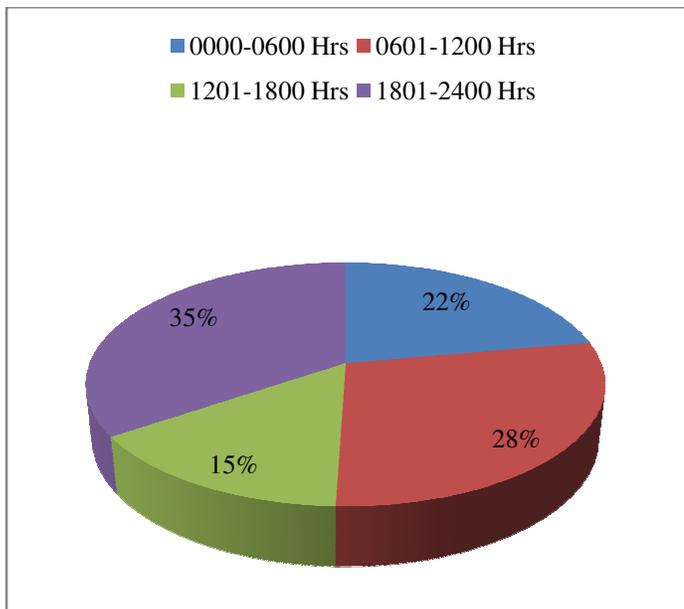


**Figure-9:** Total injured and injured in Fire Incidents in S-W Division, Delhi<sup>2</sup>.

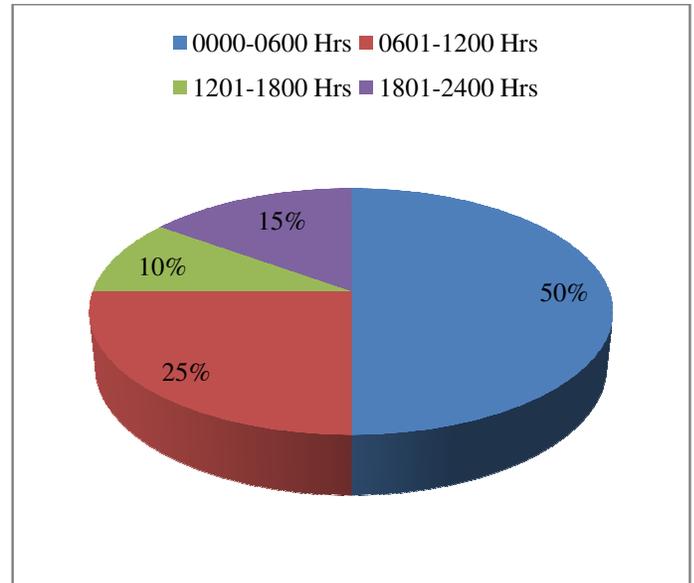
It is found that about 60% of the total deaths and injuries in fire incidents are happenings in low rise private dwellings and apartment houses under residential occupancy.

**Timings of deaths and injuries in residential occupancy:**

Further the timings of deaths and injuries during fire incidents in low rise private dwellings and apartment houses under residential occupancy were plotted in four quadrants i.e. i. 0000 Hrs to 06:00 Hrs, ii. 06:01 Hrs to 12:00 Hrs, iii. 12:01 Hrs to 1800 Hrs and iv. 18:01 Hrs to 24:00 Hrs and the results are shown in Figure-10 and Figure-11.



**Figure-10:** Time of Injured in low rise residential (A-2, A-4) fire incidents<sup>2</sup>.



**Figure-11:** Time of deaths in low rise residential (A-2 and A-4) fire incidents<sup>2</sup>.

The maximum number of injuries under residential fire incidents (Sub category A-2 and A-4) is taking place between 18:00 hrs to 24:00 hrs and maximum numbers of deaths are occurring between 00:00 hrs to 06:00 hrs.

**Conclusion**

The main purpose of fire prevention and fire protection policies/regulations has always been to avert fire and control probable fire incidents, decrease number of casualties / injuries, and safety of the occupants in buildings. Delhi receives maximum number of fire incidents as compared to other metropolitan cities of India. Findings of this study suggest that environmental factors like temperature and humidity has influencing effects on the number of fire incidents. Statistical analysis of the fire incidents data revealed that there exists a positive relationship between day temperature and day fire incidents, whereas day humidity has a negative relationship with the day fire incidents in the study area. Further the population density is not found to be significantly associated with fire incidents occurrence.

Amongst all occupancies, as per National Building Code of India, fire incidents in low rise private dwellings and apartment houses, under residential occupancy (Group-A), are found to have the highest number of fire incidents i.e. about 38 % of total fire incidents. Approximately 60 % fatalities and injuries in fire incidents are found to have occurred in low rise residential occupancy (A-2 and A-4) buildings.

The timings of fire incidents of about 50 % of total fatalities in these residential occupancy occurred between 00:00 hrs to 06:00 hrs and the number of total injuries of about 35% were between 18:00 hrs to 24:00 hrs.

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