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Are Road Accidents Affected by Rainfall? A Case Study from a Large Indian Metropolitan City

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Case Study

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ABSTRACT

The projected 40% increase in global deaths resulting from injury between 2002 and 2030 is predominantly due to the increasing number of deaths from road traffic accidents. Road crashes deserve to be a strategic issue for any country's public health and can lead to overall growth crisis, if not addressed properly. World Health Organization (WHO) warned that alarming situation is coming in future days as some studies predicted that without appropriate action, by 2020, road traffic injuries will be the third leading contributor to the global burden of disease in terms of DALYs ('disability-adjusted life years' i.e. Years of life lost to premature death and also years lived with a disability, adjusted for the severity of the disability). India already accounts for about 9.5% of the total 1.2 million fatal accidents in the world. In 2007, 1.14 lakh people in India lost their lives in road mishaps — that's significantly higher than the 2006 road death figures in China, 89,455. One person dies at every 4.61 minutes in India for road crashes. Road deaths in India registered a sharp 6.1% rise between 2006 and 2007. Road crashes are complex interaction of different parameters like road, vehicle, environment, human etc. Skidding of road vehicles is considered as one of the major causes of road accidents occurring all over the world. Skidding, caused by lack of tire-to-road friction, is one of the most important single causes of traffic accidents. This paper aims to critically analyze the weather and wet road related crashes. Critical analysis of wet road driving conditions due to rainfall and 1966 number of road crashes from a large Indian metropolitan city has also been presented in this paper. It has been found that nearly 19% of

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total crash took place in wet days. It has been noted that the value of rain-crash-effect were positive for seven months for year 2006 and none of them had the highest rainfall. A negative rain-crash-effect during months with high rainfall may be the results of small dry spell, extra care of drivers during rainy days, low vehicle speed due to traffic congestion and runoff effect. High values of rain-crash-effect during March, April, August, October and December months may be explained by dry spell effect. It is clear that dry spell has positive and significant effect over average rain-crash-index. Shift from 'no dry spell' to 'small dry spell' (1-5 dry days) increased the average rain-crash-index by 23.3% and shift from 'small' to 'large dry spell' (>5 dry days) increased the average rain-crash-index by 115.7%. An enhancement of the accident count and average rain-crash-index after a dry spell could be due to physical or psychological factors, e.g., the build-up of oil and dirt on the road surface or the slow mental realignment to wet conditions. Trend of the relationship of rainfall class and 'rain-class-crash-rate' revealed that heavy rainfall reduced 'rain-class-crash-rate' than drizzling or light rainfall. Different probable physical and psychological reasons are discussed to analyze the rainfall class effect. In general, rainfall creates driving hazard. But rainfall hazard is complexly related with road crash and needs more specific and distinguished research rather than general approach to minimize rainfall related road crashes.

Keywords: Crash, rainfall, road accident, India;

1. INTRODUCTION

Road crashes deserve to be a strategic issue for any country's public health and can lead to overall growth crisis, if not addressed properly. Road traffic injuries are the leading cause of death globally among 15-19 year-olds, while for those in the 10-14 years and 20-24 years age brackets they are the second leading cause of death (WHO, 2007[a]). The projected 40% increase in global deaths resulting from injury between 2002 and 2030 is predominantly due to the increasing number of deaths from road traffic accidents (WHO, 2007[b]). Road traffic crashes kill 1.2 million people each year and injure 50 millions. It is estimated that road traffic deaths will increase worldwide, from 0.99 million in 1990 to 2.34 million in 2020 (representing 3.4% of all deaths). India already accounts for about 9.5% of the total 1.2 million fatal accidents in the world (Mondal et al., 2011b). In 2007, 1.14 lakh people in India lost their lives in road mishaps — that's significantly higher than the 2006 road death figures in China, 89,455 (Mondal et al., 2011a). One person dies at every 4.61 minutes in India for road crashes. Road deaths in India registered a sharp 6.1% rise between 2006 and 2007. The Planning Commission of India had assessed the social cost at Rs. 55,000 crore (Rs. 550 billion) on account of road accidents in India (Mondal et al., 2008). A huge number of researches have been conducted to analyze road crashes. Skidding of road vehicles is considered as one of the major causes of road accidents occurring all over the world. Skid resistance is undoubtedly a vital factor for this type of accidents. Some of the other factors affecting the risk of skidding accidents are vehicle speed, road geometry, traffic density, percentage of trucks in the traffic flow, and wet-pavement exposure. Critical analysis of different crash parameter merits itself as a necessary study from public health point of view. It is a well known fact that rainfall creates lots of road traffic hazard. A number of studies show that precipitation results in more accidents compared with dry conditions (Keay and Simmonds, 2006). So analysis of weather and wet road related crashes deserves special attention. This paper aims to critically analyze the weather and wet road related crashes. A case study consisting of critical analysis of wet road driving conditions due to rainfall and 1928 number of road crashes from a large Indian metropolitan city (New Delhi) has also been presented in this paper.

2. PHYSICS BEHIND THE WET ROAD CRASHES

Short discussion of the physics behind the wet road accident may be interesting, even to the readers of a medical journal. Many researchers stressed that wet road traction deserves special attention during accident analysis. When a vehicle is running on the wet road at high speed, the rainwater flow through the tire tread grooves gives rise to the hydrodynamic pressure. The occurrence of this hydrodynamic force deteriorates the tire traction efficiency because it decreases the tire contact force (Mondal et al., 2008, Cho et al., 2006), so that the driving controllability and the braking performance become worse than those on the dry road. Rohde (1977) presented a classical model of the thin film wet traction problem by considering the tire tread element to be rigid and the pavement to be smooth. Burns (1976) reported that differential friction should be given major consideration in any pavement friction analysis. Differential friction, is a term derived to describe the condition that exists when the individual wheel paths on which a vehicle rides have different or unequal coefficients of friction. There are also strong indications that differential friction may be as important a cause of wet pavement accidents as low friction level. Persson et al. (2004), in an article in Nature journal, proposed a novel theory of “sealing effect” to analyze the rubber friction on wet and dry road surfaces. The theory showed that this cannot be due to hydrodynamics and proposed an explanation based on a sealing effect exerted by rubber on substrate “pools” filled with water. Water effectively smoothens the substrate, reducing the major friction contribution due to induced viscoelastic deformations of the rubber by surface asperities. Ali et al. (1998) studied the problems of skidding, particularly during the wet season. A predictive relationship between the friction coefficient and the skid length was obtained. Minimum required values of friction coefficient were recommended for safe performance. On the basis of criteria such as those proposed in that study, recommendations were made to improve the skid resistance. Open-graded friction courses are strongly recommended to reduce wet weather skidding.

3. CASE STUDY OF WET ROAD CONDITION AND ROAD CRASHES

Common experience is that rainfall creates driving hazard. It is also common perception that rainfall increases road crashes. Many researchers proved the positive correlation between rainfall and road crash. Gothié (2000) reported that twice the proportion of accidents occur on wet pavements than dry. A study has been conducted to assess the seasonal and weather effects on the frequency of road accidents in California. The weather was found to be a major factor affecting accident numbers. On very wet days the number of accidents was often double that of corresponding dry days. Most of these researches are concentrating on general relationship of rainfall and crash. But critical analysis of rainfall related crashes are not much available.
The objective of the present case study is to study the effect of rainfall on road crash by analyzing risk of rain, dry spell effect and rain class effect.

4. METHODOLOGY

For this case study, the dataset of 2006 has been used. New Delhi is situated at 28° 42′ 0″ N and 77° 12′ 0″ E and 216 m above the mean sea level. Climate of this Indian metropolitan is semi-arid with high variation between summer and winter temperatures. The average annual rainfall is approximately 714 mm, most of which takes place during July to September. However, the annual rainfall is extremely variable. Traffic accident data has been provided by Delhi Traffic police. The rainfall dataset for 2006 has been collected from India Metrological Department, Lodhi road, New Delhi. Here the accident count represents only fatal accidents. Throughout the study mentioning of accident or crash will represent only fatal accident. Reliable data for serious and other type of injuries are not available from the police source and excluded from the study. Figure 4 presents the daily rainfall distribution and daily fatal accident count series in 2006. Total rainfall of 2006 was 760.1 mm. It has been noted that the total rainfall of 2006 was slightly above the average rainfall.

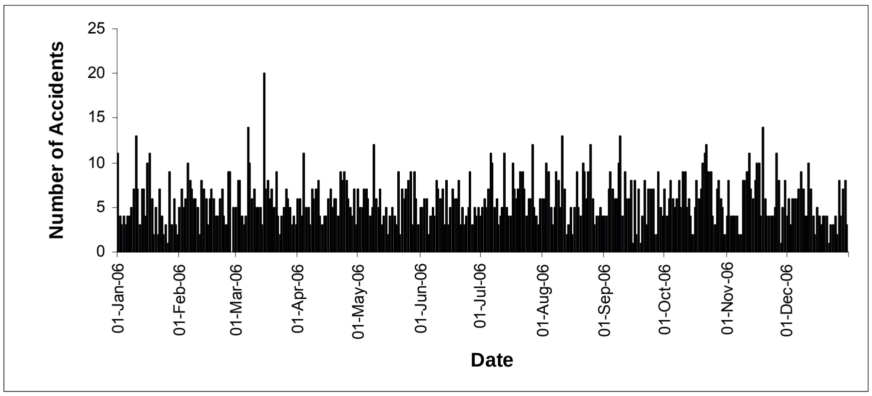

Figure 4: Daily rainfall distribution and Daily accident distribution in New Delhi during 2006

4.1 METHODS

A range of statistical methods has been applied for the data analysis. The following terms have been adopted for the study, which are defined below. Rain-crash-index (RCI) is defined as

RCI = (C/R) ………………………………………… (1)

Where C is the crash count in a particular day and R is the rainfall in mm in that respective day.

Wet-crash-rate (WCRi) for the ith month of a year is defined as

WCRi = (WC/WD) …………………………………. (2)

Where WC is the total number of crash took place in wet days of a month and WD is the total number of wet days that respective month. A day which receives any amount of rainfall is termed as a wet day for this study.

Dry-crash-rate (DCRi) for the ith month of a year is defined as

DCRi = (DC/DD) …………………………………… (3)

Where DC is the total number of crash took place in dry days of a month and DD is the total number of dry days in a month. A day which receives no rainfall is termed as a dry day for this study.

Rain-crash-effect (RCEi) for the ith month of a year is defined as

RCEi = ((WCRi-DCRi)/DCRi) x 100 …………….. (4)

Throughout the year rainfall varies in amount, intensity etc. So it is also important to know the effect of rainfall class on crash rate. Rain-class-crash-rate (RCCRi) for ith class of rainfall is defined as

RCCRi = (WCi/WDi) ………………………………. (5)

Where WCi is the total number of crash took place in wet days for ith class of rainfall in a year and WDi is the total number of wet days for ith class of rainfall in the respective year. Rainfall was classified into six classes, namely >0 to 1 mm, >1 to 2 mm, >2 to 5 mm, >5 to 15 mm, >15 to 30 mm and >30 mm. All rainfall amounts are for 24h of a day.

4.2 ANALYSIS OF IMPACT OF DRY SPELL

Dry spell is defined as the number of dry days between two consecutive wet days. Impact of dry spell has been analyzed to ascertain whether the effect of rainfall on the first day after a dry spell differs from other wet days. It is also important to know the effect of different type of dry spells. For this purpose, further, dry spell has been divided into three classes, namely, no (0 day), small (1 to 5 days) and large (>5 days).

5. RESULTS AND DISCUSSION

5.1 RISK OF CRASH DURING RAINFAL

To analyze the risk of crash during rainfall, an exhaustive study of WCRi, DCRi and RCEi for all months of 2006 has been conducted. Crashes occurred during wet day and dry day have been segregated. Wet crash count and dry crash count series for all the months of 2006 have been presented in Figure 5. According to the metrological department, normal monsoon stays in New Delhi from June end to August end. Nearly 16.7% of total crash took place in wet days. It is surprising to note that total number of crash is reduced during peak monsoon months. It is surprising to note that the lowest total crash (140) took place in the month of July which received very high (193.9 mm) total rainfall. It has been also noted that average of total crash of these three months is also less by 2.1% from monthly total crash average (163.8). Eisenberg (2004) also observed surprising negative and significant relationship between monthly precipitation and monthly fatal crashes. The reasons may be the extra care, taken by the drivers, low vehicle speed for traffic congestion and washing off the traffic dirt. Number of wet crash in July is 15.6% higher than dry crash. It may be due to more number of wet days in July than dry days.

Figure 6 presents relationship of rainfall and rain crash effect. Some surprising result came out from the comparison of rainfall and RCEi. It has been noted that the value of RCEi were positive for only five months (Jan., Mar., Apr., May. and Nov.). January had highest RCEi

(49.68%), followed by May (33.10%). September had lowest RCEi (-19.70%) followed by August (-17.80%). It has been also noted that the month of September received highest monthly rainfall (231.6 mm) during 2006. October and December had no wet days and marked with circle in graph and excluded from comparison. A positive RCEi means more crash per unit wet day than unit dry day in a month. It is also interesting to note that monsoon months (June to August) have negative RCEi. A negative RCEi during monsoon months may be the results of extra care of drivers during monsoon, low vehicle speed for traffic jam and runoff effect. High positive values of RCEi during January, April and May months may be explained by dry spell effect, discussed at length in next section.

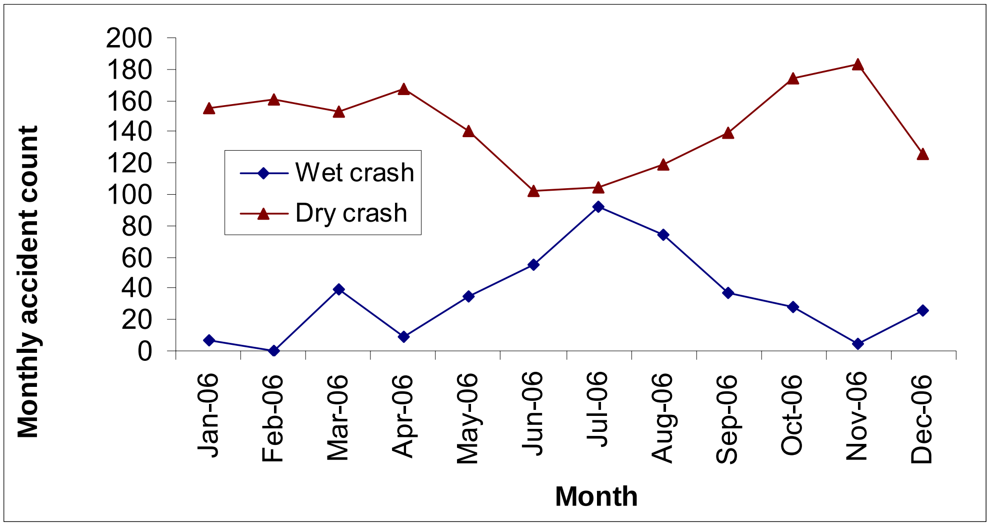

Figure 5: Distribution of monthly wet crash count and dry crash count

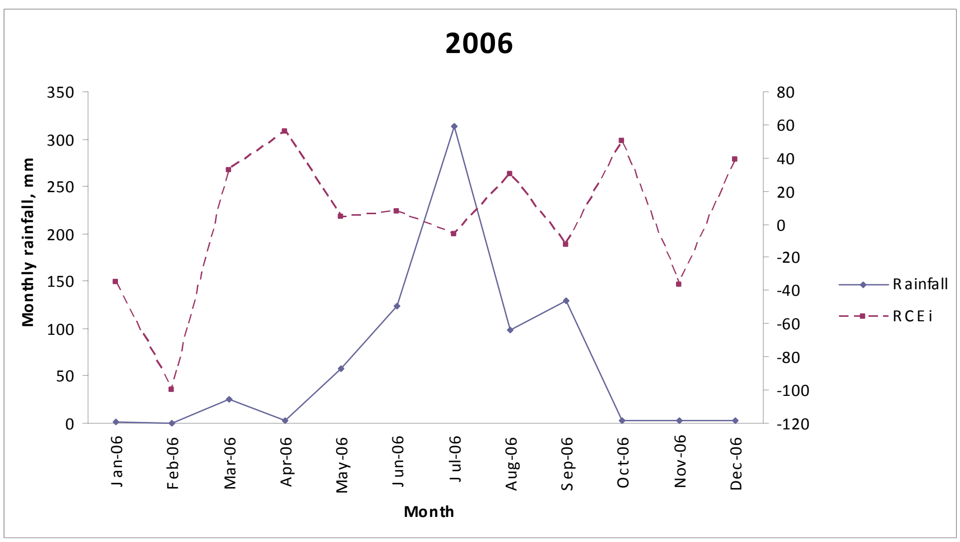

Figure 6: Relationship of rainfall and rain crash effect.

5.2 DRY SPELL EFFECT

It has been found very important to address the extent to which the effect of rainfall on the road accident count depends on the length of time since the last rainfall, i.e. the impact of a dry spell. Relationship of dry spell and average rain-crash index (RCI) is presented in figure 7.

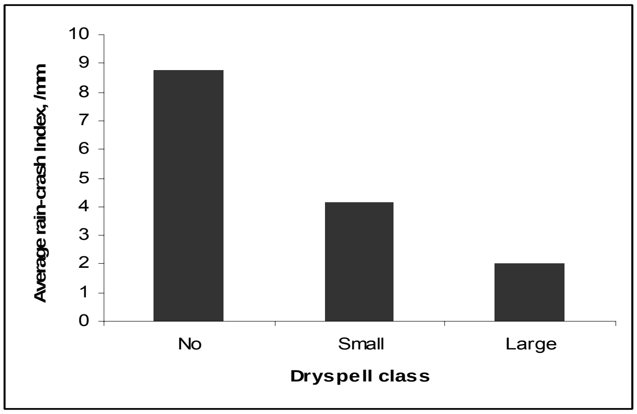

Figure 7: Relationship of dry spell and average rain-crash index

Relationships of different average crash rates are presented in figure 8. No (0) dry spell means no dry day between two consecutive wet days. For the present study small dry spell and large dry spell (>5 dry days) consisted of continuous dry days of 1 to 5 days and 6 to 40 days, respectively. Any immediate wet day after a dry spell is designated by name of the dry spell. For example, a wet day after a large dry spell is designated as 'large dry spell wet day'. It has been found that only 'large dry spell wet day' has greater average crash rate than normal average crash rate (Figure 8). It is clear from the figure 7 that dry spell has positive and significant effect over average RCI. Shift from no dry spell to small dry spell increased the average RCI by 23.3% and shift from small to large increased the average RCI by 115.7%. Brodsky and Hakkert (1988) also found that rain presents a greater risk when it follows a dry spell. In Israel the risk of an accident in wet weather appeared to be much higher during the occasional rains of the transitional months of March and November. Using a difference-in-means method and weekday injury accidents for 1979–1981 they found that the daylight risk ratio was 11.2 for the transitional months compared with 2.2 for the winter months, which had more persistent rain. During winter 55% of wet day accidents were attributed to rain, rising to 91% for March and November. The increased risk was attributed to the increased slipperiness of wet roads due to the accumulation of pavement grime during dry periods. Eisenberg (2004) observed a spell effect in an analysis of US daily accident counts. He also cites the buildup of oil on roads during a dry spell as a mechanism for causing increased slipperiness when the first rain breaks the spell. He found that after a spell of 1day there was a 9.7% increase in the non-fatal injury crash rate on the next wet day for 17 states over 1990–1999. This rate rose to 17.9% after 6 dry days and 23.1% after >21 days.

An enhancement of the accident count and average RCI after a dry spell could be due to physical or psychological factors, e.g. the build-up of oil and dirt on the road surface or the slow realignment to wet conditions. It is possible that drivers have 'forgotten' how to drive appropriately in wet and slippery conditions (Mondal et al., 2008). Reduction in average RCI during no dry spell may be due to runoff of lubrication oil, dust etc. from road and more attentive driving.

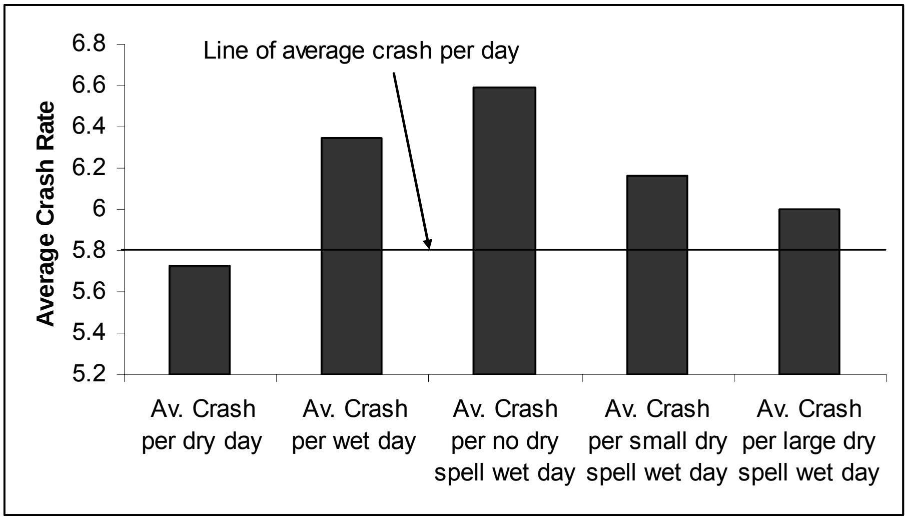

Figure 8: Relationship of different average crash rates

5.3 RAINFALL CLASS EFFECT

It is worthy to know the effect of rainfall class on road crash. Total day count for different classes of rainfall is presented in figure 9. It has been found that (>2 to 5) class rainfall had highest day count (15) followed by (>0 to 1) class with 14 total day count during 2006.

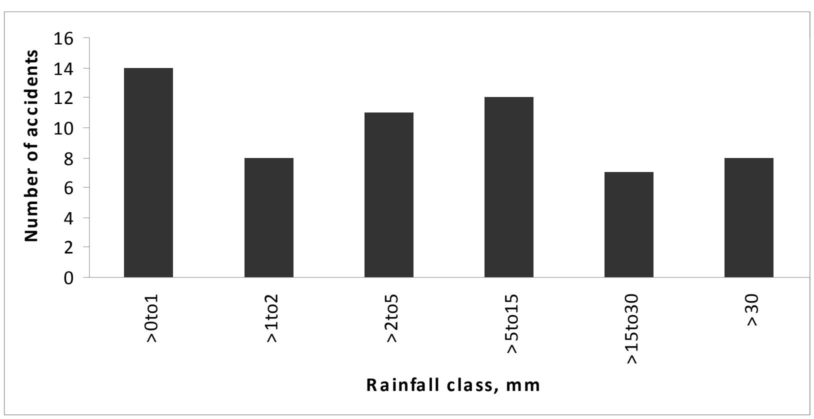

Figure 9: Distribution of total day count for different classes of rainfall

Relationship of rainfall class with number of accidents and RCCRi is presented in figure 10. Trend line of the relationship of rainfall class and RCCRi revealed that high amount of rainfall reduced RCCRi. High values of RCCRi have been recorded for classes with small rainfall. Class (>1 to 2) had highest RCCRi (6.83), whereas class (>15 to 30) had lowest RCCRi (3.71).

Probable reasons are listed below:

a) Drizzling or light rainfall may create more lubrication and slippery condition on the road by mixing with dust, oil etc. On the contrary heavy rainfall may washed away dust, oil etc. from road (runoff effect).

b) Drizzling or light rainfall may create 'don't care' attitude among drivers, whereas a heavy rainfall psychologically threatens drivers and extracts more attentive attitude from them.

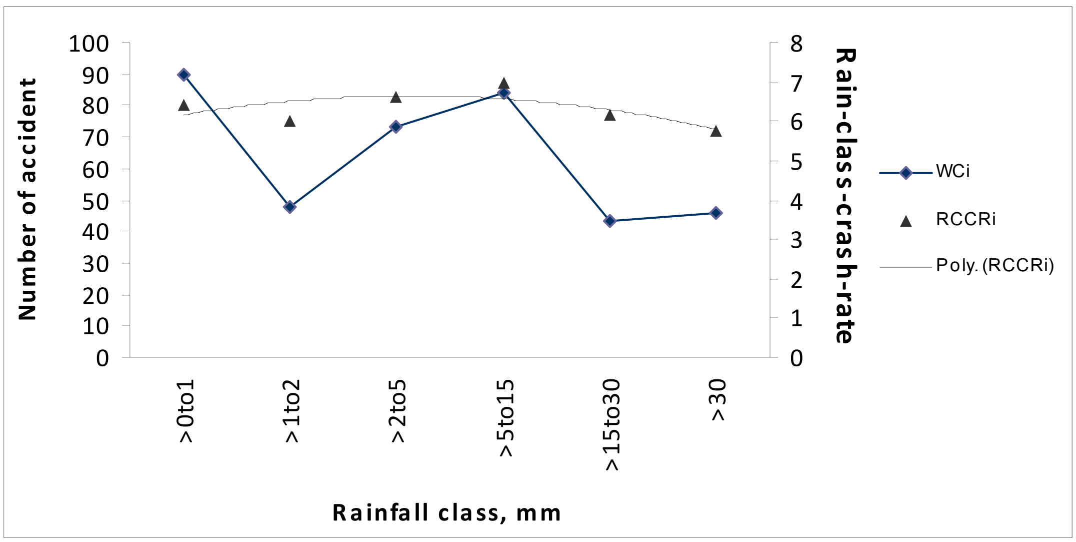

Figure 10: Relationship of rainfall class with number of accidents and RCCRi

6. CONCLUSION

- A case study of effect of rainfall on road crash in New Delhi has been presented in this paper. Nearly 16.7% of total crash took place in wet days.

- Comparison of WCRi and DCRi also reveals some surprising results. It has been noted that the value of RCEi were positive for only five months. September had lowest RCEi (-19.70%) followed by August (-17.80%), whereas both September and August month received very high rainfall. A negative RCEi during monsoon months may be the results of extra care of drivers during monsoon, slow vehicle speed and runoff effect. High values of values of RCEi during January, April and May month may be explained by dry spell effect.

- It is clear that dry spell has positive and significant effect over average RCI. Shift from no dry spell to small dry spell (1-5 dry days) increased the average RCI by 23.3% and shift from small to large dry spell (>5 dry days) increased the average RCI by 115.7%. An enhancement of the accident count and average RCI after a dry spell could be due to different physical or psychological factors.

- Trend of the relationship of rainfall class and crash per day count revealed that high amount of rainfall reduced crash per day count. High values of RCCRi have been recorded for classes with small rainfall. Class (>1 to 2) had highest RCCRi (6.83), whereas class (>15 to 30) had lowest RCCRi (3.71). Different probable physical and psychological reasons are discussed to analyze the rainfall class effect.

- This paper proves that rainfall hazard is complexly related with road crash and needs more specific and distinguished research rather than general approach to minimize rainfall related road crashes.

- It is expected that unique and specific results of this research, differing from traditional generalized rain-crash relationship will initiate more future research and will be instrumental to enforce some specific protective regulations as well precautions.

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