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Analysis of Weather and Wet Road Crashes in Enugu Urban

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Abstract: The problem of deaths and injuries as a result of traffic crashes has been acknowledged to be a global phenomenon. Wet weather contributes to several hazards within the transportation sector. The study focused only on vehicular types for example, cars, trucks, buses and motor cycles, etc. that plies on roads. The purpose of this study is to identify several potential interactions between specific rainfall characteristics and road crashes in Enugu urban. A range of statistical methods were employed in the analysis. The following statistical terms were adopted for the study and are defined in the text: Rain Crash Index (RCI), Wet Crash Rate (WCRi), Dry Crash Rate (DCRi), Rain Crash Effect (RCEi) and Rain Class Crash Rate (RCCRi). The research established some surprising results based on the analysis of WCRi and DCRi. About 29.8% of road crashes in Enugu occurred during wet months of 2009. It was surprising to observe that the highest wet crash occurred in the month of June (28 crashes) with only 10 wet days compared to the month of September with the highest wet days (22 days) and only 13 crashes. A negative rain crash effect during months of 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. It was also found that the effect of rainfall on road accident count depends on the length of time since the last rainfall (that is the impact of a dry spell). Large dry spell days recorded more accident counts. A shift from no dry spell to small dry spell days increased the average RCI by 26.4% while a shift from small to large dry spell increased the average RCI by 117.8%. Rainfall class and rain class crash rate showed that rainfall class of >30 mm reduced rain class crash rate more than rainfall class of between 0-1 mm (drizzling or light rainfall). Rainfall class (0-1 mm) had highest RCCRi (4.18) while rainfall class (>5-15) had lowest RCCRi (0.69). Some recommendations on areas for further research were made.

Key words: Road crash, wet crash, dry crash, dry spell, rainfall, weather

INTRODUCTION

The problem of deaths and injury as a result of road crashes is now acknowledged to be a global phenomenon. Road traffic injuries are the leading cause of death globally among 15-19 years old while for those in the 10-14 and 20-24 years age brackets, they are the second leading cause of death. Also, WHO publications shows that in 1990 road crashes as a cause of death or disabilities were by no means insignificant, lying in 9th place out of a total of >100 separately identified causes. However, by the year 2010 forecasts suggest that as a cause of death, road crashes will move up to 6th place and in terms of Years of Life Lost (YLL) and Disability-Adjusted Life Years (DALYs) will be in 2nd and 3rd place, respectively.

The convention of road traffic defined fatality as a road death deemed to have occurred when a person injured dies within 30 days of the crash and as a result of the crash while an injury road crash involves a collision of a moving vehicle on a public road in which a road user (human or animal) is injured (Irta, 1992). In this study, the term crash or accident is used to represent fatal, injury or minor cases. Road traffic crashes kill 1.2 million people globally each year and injure 50 millions. It is estimated that road traffic deaths will increase worldwide from 0.99 million in 1990-2.34 million in 2020, representing 3.4% of all deaths (Mondal *et al*., 2011). Worrisome aspect in the 2004 world report is that in developing and underdeveloped countries, deaths resulting from traffic injuries is expected to rise by 80%. Africa's global road fatality share is three times as large (11%) as its motor vehicle share. Crash data was available on only half of Africa countries but those countries accounted for two-thirds of the regional population (Jacobs *et al*., 2000). Two countries, South Africa and Nigeria, account for more than half of the regions road fatalities.

In Nigeria, Road Traffic Accidents (RTA) occur daily in Nigeria, killing an average of 12 persons. About 80% of RTA in Nigeria occurs on major highways and about 80% of the victims of RTAs in the country are male and fall within the productive age group (20-50 years). Poor road conditions and defective road engineering contribute significantly to road traffic accidents in Nigeria (2010

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FRSC annual report). The crash of 2009 showed that 5695 Nigerians lost their lives in road mishaps with Enugu having 457 cases. This is significantly lower than the 2008 road death figure of 6,661. Road deaths claimed a total of 17024 lives between 2007 and 2009 and injured 73048 in Nigeria during the same period.

A 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, wet-pavements and exposure.

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 study aims at assessing the weather and rainfall effects on the frequency of road accidents in Enugu state, Southeast Nigeria using 2009 as a case study. Again this is to help FRSC in its guest to sustain the decline in road crashes and injuries in order to achieve the objective of the Accra declaration of reducing road crash fatalities by 50% by 2015 and also the UN decade of action on road safety 2011-2020 which hopes to make Nigeria roads to rank among the world's 20 safest roads by the year 2020.

Conceptual framework: The physics behind the wet road accident is an interesting one as wet road traction spurs special attention during accident analysis. When a vehicle is running on a 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 (Cho *et al*., 2007; Mondal *et al*., 2008) so that the driving controllability and the braking performances become worse than those on the dry road.

Researchers such as Burns (1976) and 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 and reported that differential friction should be given major consideration in any pavement friction analysis. Persson *et al*. (2004) 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 visco elastic deformations of the rubber by surface asperities.

Ali *et al*. (1999) studied the problems of skidding, particularly during the rainy 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 their part, Mondal *et al*. (2011) showed the trend of the relationship of rainfall class and rain class crash gate. The revelation showed that heavy rainfall reduced rain class crash gate than drizzling or light rainfall. Many researchers proved the positive correlation between rainfall and road crash. Gothie (2000) reported that twice the proportion of accidents occur on wet pavements than dry pavements. In general, rainfall creates driving hazard but rainfall hazard is complexly related with road crash and needs more specific research rather than general approach to minimize rainfall related road crashes in Nigeria. This objective is therefore, what this study is set to achieve.

The study area: The study was carried out in the southeast zone of Nigeria, precisely Enugu state. Enugu, popularly known as the Coal city is located on the Eastern fringe of Udi Escarpment. It lies between 6°20' and 6°30'N and 7°25' and 7°30'E. Its origin dates back to 1909 when Mr. Kitson, a British mining engineer with British Geological Exploration team discovered coal at the foot of Udi escarpment together (Nnamani, 2002).

The study area lies within the rainforest-savanna Ectone. It is a belt of tall trees with dense undergrowth of shorter species dominated by climbing plants. There is a prolonged rainy season, resulting in higher annual rainfall >1,800 mm. However, the annual rainfall is extremely variable. Humidity >80% during the raining season and temperature of 27°C annually has been observed in the study area (Enete, 2009).

MATERIALS AND METHODS

Traffic accident data has been provided by Federal Road Safely Commission of Nigerian (FRSC). The daily rainfall dataset for 2009 was collected from Nigeria meteorological Agency, Oshodi. The statistical technique employed here was adopted from Mondal *et al*. (2011).

A range of statistical methods has been applied for the data analysis. The following terms have been adopted for the study which Rain Crash Index (RCI) defined as:

$$RCI = (C/R) \qquad (1)$$

Where:
C = The crash count in a particular day
R = The rainfall in mm that respective day

Wet Crash Rate (WCRi) for the ith month of a year's defined as:

$$WCRi = (WC/WD) \quad (2)$$

Where:
WC = The total number of crash that took place in wet days of a month
WD = The total number of wet days that respective month

A day which receives any amount of rainfall is termed as a wet day for that day. Dry Crash Rate (DCRi) for the month of a year is defined as:

$$DCRi = (DC/DD) \quad (3)$$

Where:
DC = The total number of crash that took place in dry days of a month
DD = 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:

$$RCEi = \frac{(WCRi - DCRi)}{DCRi} \times 100 \quad (4)$$

Throughout the year rainfall varies in amount and intensity. So, it is also important to know the effect of rainfall class on crash rate. Rate Class Crash Rate (RCCRi) for ith class of rainfall is defined as:

$$RCCRi = (WCi/WDi) \quad (5)$$

Where:
WCi = The total number of crash that took place in wet days for ith class of rainfall in a year
WDi = The total number of wet days for ith class of rainfall in the respective year

Rainfall was classified into six classes namely; >0-1, >1-2, >2-5,>5-15, >15, >15-30 and >30 mm. All rainfall amounts are of 24 h of a day.

Analysis of impact of dry spell: Dry spell is defined as the number of dry days between 2 consecutive wet days. Impact of dry spell has been analyzed to ascertain whether the effect of rainfall on the 1st 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, dry spell has been divided into three classes, namely no (0 day), small (1-5 days) and large (>5 days).

RESULTS AND DISCUSSION

The wet crash, wet days, dry crash and dry days records for the year 2009 were examined. A total of 146 crashes were witnessed under wet conditions while 310 crashes were under dry conditions. The year 2009 had only 116 wet days and 249 dry days. An annual rainfall of 1769.7 mm was recorded in Enugu for the year 2009. The month of October had the highest rainfall record of 382.2 mm followed by May with 305.4 mm. The month of March had the least amount of rainfall of 11.1 mm followed by February with 12.3 mm. The month of September had the highest number of wet days of 22 days followed by October and August with 19 and 18 days, respectively. The month of March and February had only one wet-day each followed by January with 3 days only.

About 29.8% of total crash took place on wet days. However, it is surprising to observe that the highest wet crash occurred in the month of June (28 crashes) with only 10 wet days while the month of September with the highest number of wet days (22 days) had only 13 crashes. The month of June with 28 crashes had 241.9 mm of rainfall. And October with the highest amount of rainfall (382.2 mm) had only 18 wet-crashes (Fig. 1).

Observation showed that wet crashes increased in the 1st 3 months of rainy season (April to June) and then decreased. This observed negative relationship between monthly rainfall and monthly crashes may be because of the extra care taken by the drivers, low vehicle speed, traffic congestion and the washing off of the traffic dirt on

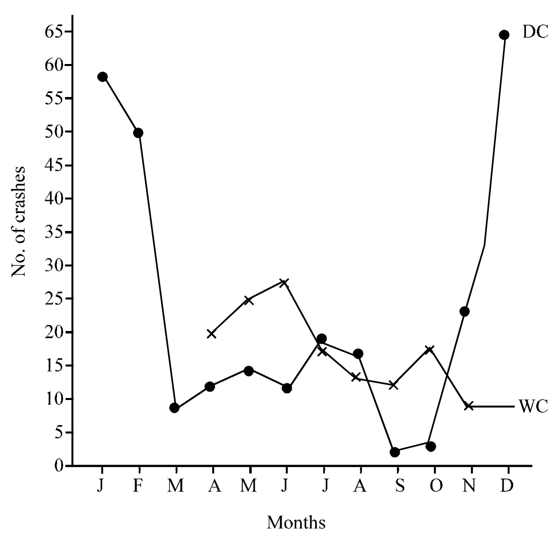

Fig. 1: Showing no. of wet and dry crashes

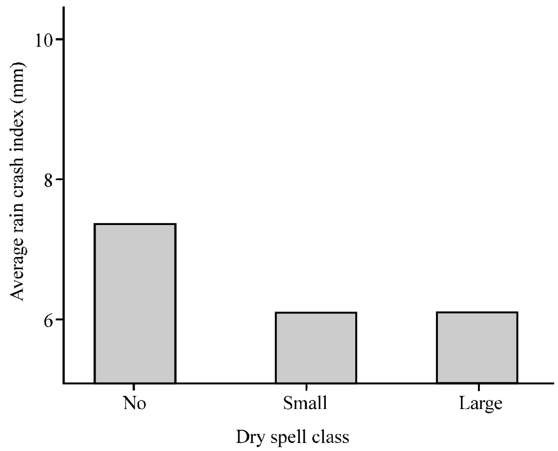

Fig. 2: Relationship between dry spell and average rain-crash index

the road (Eisenberg, 2004; Mondal *et al*., 2011). The values of RCEi were positive for the months of April, May, June, September and October. The month of September had the highest RCEi (1200%) while August had the lowest RCEi (-12.5%). The negative RCEi during the months of July, August and November may be because of the extra care, run-off effects and mber months campaign of the FRSC.

Dry spell effect: It was observed that the effect of rainfall on the road accidents count depends on the length of time since the last rainfall (i.e., the impact of a dry spell). The relationship between dry and average Rain Crash Index (RCI) is shown in Fig. 2.

In Fig. 2, No (0) dry spell means no dry day between consecutive wet days. The small dry spell and the large dry spell (>5 dry days) consisted of continuous dry days of 1-5 and 6-40 days, respectively. Any immediate wet day after a large dry spell is designated as large dry spell day. It was found that only large dry spell wet day had greater average crash rate than normal average. These findings confirm the findings of Mondal *et al.* (2011).

The average crash per wet day was 4. A shift from no dry to small dry spell increased RCI by 26.4% and a shift from small to large increased the average RCI by 117.8%. Although, various spells were above the average crash per day, the large spell wet day was greater and more significant than others. It was on that bases that Brodsky and Hakkert (1988) stated that rain presents a greater risk when it follows a dry spell. In Enugu, it was found that rainfall during the transition months increased crashes to 3.4% of large dry spell days. The increased accident rate and average RCI after a dry spell could be due to physical or psychological factors e.g., the build-up

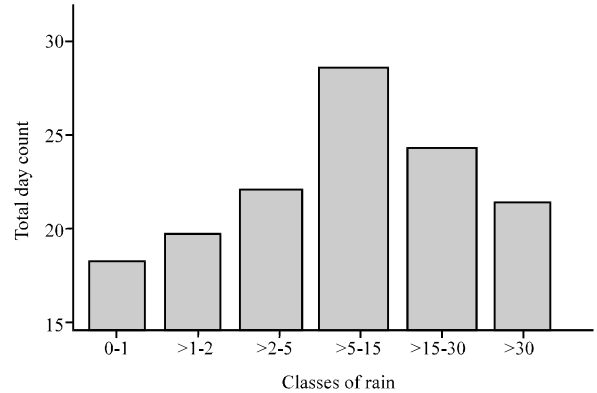

Fig. 3: Distribution of total day count for different classes of rainfall

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).

Rainfall class effect: Total day count for different classes of rainfall is shown in Fig. 3. It was found that (>5-15) class rainfall had highest day count (29) followed by (>15-30) class with 20 total day count during 2009.

The relationship between 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 (0-1) had highest RCCRi (4.18) while class (>5-15) had lowest RCCRi (0.69). Probable reasons according to Mondal *et al.* (2011) are listed as:

- 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 wash away dust, oil, etc. from road (run off effect)
- Drizzling or light rainfall may create don't care attitude among drivers whereas a heavy rainfall psychologically threatens drivers and attracts more attentive attitude from them

CONCLUSION

This study has provided a sample of possible interaction or impacts between aspects of weather including specific rainfall characteristics and road accidents. The research has established some surprising results. About 29.8% of road crashes in Enugu occurred during wet months. It also showed that the value of RCEi were positive for only 5 months. August had lowest RCEi (-12.5%) followed by July (-10%) whereas both August and July months received 128.7 and 265 mm of rain, respectively. A negative RCEi during these months may be the results of extra care of drivers, slow vehicle speed, run off effect and August break. The high values of RCEi during the month of May, may be explained by the dry spell effect.

This study therefore, has proved that rainfall hazard is highly related with road crash. However, there are many gaps that exist in the understanding of weather and rainfall related crashes, adaptation strategies, various costs and relevant behaviour of drivers. This especially relevant for transportation system in Enugu where weather related research is scarce. A number of areas for further research were identified through the development of this study with regard to driving and weather events. They include:

- Actual crash rates directly related to extreme weather events in Nigeria
- Driver behaviour and attitude in relation to the impact of various extreme weather events
- Costs and adaptation of road infrastructure development and maintenance to alleviate potential impacts of extreme weather events

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