

EFFECT OF ADVERSE WEATHER CONDITIONS ON VEHICLE BREAKING

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Abstract— Adverse weather and road conditions, following rain, fog and temperature fluctuations are the major causes of an elevated risk of traffic accidents and compromised flow in India. Drivers can control their risks at several levels; however, it is useful to consider driver behavior as hierarchically organized, separating tactical and operational on road control and level decision making. The former is exemplified by compensating for the weather-related risk with adaptive driving behavior, such as lower speeds, longer headways and avoidance of overtaking on two lane roads. However, in countries like India where hard winters and impaired road conditions are not unusual enough to stop daily routines, people are not free to make safe travel decisions, despite their safe intentions. So, it is in need to study driver behavior and crash characteristics during Adverse Weather Conditions.

1. INTRODUCTION

Adverse weather in India poses serious hazard to roadway safety through increasing travel time, reducing speeds, increasing speed variance and decreasing roadway capacity. Every year manifold variations in weather can be seen in account of temperature, humidity level and rainfall and this resultant to the occurrence of climatic anomalies such as cold wave, fog, snow storms, avalanches, hailstorm, thunderstorm, dust storms, heat wave, tropical cyclones and tidal waves (De et al 2005). The effects of these variations are underestimated, especially due to underreported weather-related accidents, lack of research work and insufficient measures to handle the demanding driving conditions in adverse weather conditions. Transport demand and unsafe operation factors influence the rate and severity of road accidents, the former is related to traffic exposures i.e. volume and traffic characteristics, while the latter is concerning unsafe vehicle operations (Andrey et al 2001). Extreme weather such as heavy rain and fog poses severe threat in road safety in India. Due to low visibility sometimes fog related road traffic accidents involve multiple vehicles resulting in vehicle pile ups. These accidents are in general fatal or severe due to the fact that multiple vehicles are involved which makes escaping

very hard. The risks in vehicle operation may be contributed by the deterioration in driving and vehicle performance as well as unfavourable road and environmental conditions. Adverse weather is one of the environmental factors that are known to affect the performance of a “moving vehicle”, especially in the situations where road friction is reduced; visibility is poor and many other factors such as arterial mobility, poor traffic signal operations that impair driving performance and road safety (Andrey et al 2003).

Driving largely is a visual task, poor visibility conditions such as rain, fog, or snow create several additional demands on the driver and their ability to collect necessary visual information is drastically reduced. The driving task becomes more complex when weather-related conditions of reduced visibility are accompanied by wet surfaces. The effect of these adverse weather conditions on driver behavior has been a matter of concern for many years and the subject of past research. The review of related literature highlights that over the past couple of decades, international groups such as the Intergovernmental Panel on Climate Change (IPCC), and the Climate Change Science Program (CCSP) and Transportation Research Board (TRB) have done several studies that describe the details of climatic changes and their potential societal impacts, including those on the transportation sector. A study conducted by Robin Burgess et al 2011 highlights that adverse weather conditions in India appear to lead to significantly deaths.

Mortality increases steeply due to the rise of temperate- (- at adverse weather. One single additional day with a mean to a -Delhi, capital of India is a monsoon-influenced humid subtropical with high variation between summer and winter temperatures. The monsoon starts in late June and lasts until mid-September and the post-monsoon season continues till late October, winter starts in November and peaks in January. Last year, according to the weather telecast, the cloudiest month was recorded August, with 90% of days were more cloudy than clear. The longest spell of cloudy weather was from July 25 to August 12, constituting 19 consecutive days that were cloudier than they were clear.

During rainy season majority of the roads become choked with overflowing rainy water with loose potholes, wires, debris. Many researchers such as Kanelaidiset al., 1990; Fitzpatrick et al., 2003; Ali et al., 2007; Park et al., 2010; Eluru et al., 2013 have carried out investigation to determine the factors which influences influencing operating speeds and traffic volumes in rural and urban environments. But most of them have investigated the effects of geometric characteristics or speed limits, using cross-sectional data primarily. However, no study has explored the effect of weather on different vehicle operating condition and its impact on speed in urban condition of Hyderabad city. In this study, regression model, time-series regression techniques (ARIMA models) and derived pattern of driving along corridor in different weather condition is explored which also shows that effect of weather condition on average speed, acceleration deceleration cursing during different weather condition.

The gamut of these researches helped to create the background of the present case study in Hyderabad, India under different Indian weather conditions where it was felt to study the speed profiles and vehicle idling time for all weather conditions. In this study, regression model, time-series regression techniques (ARIMA models) and derived pattern of driving along corridor in different weather condition is explored which also shows that effect of weather condition on average speed, acceleration deceleration cursing during different weather condition in the capital of India.

2. LITERATURE SURVEY

Existing intelligent visibility detection and warning systems

The visibility systems applied to mitigate the negative effect of the reduction in visibility can be mainly divided into two kinds: active and passive systems [1]. Active systems mainly include driver warning systems including Lane Departure Warning system and variable speed limit signs. Passive systems comprise of various pavement markings and signs which are helpful to warn and delineate traffic [1]. By examining the configurations and management strategies of these adverse weather detection systems, it is indicated that some of these systems can accurately detect the severity of reduced visibility and respond accordingly in real time to send necessary warning messages to drivers [1]. Kilpeläinen and Summala [2] pointed out that variable message signs and web portals are efficient ways for transportation agencies to provide warning information to drivers during adverse weather conditions.

Effect of adverse weather on traffic flow and driving behavior

Very few researchers have compared the effect of reduced visibility due to fog and rain on the traffic parameters using field data since the vehicle-based traffic data and weather data especially the reduced visibility data under fog condition are hard to collect. Most researchers have conducted driving simulator-based studies in order to identify the effect of

adverse weather including fog and rain separately. Broughton et al. [5] divided the fog into two levels and found that the mean headway distance in light and dense fog reduced 19 percent and 33 percent respectively compared to the sunny weather. Konstantopoulos et al. [6] analyzed drivers' eye movements in day, night and rain driving cases using driving simulator and found that visibility related factors such as driving during night and rain increase the risk of a crash. In addition, the effects of low visibility become more significant with increased experience.

Yan et al. [7] also examined the influence of foggy conditions on the speed based on simulation data. They investigated the average speed in different geometric alignments and in various fog conditions. It was shown that driving speeds are significantly reduced by the existence of fog in the straight segments but the difference between speeds in light fog and fog on the straight segments was not significant. On the other hand, speeds in light adverse weather are significantly higher than that in clear conditions on S-curve segments. Some researchers found that rain will lead to the significant decrease in traffic volume [8–12]. Ghasemzadeh [13] analyzed driver lane-keeping behavior in rain using naturalistic driving data recently and found that heavy rain can significantly increase the variance of lane position.

Others indicated that the severity of reduced visibility increase as the increase of precipitation. The condition of road surface is also being challenged as the precipitation increases, which will lead to the further decrease of traffic volume [14]. Muller and Trick [15] investigated the effect of driving experience on driving behavior using simulated fog data. They compared speed and hazard avoidance rates during fog between experienced drivers and novice drivers. Novice drivers exhibited higher speeds and less hazard avoidance in foggy weather. Jomaa et al. [16] evaluated the effectiveness of vehicle-activated signs on driver behavior and the trigger parameters used in each study. This research suggests that the newly-developed dynamic activation threshold values should be considered in future studies. During adverse road weather, deterioration in driving conditions reduces safe driving speeds substantially, and most drivers do not recognize those hazards, which exaggerate the crash risk. Edwards [17] proposed that adverse weather including rain and snow will deteriorate the road condition and increase the risk of traffic crashes. Recently, researchers have been trying to understand the relationship between real-time traffic parameters and crashes that occur during reduced visibility conditions.

Abdel-Aty et al. [18] investigated the relationship between real-time traffic data and the risk of crashes during reduced visibility related conditions caused by adverse weather by using the data collected from loop or radar detectors and automatic vehicle identification. It was found that 73% of VR crashes could be identified. Hassan and Abdel-Aty [19] examined how real-time traffic flow data could predict crash occurrence during reduced visibility conditions. It was also shown that the factors leading to visibility-related crashes were different from those crashes

occurred in clear cases. In addition to the fixed roadside sensors, in-vehicle sensors [20–21] can be considered as another data source to explore the impact of adverse weather on traffic operations. It can be concluded from above related researches that one of the common limitations of them is that most of them relied on simulation results. Moreover, few of them compared the difference of the effect of fog and rain on traffic parameters. Therefore, there is a need for further investigation that can clearly describe the driving behavior and traffic parameter changes in adverse weather conditions including fog and rain using real traffic and weather data. The results would be helpful to develop more effective ITS strategies to mitigate the negative effects of adverse weather.

3. MATERIALS AND METHODS

3.1. Sample Size and Characteristics:

Main focus of the present study was to understand how an individual driver responds to certain stimuli according to his/her individual characteristics during various adverse driving conditions. The data acquisition of this study was done under two different settings i.e. a) Laboratory Setting and b) Field Setting to achieve overall experience about the driver's response pattern under adverse weather condition in India.

- a) Under laboratory setting different psychophysical tests were conducted under controlled settings the tests were visual acuity test, Glare tolerance test, night vision test. With the driving simulator driving simulation tests were conducted to analyze the crash characteristics and risk taking practices, average reaction time of the driver under adverse weather conditions.
- b) Under field setting with the help of the V-Box driver's characteristic were measured. In which driver's reaction time, facial movements and road assets were measured with the help of three cameras of V-box during the various driving situations. Different driving cycles were also processed during the data acquisition.

3.2 Sample Size and Characteristics:

Twenty-one commercial vehicle drivers pertaining to the age group up to twenty to forty years with minimum two years to maximum fifteen years commercial driving were randomly selected for the present study. All the drivers were male and from same economic status.

As mentioned earlier, present study was conducted in two parts which are as following:

- a) Laboratory Setting and b) Field setting.

Laboratory Study

During laboratory setting the test battery consisting of visual and other Sensorimotor behavioral traits was conducted in Laboratory setting under controlled conditions. In the present study different computerized and semi computerized tools were selected to measure driving

behavior and crash characteristics at simulated adverse driving condition and realistic settings. Before conducting tests driver's individual records or demographic characteristics (e.g. number of accident records, drug or alcohol addiction records, smoking addiction records, wearing spectacles or not, driving experience and mileage covered, type of vehicle) were documented before conducting different psycho physical or skill tests. After providing comfort to the drivers, different vision related tests were conducted with the help of Porto Clinic and Porto Glare equipment's. The details of these equipment are as follows:

Porto Clinic:

It is portable apparatus for testing automotive operators for visual acuity, color blindness, depth perception, horizontal field test & phoria (Pic 1). In the test the driver has to read the Smelled chart letters or similar numbers, followed by the Ishihara color blindness test where the driver has to identify the correct number inside the chart to see the driver's comfort ability no time limits are set for these tests. In this study only visual acuity were measured.

Visual Acuity Test (Both Eyes): The observance of the data analysis has shown that for the both eyes 27% drivers needed retesting and 11% performed poorly.

Visual Acuity Test (Right Eye): For the right eye 29% needed retesting and 16% performed poorly.

Visual Acuity Test (Left Eye): For the left eye 21% needed retesting and 12% have performed poorly.

Glare Test: 28% drivers performed satisfactorily, 5% below average & 3% poor for glare recovery time.

Night Vision Test: In night vision 22% drivers performed satisfactorily, 4% below average and 2% performed poorly.

4. EFFECT OF WEATHER CONDITION ON DIFFERENT VEHICLE OPERATING MODES

The computed percentage of time spent in idling, acceleration and deceleration with travel time and speed data for both the years have been shown below in tables 1 & 2. Percentage of time proportions for representative driving cycle for each weather conditions on the basis of speed variable are shown here in bold letters.

With the development of technology that has been made in traffic and weather data collection and real-time communication area, it is plausible to detect and predict adverse weather case areas in real time. Real-time measurements of traffic parameters and weather can help in warning drivers when the reduced visibility related to fog has fallen below certain acceptable levels or the level of rain has increased to certain unsafe levels. The credibility of detection about change of weather and traffic pattern is essential to ensure drivers' compliance with these warning systems. Moreover, how drivers react to the effect of weather change is crucial to the effectiveness of adverse weather warning systems. This study comprehensively investigated the

relationship between traffic and adverse weather based on field data collected by advanced traffic and weather sensors. Most of previous related researches focused on analysis based on simulated data. The results will be beneficial to understand how different types of adverse weather affect traffic and also how changes in traffic can indicate to traffic management centers that there is a weather problem. In addition, the result is helpful for researchers in the future to develop more accurate and reliable adverse weather warning message or more accurate dynamic advisory message to mitigate the negative effect of adverse weather. The traffic management centers will be able to send warning messages in the future when they detect certain special traffic patterns caused by certain types of adverse weather and it would be beneficial to reduce related congestion or crashes caused by adverse weather. For future works, the results of this research can be further verified and compared with data collected in other districts.

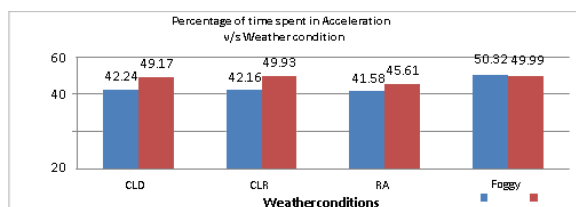
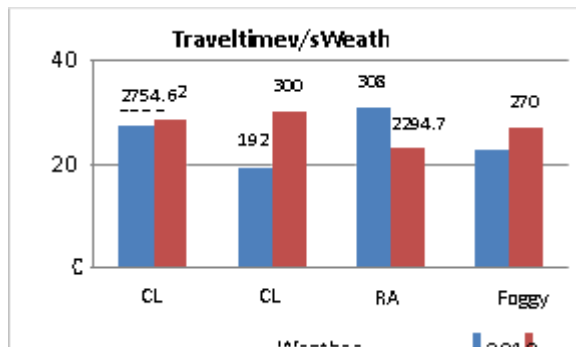
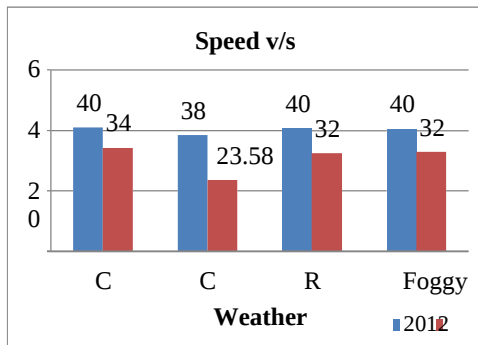


Figure: Percentage of time spent during Acceleration at different

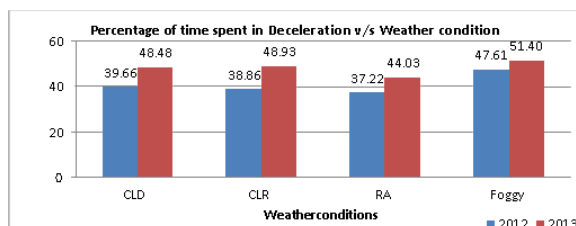


Figure : Percent time spent during Deceleration at different weather

$$V_{cld} = \sum_{i=0}^n \frac{V}{n} \dots \dots \dots (1)$$

$$V_{clr} = \sum_{i=0}^n \frac{V}{n} \dots \dots \dots (2)$$

$$V_{rain} = \sum_{i=0}^n \frac{V}{n} \dots \dots \dots (3)$$

$$V_{fog} = \sum_{i=0}^n \frac{V}{n} \dots \dots \dots (4)$$

V as the average speed in both the directions

5. CONCLUSION

The findings of the present study reported the impact of adverse weather on human psychomotor capacities and behaviour and related speed profile. In the study driver's visual traits and psychomotor behaviour along with their choice of speed, reaction time and lane driving behaviour during adverse weather conditions under simulated and realistic field conditions capabilities of the commercial drivers were evaluated.

The study has following major findings:

- Present study highlights the recorded average speed during adverse weather were 34.1kmph, 47.7kmph and 63.25 kmph while driving at plain area for two, three and multiple lanes respectively
- The recorded average speeds during adverse weather were 48.0 kmph while ascending and 56.6 kmph while descending the flyovers.
- Driver's mean reaction time was recorded while driving at plains as 3.367 seconds while ascending the flyovers as 3.233 seconds and descending the flyovers as 2.70 seconds respectively.
- Recorded Idling time was found more during rainy & cloudy weather conditions.
- Distracted and searching eye-hand movements while driving among all drivers were observed highest during rainy weather followed by cloudy, clear & foggy days.
- Recorded speed and road signals violation of experienced drivers were found higher during simulated traffic as with more speed and irrespective to weather conditions as compared to the other group.
- During laboratory tests only 21% drivers performed very good and above in glare test, 45% performed very

good and above in night vision. 27% drivers needed retesting and 11% have performed have poor for visual acuity test (both eyes).

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Based on these findings this has been recommended that frequency and severity of accident like situations and other related incidents can be reduced by providing drivers with enough information about the roadway and traffic conditions as well as through better traffic management during adverse weather conditions. Researches on the area of developing advanced motorist warning systems will be beneficial for better understanding about adverse weather conditions. This information is particularly can be deployed by advance ITS technologies. Based on the findings of this study it is emphasized that it is worthwhile to carry out special screening and training of the commercial vehicle drivers regarding use of GPS and another informatics.

Much of the research work pertaining to weather impact is obtained from studies outside India so it is also recommended that further researches in this area should be conducted to expand the limited knowledge about the impacts of weather on traffic flow on urban and non-urban roads in India.

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