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# Analysis of Driver Behaviour and Crash Characteristics during Adverse Weather Conditions

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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 behaviour 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 behaviour, 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 behaviour and crash characteristics during Adverse Weather Conditions.

**Objective**: The main objective of this paper is to study the visual traits and psychomotor behaviour of the drivers along with their choice of speed, reaction time and driving behaviour during adverse weather under simulated and realistic environment conditions.

**Methodology:**
In the study field observations related to driver's speed variations have been created to understand how individual driver responds to certain stimuli, and focused was on driver's individual reactions during various driving conditions. There was increasing focus on the behavioural individual characteristics of the drivers. During the data collection, primary factors which were measured through different psychophysical tests e.g. visual fatigue test, visual acuity test, driving simulation tests to analyze the crash characteristics and risk taking practices, reaction time under adverse weather conditions. Driver's characteristic have been measured with the help of the V -Box with three cameras to measure driver's reaction time, eye movements along with road assets during the various driving situations. Different driving cycles were also obtained during the data acquisition.

**The findings:**
The findings highlight drivers' state and pattern of crashes during rain and foggy conditions during simulated adverse weather conditions. Different driving cycles were analyzed after the data processing.

Keywords: Weather; Driver behaviour; Driving Cycle; Road Conditions; Driving Speed

## 1. Introduction

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 behaviour 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 temperat

( - at adverse weather. One single additional day with a mean to a - 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.

R.R. 2000). Changes in driver behaviour have been noted in the literature e.g. changes of speed and following distance during times of rain (Edwards, 1998; Hogema, 1996). In response to a perceived increase in risk, traffic adapts lower speeds and increased following distances.

However, this compensating for the increased risk is insufficient and higher collision rates are still evident during times of rain (Edwards, 2000; Andrey & Yagar, 1993).The driving task involves performing a number of activities e.g. guiding the vehicle within the road,detecting other vehicles , non motorized users , judging their speed, position, their possible behaviour and reacting accordingly . Collins, D.J., Neale, V.L., & Dingus, T.A. (1999) studied several factors that can affect the visibility and conspicuity of road signs. Khattak, A.J., Kantor, P., & Council, F.M. (1998) analyzed the impacts of adverse weather interactions with driver and roadway characteristics on occurrence and injury severity of selected crash types. Khattak, A.J., Koppelman, F.S., & Schofer, J.L. (1993) developed a conceptual framework to assess the impact of adverse weather on travel behaviour. The framework was used to evaluate the effects of weather and traffic information, individual attributes, and situ
ational factors on drivers' willingness to change normal travel patterns. Similarly, de Vos 1992
presented a traffic simulation model based on literature sources and model analysis. This model incorporates the influences of reduced friction and visibility. Creating sudden reduction in visibility during simulation exercise showed that road capacity and traffic safety behaviour both decreased.

Conditions such as wet pavement, impaired visibility, heavy precipitation, frozen precipitation, flooding, high winds, and extremes of temperature can act in various ways to increase risks to drivers and their vehicles, as well as the infrastructure. The vulnerability of the national highway system, drivers to weather conditions and climate change arises from potential exposure to both unforeseen and anticipated changes in weather or climate patterns and from potential increases in the intensity and frequency of extreme weather events. A study done by AshishVerma et al 2011 highlights that driver behaviour through better driver education, driver training and licensing procedures along with good on-road enforcement can be improved. The gamut of these researches helped to create the background of the present study under different Indian weather conditions.

## 2. Objective

The main objective of this paper is to study the visual traits and psychomotor behaviour of the drivers along with their choice of speed, reaction time and lane driving behaviour during rainy season under simulated and realistic environment conditions.

## 3. Methodology and Findings of the Present Study

### *3.1. Sample Size and Characteristics:*

Twenty one commercial vehicle drivers pertaining to the age group up to thirty five 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 having same economic status.Present study was conducted in two parts which are as following:

### *3.2. Laboratory Setting:*

The observation and analysis of driver's visual acuity and other behaviour in Laboratory setting: In these parts individual records of demographic characteristics were maintained before conducting different psycho physical tests and

to analyze the driver's characteristics e.g. number of crashe
l acuity, adaptation for
glare etc. The Zen car driving simulator was used to obtain behavioural data from the drivers related to the crashing and different driving related skills.

### *3.3. Field Setting:*

The field surveys were conducted for 21 days. During the survey the observation and analysis of driver's R.T. and other behavioural aspects were measured with the help of video footage taken during in field survey. In field setting during rainy season and winter season driver behavioural data will be obtained. In continuation of this

reaction time, behavioural movements and road assests during the field study. On the basis of various collected parameters, factor analysis of several at-risk driving behaviours were done to share common problems identified due to adverse weather conditions.

*3.4. Tools*

In the present study different computerized and semi computerized tools were selected to measure driving behaviour and crash characteristics at simulated adverse driving condition and realistic settings. The details of *laboratory equipments* are as follows:

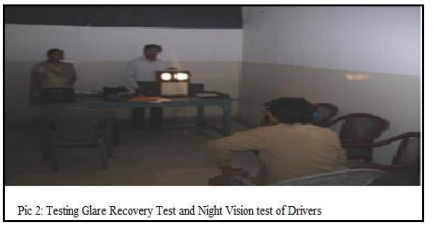
***3.4.1.*** *Porto Clinic:*

It is portable apparatus for testing automotive operators for visual acuity, colour blindness, depth perception, horizontal field test & phoria (Pic 1). In the test the driver has to read the Snellen chart letters or similar numbers, followed by the Ishihara colour blindness test where the driver has to identify the correct number inside the chart In this study only visual acuity were measured.

*3.4. 2. Porto Glare:*

This apparatus is used for testing tolerance capacity for oncoming glare from the vehicle headlights i.e. glare test. It is also used for measuring vision capacity at night time i.e. night vision test (Pic 2).

Pic 1: Visual Screener :Porto Clinic and Porto Glare Tests



Pic 2: Testing Glare Recovery Test and Night Vision test of Drivers

*3.4.3. Driving Simulator:*


Picture3: Driving Simulator at CSIR-CRRI

The simulator was used to measure driving skills and crash behaviour. The drivers were divided according to the driving experience i.e. upto two year, two to five years and more than five years. .Total three sessions for each drivers 30 minutes each were conducted for evaluating driver errors during clear weather then rainy and foggy conditions simultaneously. The position of driver performances were continuously monitored and evaluated.

*Findings of Laboratory Study:*

a) *Visual Acuity Test (Both Eyes):*The observance of the data analysis has shown that for the both eyes 27% drivers needed retesting and 11% performedpoorly.
b) *Visual Acuity Test (Right Eye):*For the right eye 29% needed retesting and 16% performed poorly.
c) *Visual Acuity Test (Left Eye):*For the left eye 21% needed retesting and 12% have performed poorly.
d) *Findings of Night Vision and Glare Test:*28% drivers performed satisfactory, 5% below average &3% poor for glare recovery time. In night vision 22% drivers performedsatisfactory, 4% below average and 2% performed poorly.

*Findings of Simulation study: The data of the study revealed that following salient points (table-1)*

a) *Overall crash frequency***:**Overall crash frequency among drivers up to 2years driving experience was having13.64% in clear, 15.91% in rainy and 14.29% in the foggy weather conditions.
b) *Driving Pattern:*During foggy weather high experienced driver
c) *Speeding Behaviour:* Experienced drivers drove the simulated vehicle at higher speed.
d) *Improper merging* in the roundabout was found highest among drivers experienced up to two years.
e) *The speed limit violation and violation of road signals* were recorded maximum among experienced drivers.

Table1: PercentageErrors Committed By the Commercial Drivers in Simulated Traffic Environment

| Percent Errors committed | Weather | Driving Experience Upto 2 Years | 2 to 5 Years | 5 Years & above |
|---|---|---|---|---|
| Crashing (Av. Frequency) | Clear Weather | 13.64 | 10.81 | 0.00 |
| | Rainy | 15.91 | 13.51 | 5.50 |
| | Foggy | 14.29 | 9.51 | 9.43 |
| Speeding (Km/hr.) | Clear Weather | 23.08 | 22.35 | 40.00 |
| | Rainy | 10.00 | 17.35 | 25.00 |
| | Foggy | 7.59 | 17.99 | 12.50 |
| Improper Merging (Av. Frequency) | Clear Weather | 33.33 | 20.00 | 0.00 |
| | Rainy | 33.33 | 40.00 | 12.50 |
| | Foggy | 35.71 | 18.75 | 14.89 |
| Signal Violations ( Av. Frequency) | Clear Weather | 18.75 | 17.95 | 20.00 |
| | Rainy | 31.25 | 20.51 | 40.00 |
| | Foggy | 16.67 | 15.38 | 34.78 |

*3.5. Field Study*

*3.5.1 Process of Instrumentation with V Box:*

In this part the driver's characteristic has been measured with the V-Box. During the field work V-Box was set up with three cameras on the Tata Safari vehicle to measure driver's behaviour (e.g. driver's reaction time, behavioural movements and road assets) during the acquisition. One camera was set to monitor eye movements and other facial movements of the driver. The other one was located on the centre -view mirror to collect relevant data from the road (e.g., traffic density, signs and markers, and headway distance). Third camera was providing a

view of driver's foot movements. These data were recorded and stored automatically during whole driving period.

*3.5.2. Route Selection:* Theroute was selected from Central Road Research Institute (CSIR-CRRI), NH-2 to the Institute of Driver Training and Research (IDTR)Loni border (table-2) for its manifold variation (e.g. road width, median width, accessibility) of road infrastructure. The road width and the median width were measured with the measuring wheel. Weather conditions were also recorded.

Table 2-: Road Characteristics of the Selected Stretch

| *Corridor* | *W. (m)* | *M.W. (m)* | *Road type* | *Road side trees* | *Road Condition* | *Road Utilities* | *Road marking* | *Road signs* | *W.L.(y /n )* |
|---|---|---|---|---|---|---|---|---|---|
| CRRI to Maharani Bagh | 9.69 | 2.75 | BT | Yes | Good | Bank | Yes | Yes | Yes |
| Maharani Bagh to Akshardham | 13.7 | 3.50 | BT | Yes | Fair | Shops/Temple | Yes | Yes | Yes |
| Akshardham to Ghazipur | 9.09 | 2.75 | BT | Yes | Poor | Temple | Yes | Yes | NO |
| Ghazipur to UP border via Seemapuri | 13.7 | 3.50 | BT | No | Poor | Petrol Pump | Yes | Yes | Yes |
| Seemapuri to IDTR via Loni Border | 9.09 | 2.75 | BT | Yes | Fair | Shops | Yes | No | Yes |

* W= Width; M.W. Median Width; W.L. = Water Logging Yes/No; *Institute of Driver Training and Research, Loni ( Maruti Suzuki); BT=Bituminous

*3.5.3. Field Observations:*

Many hazards of road side were observed during the field survey, some of them are as following:

a) Frequent Openings/Access without proper treatment
b) Absence of Hazard Marker on Road
c) Poor placement /Maintenance of Road Signage & absence of Street Lighting.
d) Unauthorized Opening at Median
e) Improper Placement of Reflectors
f) Loose Debris on Road Side

*3.5.4. Effect of Adverse Weather Conditions on Vehicle Speed*

To study the effect of weather condition on speed of the vehicle, data collected from 21 samples were taken at different weather conditions on same road section. After analysis the flyover speed we get as Standard deviation, mean of speed & mean square values for Speed at flyover for ascending 0.808, 50.467 & 0.980 and for descending it is 1.097,54.033 & 1.805. Result shows that average speed values on 2 lanes, 3 lanes and 4 lanes were 34.1kmph, 47.7kmph and 63.25 km/hr respectively. 2 lane road shows significant variation in speed due to changes in weather with standard deviation of 2.5 km/hr whereas as for 3 lanes and 4 lane roads showed no significant variation in speed due to changes in weather condition. Average speed on plains at different lanes is

48.35km/hr with standard deviation of 4.987. Overall, the average speed was observed increasing with the increase in number of lanes (table-3).ANOVA analysis confirmed the level of significance .05 levels (table-4).

Table3- Average Speed (Km/hr): CRRI to IDTR (Up) and CRRI (Down)

| Weather Condition | 2 Lane | | 3 Lane | | 4 Lane | |
|---|---|---|---|---|---|---|
| | Up | Down | Up | Down | Up | Down |
| Clear | 32.58 | 38.5 | 42.09 | 57.34 | 70 | 57.705 |
| Rainy | 33.73 | 36.12 | 50.83 | 53.75 | 56.73 | 65.86 |
| Cloudy | 36.15 | 42.825 | 50.19 | 52.75 | 63.02 | 63.7 |
| Foggy | 25.1 | 31.9 | 38.7 | 26.4 | 30.5 | 31.5 |

Table4- Analysis Of Variance of Average Speed (Km/hr): Up: From CRRI to IDTR and Back

| Source of Variation | df | Ss | Ms | F | Significance |
|---|---|---|---|---|---|
| Among mean | 5 | 21606 | 4321.28 | 2.16 | 0.05 |
| Within Conditions | 12 | 23994 | 1999.51 | | |
| Total | 17 | | | | |

*F (5, 12) =2.16, p<.05

*3.5.5. Impact of Adverse Weather Conditions on Human Behaviour and Responses*

*3.5.5.1. Searching and other Non Driving movements for Inside and outside objects:*

Average searching movements for inside objects while driving is a form of distraction and leads to accidents .In the present study search movements were observed highest in rainy days followed by cloudy, clear days subsequently. This may be due to low visibility. Minimum search movements were observed in foggy days as the drivers were more cautious (table-5).A perusal oftable-6confirmed that there was significant difference of the time factor among different human responses while driving during adverse weather conditions.

Table5: Impact of Weather Conditions on Human Behaviour

| S.No. | Human-Factors | Clear day | Cloudy Day | Rainy Day | Foggy Day |
|---|---|---|---|---|---|
| 1 | Searching and other Non Driving movements for Inside objects (Secs.) | 92 | 104 | 147.6 | 68.8 |
| 2 | Searching and other Non Driving movements for outside (Secs.) | 22.5 | 44.25 | 24.62 | 26.3 |
| 3 | Yawning Time (Secs.) | 50 | 30 | 10.9 | 5.25 |
| 4 | Talking Time mobile phone (Secs.) | 210 | 60 | 120 | 5.5 |
| 5 | Talking To Co-Passengers (Secs.) | 270 | 330 | 504 | 90 |
| 6 | Use of Seat belt while Driving (Secs.) | 270 | 138 | 120 | 48 |

Table-6: ANOVA (Analysis of Variance) for Impact of Weather Conditions on Human Behaviour

| Source of Variation | df | Ss | Ms | F |
|---|---|---|---|---|
| Among Mean | 3 | 482344.03 | 160781.34 | 17.34* |
| Within Conditions | 20 | 185457.94 | 9272.9 | |
| | 23 | 667801.97 | | |

*F (3, 20) =17.34, p<.01

*3.5.6. Reaction Time*

The input data for reaction time was taken with the help of video V-box .The V-Box was having three cameras, one was fitted on the drivers face,the second was focused on the driver's feet to observe brake, accelerator and clutch movements. The time between releasing the accelerator and pressing the brake was calculated to find the R.T. However, total stopping distance (R.T. +Brake engagement distance +Physical force distance) could not be calculated as the third camera was only focusing outside traffic view. The findings of the data, mean values of reaction time for plains and ascending & descending were recorded as 3.367 seconds, 3.233 seconds and 2.70 seconds while standard deviation are as 0.451seconds, for 0.289 seconds and 0.265 seconds with $R^2$value of 0.996. Mean square value of 0.405 and sum of squares of 0.002. Significance difference was not found among means, within the operated conditions. Still slight variations among the values of reaction time have been noted. The drivers scoring "normal" in visual acuity test were having minimum reaction time (2.6 secs average) as compared to the drivers requiring retest (2.8 secs.) and failed drivers (3.0 secs.). These results highlight that

drivers with vision problems react slower as compared to normal vision drivers.

Table-7: Table Showing Average Driver Reaction at different weather conditions

| | Reaction Time (Secs.) | | |
|---|---|---|---|
| Weather Conditions | 2 Lane | 3 Lane | 4 Lane |
| Clear | 2.6 | 2 | 3.2 |
| Cloudy day | 3.9 | 3.1 | 2.9 |
| Rainy Day | 4.6 | 3.4 | 3 |
| Foggy day | 3.2 | 2.2 | 1.8 |

Table-8: Table Showing Average Driver Reaction at different Visual Acuity

| Grade | Avg.Reaction Time(Secs.) |
|---|---|
| Unsatisfactory/poor | 3.0 |
| Retest | 2.8 |
| Normal | 2.6 |

*3.5.7. Effect of Weather Conditions on Vehicle Idling Time*

From the data observed it was found that idling was less during rainy season as compared to clear weather. Average Idling time for clear day was 7.9minutes and for Cloudy / Rainy day it was recorded as 10.4minutes. St. Deviation is 1.443 and mean is 9.567minutes with regression value of 0.75. Overall data showed that traffic flow reduces during rainy season that cause more idling.

*3.5.8. Effect of Adverse Weather on Driving Pattern*

It is clearly seen that average driving time differ by 120 seconds in rainy season on the same track i.e. 4 % extra time in rainy season.

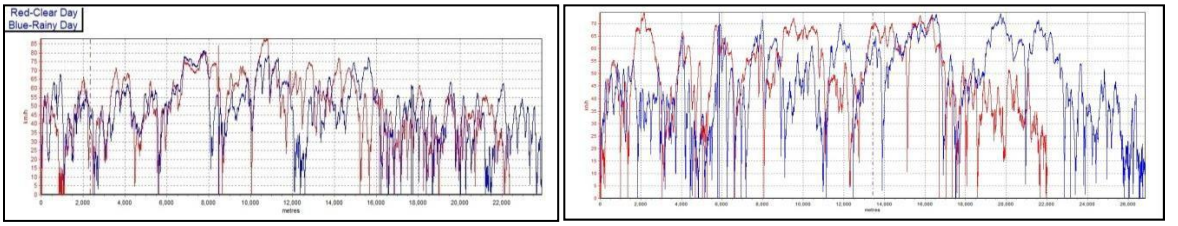



Figure1&2: Up-Down driving cycle pattern along corridor from CRRI to IDTR Loni Border & Back

*3.5.9. Differences between Laboratory and Field Settings and How These Differences Influence Driver's Choice*

The findings of the present study highlights that in the simulated traffic enviornment , though the drivers slowed down during adverse weather e.g. rainy and foogy weather ,but overall average speed of the vehicle did not affected as during simulation excersises the simulator maximum speed limit was set upto 40km/hr,hence the congestion of traffic could not be created hence overall crash rate increases.In the realistic setting the overall observed speed wasrecorded slower during adverse weather as compred to the clear weather so chances of collsion was negligible in bumper to bumper traffic conditions.Level of discomfort and aggressive postures among the drivers increased during the adverse weather especially rainy season.

**4.Conclusion**

Recorded average speed were recorded as 34.1kmph, 47.7kmph and 63.25 kmph respectively on plain and from
48.0 kmph while ascending and 56.6 kmph while descending flyover.Idling time was recorded more during rainy & cloudy weather conditions.Mean values of reaction time for plains, while ascending & descending flyovers were recorded 3.367 seconds, 3.233 seconds and 2.70 seconds respectively.Searching

movements were observed highest during rainy days followed by cloudy, clear & foggy days.Experienced drivers driving were driving at higher speed with more speed and road signals violation during simulated traffic 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).

## 5. Limitationsand Future Perspective of the Study

The data of the paper has been taken from an in-house ongoingCSIR-CRRI research project. In Delhi, India the peak of all the seasons are not more than fifteen days. To administer the whole test on a driver minimum four hours are required so the sample size was small. Duration of V-Box setting inside the vehicle was also varying time consuming and driving at adverse weather especially at adverse weather was very risky as some inexperienced and risky drivers are always on the road without much traffic enforcement. This data pertains to the last year seasonal variations, this year data acquisition is in progress. The authors tried to achieve the maximum inputs form the acquired data.

## 6.The Application of Outcomes

As a future perspective of this study the sensitivity analysis may be conducted by considering different locations with large sample population including private drivers vs. Commercial drivers of medium motor vehicle and large motor vehicle, truck drivers may also be included.The findings related to the visual limitations of the present study were submitted to the Director of Road Transport, New-Delhi. As an outcome of our research findings there has been an urgent demand of testing and screening among the drivers.

## 7. Copyright



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## References:

Andrey, J., Mills B.,&Vandermolen, J. (2001). Weather Information and Road Safety, (Paper Series No. 15), Institute for CatastrophicLoss Reduction, Canada.

Andrey, J., Mills B, Leahy, M.&Suggett, J.(2003).Weather as a Chronic Hazard for Road Transportation in Canadian Cities.*Natural Hazards*,28,319-343.

Andrey, J. &Yagar, S. (1993). A Temporal Analysis of Rain-Related Crash Risk.*Accident Analysis and Prevention*, Vol. 25, nr. 4, 465 472. Verma, A.,Velumurugan,S.,Chakrabarty, N.&Srinivas,S.(2011 ).Recommendations for driver licensing and traffic law enforcement in India aiming to improve Road safety.*Jr. of Current Science*, Vol. 100, No. 9.

Collins, D.J., Neale, V.L., &Dingus, T.A. (1999).Driver Performance when Using an In-Vehicle Signing Information System Considering Adverse Weather, Visibility Condition, and Age.In *Proceedings of the 9th ITS America Meeting*.Washington,DC : ITSA.

De U.S., Dube R. K. and PrakasaRaoG.S.(2005).ExtremeWeather Events over India in the last 100 years. *J. Ind. Geophys*. Union, Vol.9, No.3,173-187.

De Vos, A.P. (1992). Driver Behaviour under Bad Weather. In *Proceedings of the 25th International Symposium on Automotive Technology and Automation: Dedicated Conference on Road Transport Informatics/Intelligent Vehicle Highway Systems*(pp. 427 434).

De Vos, A.P. (1994). A Comprehensive Approach of Traffic Safety in Adverse Weather and Road Conditions. In *Towards an Intelligent Transport System, Proceedings of the World Congress on Applications of Transport Telematics and Intelligent Vehicle-Highway Systems, 3*, 1081 1088.

Debus, G., Heller, D., Wille, M., Dütschke, E., Normann, M., Placke, L., Wallentowitz, H., Neunzig, D. &Benmimoun, A. (2005). Risikoanalyse von

MassenunfällenbeiNebel.Berichte der BundesanstaltfürStraßenwesen: Mensch und Sicherheit, Heft M 169. BundesanstaltfürStraßenwesenBASt, BergischGladbach.

Edwards, J.B. (1998). The Relationship between Road Accident Severity and Recorded Weather.*Journal of Safety Research*, Vol. 29, nr. 4, 249-262.

Highway Capacity Manual (2000).Capacity-Reducing Occurrences, Driver Response to Rainfall on an Urban Expressway&Impact of Weather on Urban Freeway Traffic Flow Characteristics and Facility Capacity,Empirical Studies on Traffic Flow in Inclement Weather: Summary Report.

Highway Capacity Manual (2000).Temporary Losses of Highway Capacity and Impacts on Performance, An Investigation into the Impact of Rainfall on Freeway Traffic Flowand Analysis of Weather Impacts on Traffic Flow in Metropolitan Washington DC .

Hogema, J.H. (1996)." Effects of rain on daily traffic volume and on driving behaviour .A study as part of the Project Road and Weather Conditions.*Rapport TNO-TM 1996-B019*. TNO Human Factors Research Institute TM, Soesterberg. "

Kelkar, R.R.(2000 The National Weather Service in India, 125 years,'*WMO Bulletin*, 49, 4, 375-382. Khattak, A.J., Kantor, P., *Proceedings of the 77th Annual Meeting of the Transportation Research Board*. Washington, DC: Transportation Research Board(Paper No. 981132).

Khattak, A.J.,Koppelman, F.S.,&Schofer, Information and Implications for Information Systems.*Proceedings of the 72nd annual meeting of the Transportation Research Board*. Washington, DC: Transportation Research Board.

Rowland, B.D., Davey, J.D., Freeman, J.E.&Wishart, D.L., (2007).Road Transport Sensitiveness to Weather and Climate Change in Australia, *Proceedings of the 30th Australasian Transport Research Forum*, Melbourne, Australia.