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A Review on Influence of Fog on Road Crash

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Abstract— **Adverse weather and road traffic crashes are the foremost causes of motorized vehicle fatalities. The degree of severity may be influenced by a number of factors. Various mechanisms were tested with different conditions and speed response, to understand the reaction of drivers in changing fog levels. New algorithms have been proposed in recent studies for rating visibility enhancement techniques, on the basis of summation of various types of fog generated on artificial and camera images. The main concern should be the development of effective detection of fog and warning system, with respect to speed and headway. Further research analysis is necessary to quantify the influences of deicing materials, particularly in relation with frequency and application rate, on transport safety. A state-of-the-art critique of study on relationship amidst fog and highway safety is provided in this paper. Reduction in the count of fatalities is expected in future on account of development of Advanced Driving Assistance Systems (ADAS).**

Keywords— Highway; Fog; Road crash; Safety; Visibility.

I. INTRODUCTION

Accidents are termed as unwanted occurrences which lead to injuries, loss of production, fatalities, or damage to property and possessions. Road accidents are undoubtedly the most prevalent and, in general, the reason behind most of the damage. Road accidents have been and will continue to be one of the greatest health hazards. There is an enormous rise in road crashes due to over speeding, low visibility due to dense fog, road planning and construction, under age driving, drunk driving, lack of public awareness, inefficient authorities and need for enforcement of existing laws to undertake the menace of discourtesy to rules and laws [5].Weather has wide and significant effect on the roadway environment. The interconnection amidst road accidents and weather is nevertheless smooth and unobvious one. Heterogeneous roadway activities, like roadway maintenance and construction, shipping, motion, and police operations, are straightforwardly affected by inclement weather. Weather-related accidents lead to ample costs in terms of fatal injuries and damage to property [6]. The formulation of the connection between weather and crashes is vital to pinpoint the variables devoting to these types of crashes and the employment of various remedies for road weather safety schemes. It has been high time since it was figured out that road accidents are immediate results of the combined effects of behavioural, technological, and environmental factors [7]. Accidents in which minimum one person is incurably injured and expires within 30 days, as a result of that accident, is defined as a fatal accident. An accident is termed as serious when no one is demised but minimum one person is gravely injured, for instance as in fractures, severe cuts and lacerations, internal injuries, concussion, and severe general shock [6]. The one in which no one is deadly or seriously injured but minimum one person is mildly injured, from injuries such as sprains, bruises, and cuts found not to be severe, is termed as minor accident.

Conventional statistical approaches along with data mining techniques have been used in research practices. The mostly used method for examining road accident data in present research is data mining. Trend analysis is another important research area in road accident domain. Trend analysis comes out to be another significant approach in identifying the increment or decrement in accidents rate in various regions. Sachin [1] proposed a data mining clustering approach to interpret hourly road crash data using Cophenetic correlation coefficient, which makes cluster to count the hourly road accidents. Ghazan [2] used spatial statistical methods to determine significant crash patterns occurring in harsh weather conditions, using the Getis-Ord $Gi^*(d)$ statistic. The outcomes of the analysis of injury severity for Fog and Smog (FS) related crashes was presented by Abdel in [3] on a multilevel ordered logistic model. To examine the effect of harsh weather on fatal crashes in terms of self-governing risk factor, the Mantel-Haenszel odds ratios was computed by Shubhayu in [4] for familiar risk elements (e.g., poor driving skills, alcohol and drug intake, poor light conditions, highway driving) to be correlated along with harsh weather. The familiar risk factors were interpreted for fatal crashes and correlated with harsh weather, thus contradicting the possible association between harsh weather and fatal crashes.

Safety threat is created as vehicle handling becomes troublesome due to low visibility and reduction in road friction, as a result of weather conditions [2]. Weather conditions like snow, mist, rain, fog, hail, etc. makes it difficult for drivers to run their vehicles cautiously, severely rise travel times, and significantly lessen roadway capacity. Society, especially the transportation sector, has been adversely affected, both in terms of cost and setbacks, due to fog [5]. Fog is itself self- explanatory, but generally recorded when its occurrence hinders visibility noticeably. Fog formation is linked to the natural processes as radiative, microphysical, thermo-dynamic and aerosol processes [7]. Occurrence of fog is witnessed when air chills down below its dew point. The difference between temperature and dew point is mostly less than 2.5°C or 4.5°F. Across India, fog is categorized into two types as:

a) Radiation Fog
b) Advection Fog

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Radiation fog (sometimes called Ground fog) is formed after sunset (evening time) when there is change of seasons from summer to fall and winter [7]. Advection Fog is wind directed fog formation. It is formed by the passage of warm humid air over a cool surface with the aid of wind. The term "advection" scientifically denotes "the movement of fluid". Fog is measured with respect to visibility distance. In Meteorology, Visibility is explained as a measure of the distance at which an object or light can be surely anticipated [8]. The visibility scale which depicts the link between fog and visibility is shown in Fig. 1.

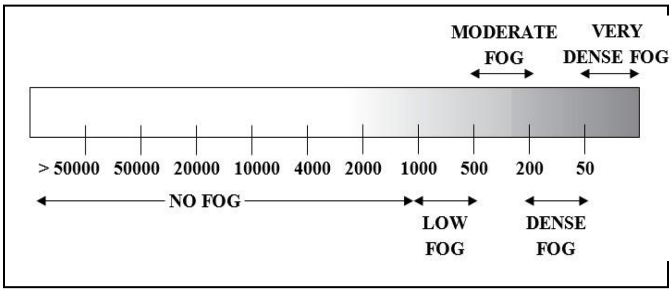

Fig. 1. Visibility scale (in metres)

Fog data is represented in form of visibility codes as in Table 1.

TABLE I. VISIBILITY CODES

S. No.	Visibility (in metres)	
	Visibility Codes	*Visibility*
1.	90	0-50
2.	91	50-200
3.	92	200-500
4.	93	500-1000
5.	94	1000-2000
6.	95	2000-4000
7.	96	4000-10000
8.	97	10000-20000
9.	98	20000-50000
10.	99	>50000

Slowing down of drivers is not seen considerably until the visibility distance is curtailed due to fog, nevertheless lane keeping potentiality is sustained over utmost visibility range [9]. Research conventions are progressing not only on fog detection, but also on visibility enhancement to minimize the count of road crashes.

II. BACKGROUND

Fog is regarded as an alarming weather condition for driving, owing to the fact that as the density of fog enhances, the visibility distance drops down exponentially. The detection and forecasting of fog for a short span of time poses particular challenges on the forecast community. As a matter of fact, it is difficult to outline fog areas of bounded extent within the coarse surface grid where stations may be 100 km or more distant. The problem turns out to be more strenuous at night owing to lesser operating stations, thus increasing the probability of fog.

A. *Fog Detection*

Previous year studies demonstrates image based fog detection systems in which detection of fog and its removal from the images was accomplished. Infrequent use of systems with on-board camera has been exhibited previously. Pavlic [10] developed a fog detection method using image descriptors with Gabor Filters at varying scales, frequencies and directions. Another technique [11] in which integration of radar with in vehicle was developed. The principle behind this is Koschmieder's law in which fog density has been categorised in accordance to visibility factor of beyond vehicle. Stereo vision based fog detection method [12], executing object detection hinged on V-disparity method wherein depth mapping of surroundings of vehicle was done. Method for computation of visibility distance during fog conditions was introduced. Fog density based fog detection technique [13], computing the vanishing point and taking road lines as reference was executed. Contrast restoration based fog detection was done by Trael [8], including planar assumption along with comparison and presentation of no-black pixel constrains. Implementation of fog detection and warning system [14] based on cluster of sensors, able to inform the drivers regarding visibility and speed.

The Hunt-Ellrod Channel Differencing technique is suitable for conditions of radiation fog, and serves as an effective tool for fog detection. The activation of fog detectors and police-activated matrix signs in [6] helps in giving fog warnings. To lessen the number of accidents or limiting their impact, Advanced Driving Assistance Systems (ADAS) are installed in vehicles, which are capable of fog detection, estimation of visibility distance and maximum vehicle for travelling, using Random Sample Consensus (RANSAC) method [15]. For accurate estimation of vehicle trajectories comprising combination of video images and range finder (telemeter) measurements was proposed in [9].

B. *Driver's Behaviour*

Decrease in visibility due to fog as compared to clear weather, makes it troublesome for the drivers to withdraw the visual information (such as road section alignment, roadway layout), needed to anticipate the upcoming events as the driver cannot visualise as far ahead in foggy weather as he could in clear weather. Perception becomes difficult as the fog becomes more dense [16]. The consequences of weather and its forecast on driver conduct have been studied in [17], and suggestions have been given about informing drivers regarding specific localised weather conditions instead of regional forecasts. Underestimation of driving speed or speeding the vehicle than the safer driving limits is generally done by drivers. The influence on drivers behaviour in accordance to speed and headway due to fog detection and warning system has been estimated in [18], by means of visibility sensors notifying an advisory speed by automatically triggering a variable message sign during risky fog conditions.

Simulator study for specific road type was carried out in order to verify the degree of similarity between the behaviour of drivers on road during foggy conditions and ensuring if it could justify fog dependent crashes on basis of road type [19]. During simulated driving, the behaviour of the driver is partially a realistic one. The layout of roadway, road section arrangement, and presence or absence of rod markings has a strong impact on driver's conduct thus leading to accidents

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due to misinterpretation of the road surroundings/environment [20], [21]. A dynamic system developed from discrete time range having predefined local rules named as Cellular Alteration (CA) model, can be used for simulating driver's [22]. Reaction of drivers to fluctuation in fog levels has been demonstrated in studies employing simulator-based methods, wherein simulation of fog is done in terms of range dependent contrast minimization when subjects drove at appropriate speeds according to their feel (or at their own pace) in [23]. Unequal affects have been witnessed on drivers such that few of them execute the adaptations linked with safety in comparison to others, like lowering speed, thereby allowing increase in reaction time of drivers to hazards [18]. Speed is an essential aspect during driving and its alteration reduces the possibility of collision [24]. Previous work proves a connection between speed and crash probability in addition to severity, and the implementation of warning systems assist drivers to keep a check on their speed, thereby reducing the crash statistics [18]. One of the strongest collision predictor is inexperience. In youths, it has been witnessed that perception errors like improper decision-making, failure in identifying threats, poor concentration while driving and use of improper visual search tactics are dominating as compared to performance errors. Simulator-based measure was used to study the effect of driving experience and capability on behavioural damage to fog, average velocity, speed variations, steering variability, hazard response time, and collision rate in [24].

The prominent root cause behind the increasing road accidents amongst youths is the tremendous usage of cell phones while driving. Demand for design of sensor-based cloud application for recognizing negligence of driving rules by the drivers to let go of the overhead of the present traffic supervising bodies has been put forward in [25]. Sensor network based cloud application or Internet of Things (IOT) is quite unacceptable [26]. For dealing with the bottleneck situations of cloud computing, fog computing has been introduced in [25], wherein the computing utilities dwells at the edge of the network. To enhance the conventional cloud-based DSS model, Fog-based DSS model was presented for better location alertness, small latency and aiding in mobility.

C. Visibility Enhancement

During night time accident severity escalates by a factor of 1.7 as compared to daytime. A major reason behind vehicle accident is reduction in visibility because of harsh weather conditions as fog. To elude the problem during bad weather, automatic methods for visibility enhancement have been proposed. On the basis of techniques, visibility enhancement methods can be sorted into various classes: physics-based, heuristics and nonphysics-based solutions [27]. Whereas on the basis of sensors used, categorization has been done as: visible spectrum sensors, infrared sensors, millimetre-wave (MMW) sensors, and laser radar (LADAR) sensors. Methods employed on visible wavelengths based on the type of input, especially those dealing with foggy/blurred images were computed through physics-based solutions, which can further be categorized as: the one using polarizing filters [28],[29], and another utilising images captured from various fog densities [30],[31]. Both strategies require multiple images captured altogether from the exact same viewpoint. All the aforementioned methods are based on the Lambert- Beer reflection model. Even though the results are reasonably good, the requirements makes these inappropriate and impractical, especially with respect to real time applications, for example vehicle systems. A model that required a single image captured using ordinary digital cameras, without any supplementary hardware, using colour and intensity details, was developed in [32]. Visibility is improved after figuring the skylight colour and the airlight values.

Designing of efficient visibility enhancement algorithms for road images can help in the betterment of numerous camera-based Advanced Driver Assistance Systems (ADAS). In [33], it has been shown for numerous detection algorithm types, that pre-processing before visibility enhancement enables the improvement of detection efficiency during fog. Two types of ADAS have been taken into consideration in [34]. Firstly, a Fog Vision Enhancement System (FVES) based ADAS which possibly exhibits the images after visibility improvement from the frontal camera. Secondly, an approach for possibly conveying adequate warning by combining pre-processing of visibility enhancement along with the tracking of stationary cars, mobile cars, pedestrians, two wheelers, etc. Owing to the physical sciences of fog, evaluation of scene luminance exclusive of fog together with the scene depth-map contributes to visibility restoration [34]. The major issue behind contrast improvement from a single foggy picture is its being an ill-posed problem. For handling the visibility restoration issues, the overall concept was by approximation of the scene depth-map, as further proposed in [30] by deriving a rough luminance map excluding fog, in [35] by presenting various elementary parametric models concerned with road view ahead of a vehicle, and in [32] on the basis of utilization of color images including pixels possessing hue distinct from gray. Additional algorithms for visibility enhancement have been proposed in [36],[37],[38], possessing the drawback of not being concerned with road images and hence intensifying the gray part of the road image. With respect to the planar surfaces, visibility enhancement was first proposed in [39], but failed to enhance the visibility of the objects lying outside the road plane with accuracy, leading to further proposal in [33], still facing the disadvantage of dependency on the assumption of homogeneous fog. Another approach for the rating of visibility improvement algorithms was evaluated in [34] with other state-of-the-art algorithms, relying on the summation of various types of fog generated on artificial and camera images, therefore producing more suitable results for homogeneous fog and aids in dealing with the heterogeneous fog in a better way.

D. Vehicular Behaviour

A study [40] revealed that: (1) occurrence of fog-related crashes is more in rural areas as compared to urban areas and (2) a greater part of fog-related crashes is seen by undivided, two-way roadways than the divided or one-way roads do. To serve the purpose of guide light for the drivers, road lighting has been put into practice, and not with the intention to irradiate the road surface [41]. For many coming years, road lighting will apparently be an effectual safety initiative on highways. However in the long period, the implementation of modern vehicle designs and road technology will reduce the benefit of road lighting. Along with this, some additional measures like light emitting diode (LED) guide lights and

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light road surfaces are also figured out in [41]. To deal with this issue, more emphasis has been put on the development of the vehicles in [42]. Thus a new discipline of Intelligent Vehicles activities, namely automotive lighting, is coming up [43]. For ensuring high safety level, innovatory developments are being established: wall effect chicane at cross roads, rural round about, dynamic warning signs, etc. A safety indicator hinged on trajectory analysis was recently developed in [9], comprising the circumstantial and contextual parameters, such as driver behaviour, geometry of the infrastructure (e.g. radius of curvature, skid resistance, slope, etc.) and of the motorized vehicle. Vehicle trajectory estimation relying on the fusion of visual images and range finder measurements was also executed.

III. DEVELOPMENTS AND RESEARCH CHALLANGES

A greater part of the research in the field of road crashes due to fog, has been done on simulated fog based models, developed environments, predetermined results, etc. Mostly the developments till date have not strongly differentiated between the impact of fog in urban and rural areas separately, especially in Northern India. Studies have been conducted which paints a more clear picture of fog-related fatal crashes and police-reported crashes by examining highway trends.

Drawbacks of simulation based driving studies are that the participants interpret the experimental tasks in a manner different from the real life, therefore their behaviour is partially realistic. In other words, their behaviour may not be completely realistic under simulated driving conditions. Despite the fact that simulated fog is identical to real fog, but still not exactly same, driver behaviour is different in simulated fog conditions. In spite of these drawbacks, simulation training approaches imparts hope to youths to acquire a bit of essential experience away from the actual road. Driving simulators provide optimal environmental conditions for training new drivers in adverse simulated weather conditions like fog, excluding the risks of being physically harmed. Nevertheless, knowing the shortcomings of driving simulator techniques, the substitute for real world acquaintance is still not there. Even though it is not always feasible to drive in fog, yet it is crucial to teach the beginners regarding risky situations at initial training, to prepare them for tackling challenging situations in real time.

Furthermore, the realistic driving studies presents an opportunity for collection of data regarding foggy driving exposure, selection of speed and performance of driver in forms unrealized during utilization of experimental strategies for simulators and with test tracks also. Along with extension of the present methodologies outside the simulator, confirmation of the results across varying population segments inclusive of older and experienced drivers is also mandatory.

In the realistic driving survey, for the further interpretation of the consequences of driving in foggy weather, emphasis should be laid upon recognition and mitigation of unsafe behaviour while driving under such conditions. In contrast to accidents in clear weather conditions, crashes due to fog lead to more serious injuries and also involving more number of vehicles. Most frequent crash types on the basis of risk associated and harshness, are namely head-on and rear-end crashes, and are more widespread on high-speed roads, undivided roads, plus roads with no sidewalks and two-lane rural roads. Hence, decrease in the speed limits and setting up the road medians can probably provide better safety at fog susceptible locations. Enhancement of road lightning on the determined hotspots is recommended as crashes associated with fog are likely to happen at night where there are no street lights, thus resulting in serious injury. Possibilities for numerous extensions of current study in context to technicality and its application are there.

The future scenario pertaining to lighting and safety of motorways will not be same as the past situations in various ways: upcoming roadways and vehicles would be safer, and decrease in crash rate in both daylight and darkness, inclusive or exclusive of road lighting. Designing and construction of ditches, slants, railings, light poles and additional constructions on roads and its immediate surroundings will be in order to avoid serious outcomes when mistakes are made by road users. Construction of vehicles will be done for better absorption of collision energy. Setting up electronic devices in vehicles to warn the driver about controlling his vehicle in emergence of crucial situations will be done. Reduction in the accident count on future highways through aforementioned safety measures will also reduce the dependency on road lightning. Such a forgiving and self-explaining environment increases safety, and combines in-vehicle strategies along with the infrastructure to improve the road safety. Deaths are the most severe consequence related to crashes. Accuracy and effectiveness of these measures cannot be totally assured but computation for the overall expenditure required to guarantee the decrease in fog accidents have to be made.

Lesser than 50m of visibility range has been observed as affecting the driver’s behaviour at the study points because motorists tend to slow down their speed only when visibility reaches below 50m. Analysis of optimal speed during conditions of critical visibility will not only help in decrement in speed but will also produce smooth traffic flow. The extensive usage of mobile phones during driving is also a leading reason behind road accidents mainly amongst the youths. The prime objective is creating awareness within people regarding appropriate traffic rules.

Casualties associated with harsh weather conditions has taken into account few risk factors for instance poorly lit conditions, driving on motorways, alcohol and drug consumption, speeding, lack of restricted use and rough driving records. These facts indicate scope for research regarding the probable risks related to motor vehicle mortalities, either due to the effect of harsh weather on drivers conduct or due to the events impact on pavements and road safety. Numerous amendments can possibly be done in visibility enhancement methodologies. Firstly, adding down new constraints as per our previous knowledge regarding vehicular environment or due to sensors like Lidar. Secondly, refining the metric used for computation of distance amidst the restored image and non-foggy image by concentrating specifically on the roadway and contents like substantial objects for smart vehicle applications, on the road or through the usage of model of human vision. Thirdly, Koschmieder’s law based algorithms for visibility improvement and image rendering were presented. Modern perspectives of research opens up due to the introduction of street lights and shadowing effect owing to the improvement in the fog model at the expense of increasing parameters.

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Inspection of safety measures, the fact that stress is laid on measures applicable only to rural and highway environments and not for urban environments, became familiar. Hence, there is requirement for visualization and development of additional innovative measures. Therefore, allowing precise analysis of interactions amidst vehicles, motorists, infrastructure of roads and conduct of the motorists is in harmony or conflict along with the vehicle and infrastructural attributes for assumed environment and specific traffic conditions. Prevailing weather conditions at the accident time has been revealed through analysis as a contributing factor for the accident severity. Use of fine weather as the non-hazardous tool, contrary to which assessment of accidents in alternate conditions has been done. The vital component behind risk reduction is the rectification of the behaviour of drivers in severe weather conditions.

IV. CONCLUSION

For the purpose of road safety, interconnection between motorized vehicles, drivers and road construction, and the driver conduct's fit or variations with the motorized vehicle and infrastructure features in some provided surroundings and specific traffic conditions have been investigated and is still going on. Consistency of speed cannot be assured by warning systems. A considerable amount of speed reduction by drivers is not recorded until there is drastic reduction in the visibility distance, however ability to maintain lanes across most of the range of visibility distances has been witnessed. Along with the obvious insignificant part of fog in annual road crash summary, a strong cyclic pattern has been noticed in fog related crashes. To serve the purpose of guide lights, Light Emitting Diodes have been proposed as a substitute to road lighting in the interior of motorways, and further some risks are being covered up with vehicles developed taking such critical situations into consideration. Studies should be conducted for all levels of crashes, as counteractions against crashes in common will lead to reduction in fatal crashes also. It is advisable to take precautionary actions instead of waiting for crashes or serious injuries to take place, for the purpose of carrying out diagnosis and suggest countermeasures.

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