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A RESEARCH PAPER ON RECTIFICATION OF BLACK SPOTS ON INDORE – BETUL ROAD, NH-59A AT VILLAGE RAGHOGARH

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The national highways network of India is responsible for development of civilizations and economic development of the country by meeting travel requirements of people and goods. Road accidents are one of the major elements which block the development of civilizations and economic growth due to the high economic loss as well as loss of life it causes. Hence it is important to identify such places of high accident chances and rectify them as soon as possible. Several methods can be adopted to identify such accident prone zones or accidental black spots.

Keywords: black spots, National Highway, Severity Index.

I. Introduction

Road traffic accidents are a significant public health and development crisis, with up to 50 million people injured annually. The WHO states that these accidents cost the world over $500 billion annually and are the leading cause of disability worldwide. The UN aims to reduce road deaths by 50% by 2020, with blackspot management being a key component of this process.

Blackspot management involves identifying locations with high concentrations of crashes due to local risk factors. Location-specific infrastructural measures can be implemented to decrease the number of crashes and put an end to the concentration of crashes at that location. The availability of good and reliable crash data is the core of any blackspot management program.

Blackspot improvement is a crash data-led investigation process to understand the causes of road crashes and design and implement matching countermeasures. However, road safety professionals should note that blackspot identification and treatment are only one of many road safety interventions to reduce road crashes and associated fatalities and serious injuries. Other measures, such as road safety assessment, road safety audits, enforcement, road safety campaigns, and post-crash care, are also necessary to achieve a sustainable reduction in road crashes.

A comprehensive road safety action plan in line with the 'Safe System Approach should be implemented, covering all aspects of road safety. This guideline provides guidance towards identifying blackspots and improving crash-prone locations through engineering interventions, serving as a training aid for road safety professionals involved in planning, designing, and maintaining various categories of roads. It also provides practical guidance in carrying out the blackspot improvement program, providing a systematic process for identifying locations with an unusually high incidence of road crashes, analyzing contributory factors, and designing and implementing engineering countermeasures, including monitoring and evaluation.

1.2 PROBLEM OF ACCIDENT

Traffic accidents are a significant issue in highway transportation due to the complex flow patterns of vehicular traffic and mixed traffic with pedestrians. These accidents can lead to loss of life and property, and traffic engineers must ensure safe traffic movements for road users. The WHO states that road accidents are the leading cause of death among people aged 15-29. The Ministry of Road Transport & Highways (MoRTH) in India has identified road accident black spots on National Highways, where either 5 or 10 accidents occurred within the last three calendar years.

The growth of urbanization and the number of vehicles in developing countries has led to increased traffic congestion and accidents on road networks. Unplanned urban growth has led to incompatible land uses, high pedestrian-vehicle conflicts, and a significant deterioration in driving conditions and competition between different road users. The road network is crucial for economic and social development, and Maharashtra, one of India's fastest-growing states, has a wide road network that facilitates better and faster transportation. However, the increasing number of vehicles and accidents contribute to the problem.

To reduce accidents, accidents prone zones on highways must be studied, identified, and rectified. Accidental black spots are areas where road traffic accidents have historically been concentrated, and the WHO states that road accidents are the leading cause of death among people aged 15-29. The National Highway Authority of India (NHAI) has analyzed accidental data collected from the NHAI using the Ranking Method to identify black spots on national highways.

1.3 WHAT IS BLACK SPOT

An accident black spot is a term used in road safety management to denote a place where road traffic accidents have historically been concentrated (2) . Black spot methods are designed to identify the prone spots in particular stretch and reduce the crash risk in that area by providing remedial measures. Identification of locations for safety improvement is the starting point of all the processes. The process is sometimes known as black spot identification or hazardous identification location. Generally black spot are termed to define the location where many accidents have occurred and risk (severe, major, and minor) is involved in that accident.

1.4 ROAD SAFETY IMPROVEMENTS VARIOUS APPROACHES

1. SAFE SYSTEMS APPROACH

The Safe Systems Approach (SSA) aims to prevent deaths and serious injuries in road systems by minimizing kinetic energy exposure. This approach is promoted by The Netherlands as Sustainable Safety and in Sweden as the "Vision Zero" policy. The objective is to prevent road crashes and reduce the severity of injuries. A user-centric system approach, considering human characteristics and physical vulnerability, is essential for achieving an inherently safe road traffic system. Many countries have successfully reduced road crashes, with the "Vision Zero" policy in Sweden aiming to achieve zero fatalities on a stretch of road in the near future. Vision Zero acknowledges that human mistakes are inevitable, and safety work must focus on preventing road crashes leading to death and serious injury. Despite the United Nations' declaration of the "Decade of Action for Road Safety" from 2011 to 2020, fatalities continue to rise, highlighting the need for continued safety measures to reduce the risk of accidents and injuries.

1.5 ENGINEERING INTERVENTIONS

Safety Engineers are focused on improving road engineering in India to reduce fatalities and serious injuries. A road crash is a rare, multi-factor event that occurs when one or more road users fail to cope with the road environment, resulting in a vehicle collision. Road engineering should help users cope with the road by providing better signage, road markings, footpaths, pedestrian crossings, speed-control devices, and channelization or segregation. In some cases, it may be necessary to change the layout, alignment, etc. to make the road geometry simpler to understand and use.

In the case of a vehicle running off the road at a sharp bend, the driver died due to the impact of the vehicle sliding down the high embankment on the valley side. The police investigation revealed that the driver had been traveling too fast and under the influence of alcohol at the time of the crash. However, the Safety Engineers inspected the site and found that the sharp bend came after a long straight section and that the "sharp bend warning sign" had not been replaced after being damaged in an earlier road crash. Additionally, a roadside safety barrier was not in place in the sharp bend stretch of the high embankment to protect errand vehicles.

In a blackspot improvement program, the task is to identify where road crashes are happening and investigate them to determine the local risk factors involved so that appropriate and effective remedial measures can be applied. Taking the number of actual road crashes as the starting point is of fundamental importance, as it is not possible to reliably identify and analyze hazardous locations from the look of the road alone. The key is to identify locations where an above-average number of road crashes are occurring, showing a pattern of road crashes, as these are potentially worthwhile sites for

investigation and treatment.Road Safety Specialists recognize following four main approaches to the task of treating roads with bad road accidents records:
- Single Site Scheme or Blackspot Programme
- Route Action Scheme
- Mass Action Scheme
- Area action Scheme

Brief descriptions of these four safety engineering approaches are given below.
1. Single Site Scheme or Blackspot

Programme Single Site Scheme also called Blackspot Programme is a treatment of individual sites [e.g. junctions, bends, or short (500m) length of road) in which road crashes are clustered, with distinct pattern of crashes, which can be corrected by safety engineering interventions. In a broader sense, blackspot is defined as a road section of 500m length or a junction that has the number of road crashes higher than the Average Annual Total Crashes (AATC) computed for the candidate road section considered in the study. It is an established phenomenon that such surge in the specific type of road crashes at the identified blackspot can be fixed through the implementation of appropriate engineering measures.
2. Route Action Scheme

In the route action, the safety treatments will be applied to the whole length of a road which has a bad overall road crash record. Based on safety assessment and audit, fixing all safety issues along a road section comes under Route Action
3. Mass Action Scheme

Application of standard treatments to locations having incidences of common types of road crashes (e.g. provision of central refuges at pedestrian crossings on wide roads) is called Mass Action.
4. Area Action Scheme

In the Area Action, the safety treatments will be applied throughout an area (often a part/area of town) which has a bad overall road crash record (e.g. traffic management and traffic calming measures undertaken throughout a housing colony or a commercial zone/area).
1.6 FINAL DIAGNOSIS & DEVELOPMENT OF COUNTERMEASURES
1. FINAL DIAGNOSIS

Based on the crash data analysis and further detailed site investigation, the blackspot investigation team is expected to come out with diagnosed problems for each of the blackspot site. The findings have to be drawn and clearly expressed with sound reasoning, because these are the basis for selecting the countermeasures. The underlying aim is to identify the contributory factors tackling of which might be able to change the situation
2. IDENTIFY TREATABLE PROBLEMS

The treatable problems which have matching countermeasures shall be listed out at this stage. A second visit should be undertaken to assess the appropriateness of analysis and the findings. The analysis should always yield results with two types of locations such as:
i. Locations where distinct problems are identified
ii. Locations where the analysis are inconclusive

Where clear problems are identified, the team should proceed to the next task. In case, the analysis does not identify distinct problems, the site will be further investigated or next most serious hazardous location will be considered. If ITS facilities are already installed in a blackspot location, the details recorded therein may be analyzed to precise problem diagnosis. The use of speed camera also can be considered as an enforcement countermeasure to reduce speed.
3. DEVELOPMENT OF COUNTERMEASURES
1. Match solutions to diagnosed problems

If one or more dominant type of road crash types have been identified to be the root cause for the increased frequency of crashes and the analyses have reached some conclusion about the causal factors involved (and these causes are capable of being treated or remedied), it is then required to match

solutions (countermeasures) to the problems. The solutions should accomplish at least one of the following:
• Remove the conflict causing the problem;
• Improve the situation (e.g., provide warning earlier so that road users can cope better);
• Reduce the speed, thus reducing the crash risk and its severity;-and
• Adhering to the first principle for safe design in case of priority, roundabout and signalized intersections
2. Site Specific Consideration
When suggesting countermeasures, following consideration should be taken into account:
• Is the remedy cost-effective? - Some measures may be effective without being cost-effective. Generally black spot improvement proposal begins with implementing low-cost measures. In many cases high cost solutions may be kept in abeyance to make it financially viable in the initial period of upgrading the highway, which may have created the risk. While black spot improvement is intended to be a low cost engineering intervention; however, if a high cost measure is really warranted for a specific location to address a specific problem, it shall be adopted through a proper cost benefit analysis. Low cost solutions may still be provided as an interim measure.
• Is it adhering to first principle for junction layout design for safety? - Junction layout shall adhere to the safer practices suggested in relevant IRC documents (IRC: SP 41, 73, 84, 87) .
• Is it likely to be long-lasting? - Some speed-reduction measures for example have an immediate effect but this wears off as drivers get used to them;
• Will it result in an excessive increase in other types of crashes? - For example, in some circumstances the introduction of traffic signals can result in an increase in rear-end collisions;
• Will it need to be heavily enforced by the Police or need considerable publicity and education? -If so, consider whether this is really achievable.
• Will it be user friendly for pedestrians and other vulnerable road users?: For example, a FOB in rural section, seemingly can avoid all crashes related with pedestrian crossing, but pedestrian tend to cross the road at-grade owing to the fact that efforts required to use FOB is many fold compared with an at-grade crossing.
3. Selection of Appropriate measures
As such, countermeasures for blackspot improvement can be classified as short-term and longterm measures. Those measures that are capital intensive like proposal for grade separators are termed as long-term measures. Those measures which are low cost in nature are termed as short-term measures. Short term measures can give immediate benefits. Though long-term measures are capital intensive, it should be understood in proper context in highway development in the country and hence provision should be made for its implementation in the foreseeable future. Historically in many highway development projects in India, the high cost solutions have been removed while implementing the project to make it financially viable and some other cases due to land acquisition issues. Due to any reasons, if these high cost solutions were not implemented, it would have manifested site specific risks leading to creation of blackspot in the operational and maintenance period of the project. If a high cost solution is technically warranted, it shall be recommended after carrying out appropriate cost - benefit analysis based on the particular merits that it can reduce the incidence of road crashes substantially.
1.7 COUNTER MEASURES
It has been proven that certain engineering treatments, if implemented properly, are very successful in reducing certain common crash types. These engineering treatments are generally known as countermeasures. The most commonly occurring crash types are as follows:
Single vehicle crashes (crashes such as ran-off, overturning, etc.)
Pedestrian crashes
Crashes for vehicles driving in the same direction (usually rear end collisions, side swipe, etc.)
Crashes at junctions (usually right-angled collisions)

Crashes between vehicles travelling in opposite directions on undivided roads (usually head-on collisions)

Railway crossing crashes

It is highly likely that in most of the blackspots, any one of the above crash-type will be predominant. In such a situation (where a predominant crash type can be observed), it could be usually because of the local risk factors present in the blackspot. Such frequently occurring crash types can be treated by matching countermeasures (engineering interventions).

1.8 BLACKSPOT MITIGATION MEASURES

The blackspot safety measures shall be detailed as short term and long term. The short terms measures can be descriptive giving details of the existing road features and mitigation measures along with a sketch or site layout of the location. The long term measures shall be described along with the base map of blackspot location. A base map shall be prepared giving details of road geometry, cross sections, roadside features, intersections, etc. The mitigation measures shall be superimposed on the base map. The existing layout of the blackspot with the features shall be shown as “Existing Scenario” against which blackspot improvement measures shall be shown as “Proposed Blackspot Mitigation Measure” for the Client and Execution Agencies to appreciate all the improvement proposals. This would also ensure the implementation of all improvement measures as envisaged by the Safety Engineer, lest perhaps some measures could be neglected by the Contractor. The layouts and provision of relevant IRC codes and Manuals should be indicated in the improvement proposals.

1.9 DETAILED DESIGN OF BLACKSPOT MITIGATION MEASURES

In case of high cost long term measures being preferred to address a crash prone location instead of low cost measures, it is essential that a detailed design of the mitigation measures shall be undertaken before its implementation so as to achieve its effectiveness. The detailed design report shall be prepared carrying out all field investigations and design as these are being done in the case of upgradation of an existing roads. The detailed design may involve topographic surveys, traffic studies, soil and geotechnical surveys, geometric design, structural design, intersection designs, road signs, road delineators and pavement marking proposals, estimation of quantities and costing, cost benefit analysis and preparation of bid documents.

1.10 BACKGROUND

India ranked 1st among 199 countries in road accident deaths according to the “Ministry of Road Transport & Highways” report on “Road Accidents in India-2019” (2019). In 2019, India witnessed 4,49,002 road accidents, including 1,51,113 deaths and 4,51,361 injuries [1]. According to the “Ministry of Road Transport & Highways” report on ”Road Accidents in India-2020” (2020), India witnessed 3,66,138 road accidents, including 1,31,714 deaths and 3,48,279 injuries [2]. Therefore, it is necessary to concentrate on road safety issues to minimize road accidents.

Emenalo et al. (1977) worked on a research project in Zambia named 'road traffic problems in Zambia' since 1974 and realized the fatalities from road accidents are ten times larger than in European countries [3] and suggested addressing them quickly to reduce them. Landge et al. (2005) identified the need for community participation and developed a methodology to achieve the same. They said two people die every-six minutes, and one sustains serious injury every minute due to road traffic accidents [4]. The authors also concluded that law enforcement agencies and engineering solutions would have limited success without the community's cooperation. Dandona et al. (2006) interviewed 4183 two-wheeler drivers at petrol filling stations in Hyderabad, India, to report on the availability of a driving license, helmet use, driver behavior to traffic rules, and condition of the vehicle [5]. The reports suggested enacting and enforcing policy interventions to reduce risk factors contributing to road traffic crashes. Elvik et al. (2009) published a book on state-of-the-art summaries related to the effects of 128 road safety measures [6]. It was the second edition of the book 'handbook of road safety measures,' published in 2004. It included all areas of road safety, such as vehicle inspection, driver training, policy enforcement, and publicity campaigns. The new additions in this book include post-accident care, Driving Under the Influence (DUI) legislation & enforcement, environmental zones, and speed cameras.

Ponnaluri (2012) conducted a case study on road traffic crashes in Andhra Pradesh (AP) to discuss the trend and recommend remedial measures. The author addressed the fatality rates in AP from 2001 to 2009 and found that the urban-to-rural share was 40 %:60 % [7]. Also, recommendations were made, like developing an accident recording system, capacity-building efforts, and providing emergency response services. Yannis et al. (2016) carried out an international inquiry about the use of accident prediction models in road safety. They have included 23 countries, 18 of which were European, Australian, and the USA, with the help of a specially designed questionnaire for the inquiry of the study. Accident prediction models are necessary tools for implementing road safety [8], and they have found that most organizations do not use accident prediction models while implementing road safety. Sucha and Cernochova (2016) studied drivers' capacities (skills), personality traits, and motivational factors in the Czech Republic. They divided the drivers into two groups, professional drivers and licensed suspended drivers, and found a difference in the personality traits between the two groups. The differences in the skills of the two groups were not significant [9].

Sing (2017) analyzed road accidents in India at the national, state, and local city levels. The author showed that road accidents and injuries varied as per age, gender, month, and time in India [10]. The author concluded that India's total fatalities will likely make up to 2 50,000 by 2025. Wegman (2017) concluded on the future of road safety worldwide. The author stated that 90 % of all accidents occurred in low-and-middle-income countries [11]. Road safety was performing positively in high-income countries in the last few decades, whereas low-and-middle-income countries were not performing positively. The increase in road accidents is noticeable unless road safety in low-and-middle-income countries is improved. Pandey and Pandey (2018) studied the accident statistics for India and stated the importance of implementing road safety in India. The authors took the initiative toward the safety of road users by suggesting the remedial measures to be followed on various categories of roads in India [12]. Chantith et al. (2021) computed the economic costs of road traffic accidents in terms of the value of productivity losses for fatalities, disabilities, and severe and slight injuries. Teens and young adults bear a significant burden of the economic costs of road accidents, amounting to 121 billion BHT or 0.8 % of Thailand's GDP [13].

Keten (2020) concluded that it is essential to provide driving safety training to patients with diabetes after diagnosis. In addition to legal regulations on this issue, developed countries should tighten their activities to improve driving safety in patients with diabetes [14]. Watson and Austin (2021) concluded that rural drivers are more likely to hold unfavorable seat belt attitudes/beliefs than urban drivers in the United States [15]. Mohan et al. (2021) considered current road safety measures and estimated the fatalities in 6 cities in India up to 2030. The authors concluded that with the current measures, only 50 % of the target set by SDG 3.6 could be achieved and suggested achieving the remaining target by investing in road safety research [16].

Srinivasan et al. (1987) identified accident-prone locations on national highways in Kerala, India. They have suggested improvements for the same. The authors have observed an increase in accidents on national highways [17] and presented further analysis after identifying accident-prone locations. Cheng and Washington (2008) established new criteria for determining hot spots with the help of the existing Hot Spot Identification (HSID) methods. They collected three years of accident data on a road section in Arizona. They applied the four new criteria: reliability of results, ranking consistency, false identification consistency, and reliability, along with commonly used HSID methods [18]. They have found the EB HSID method among commonly used methods as the superior one, whereas the accident rate ranking method performed the least. Montella (2010) presented a comparative analysis of various hot spot identification (HSID) methods. The author compared seven commonly used HSID methods against four quantitative evaluation criteria. For this study, five years of crash data were available from Italian motorway A16. The author concluded that the empirical Bayes method is the most consistent and reliable [19].

Thube and Thube (2010) studied the rural highways of Maharashtra, found various causes of accidents, and suggested remedial measures. The local officers of the Public Works Department (PWD) identified the accident-prone areas as per the data obtained from the local police station [20]. These locations were classified based on the severity of accidents. Further, the type of remedial measures to be adopted was suggested by the Accident Prevention Committee (APC), which the Government of Maharashtra, India, in the year 1997 formulated. Agarwal et al. (2013) presented a four-stage methodology for ranking hazardous road safety locations using the Analytical Hierarchy Process (AHP), which does not require accident data. The authors have divided safety hazardous conditions into straight sections, curved sections, and intersections [21]. AHP was used to find the weightage of various safety factors, and a hazardous safety index was developed for all the sections separately. Isen et al. (2013) identified the most vulnerable accident black spots in the 'Alappuzha' and 'Ernakulam' districts in Kerala, India, using the Geographic Information System (GIS). The authors collected the accident data and prioritized the black spots using the Weighted Severity Index (WSI) method. Further, with the help of the ArcGIS 10.1 software package, the black spots were identified [22].
Bobade and Patil (2015) aimed to determine the black spots on the Pune-Solapur national highway in Maharashtra, India, for a stretch of 50–60 km. Various methods like severity index benchmark, weighted severity index, ranking method, and accident density method were used [23]. Sacchi et al. (2015) introduced a new technique for multivariate identification and order of hot spots based on multivariate distance, which is the extension of univariate potential developed in the Bayesian context. They have applied this technique to 173 signalized intersections in Vancouver, Canada [24], and concluded that the univariate potential is best compared to the multivariate one in terms of consistency assessment. Sorate et al. (2015) have identified accident black spots on NH4 (New Katraj Tunnel to Chandani Chowk, Pune, Maharashtra, India) for 14.6 km using methods like the method of ranking & severity index, accident density method, and weighted severity index. The accident data was from the National Highway Authority of India (NHAI) and police stations. Inspecting the 14.6-kilometer highway at every 100 m chainage by the physical survey [25]. Most of the remedial measures suggested were related to improving road geometry and traffic signs.
Ambros et al. (2016) selected a rural road network of 1000 km in South Moravia, the Czech Republic, and applied three different methods of identifying hazardous locations in the study area. The methods used were traditional black spot identification, empirical Bayes, and risk index. They have observed that the conventional black spot approach is unsuitable, whereas empirical Bayes and risk index methods, as per the availability of the data, are recommended [26]. Mohan and Landage (2017) aimed to identify the accident-prone locations along the Amravati-Nagpur road stretch from Asian Highway-46 in Maharashtra, India. Identifying top accident-prone spots using the WSI method gave suggestions to improve the transportation system. According to the recent road accident data, the authors concluded that the highly populated Maharashtra state had reported the highest accident rate [27], which calls for safety improvements. Bhavsar et al. (2020) used the association rule mining technique to identify accident hot-spots on a rural highway in India [28].

II. **Literature**

Mirbahador Yazdani, Evaluating drivers' speed choice with and without route-based warnings on approach to black spots on a rural highway: A high percentage of crashes occur at black spots of rural highways, and it is of paramount importance to employ strategies that can significantly reduce these crashes. The use of warning systems is one of the different methods of achieving this goal, and this study evaluates the effectiveness of these systems in different classes of drivers. To analyze the effects of warning systems on driver performance, three speed measures (mean speed, speed variation and speed limit violation) were applied. Forty-eight male and female drivers were categorized into three age groups, namely young (18–35 years old), middle age (36–55 years old) and elderly (above 55 years old), and they were asked to drive on a rural two-lane two-way highway in the north-west of Iran to conduct the experiment. The results indicate that middle-aged men and elderly women had the highest

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and lowest recorded mean speeds at black spots respectively both in the warning and non-warning states. On the other hand, young male drivers had the highest speed variations in the warning state, and middle-aged male drivers recorded the lowest variations in the non-warning state. Concerning the violation of speed limit at the black spots, young and middle-aged men had the highest number of violations in the warning and non-warning states respectively. Elderly women were found to be the most cautious group both in the warning and non-warning states. Conclusively, strategies such as changing the type and number of warnings are proposed to improve the effectiveness of the warning systems in special groups of drivers.
Laxman Singh Bisht, Assessing the Black Spots Focused Policies for Indian National Highways: Road Traffic Injuries (RTIs) is one of the leading causes of death across the globe. As per the Indian government statistics, 150,785 persons were killed and 494,624 injured in road traffic crashes in the year 2016. In the recent past Government of India has formulated policies to reduce the road traffic crashes on Indian highways with prime focus on the National Highways (NHs). One of the dimensions of these policies is the identification and rectification of black spots on NHs and State Highways (SHs). Ministry of Road Transport and Highways (MoRTH) provides a definition and protocol for identifying black spots, and subsequently, states have identified black spots on their NHs. Top priority has been accorded to the correction of black spots on NHs. Consequently, short-term measures such as rumble strips, reflective stickers at junctions, fixing signboard/cautionary board, providing signages and various other speed restrictions are also being used. Whereas, the long-term measures such as the construction of the vehicular underpass, by-pass, flyover, and lane widening are being taken up. This study aims to present the current scenario of the policies pertaining to black spots in the country. This study assesses the effectiveness of the policies focused on the identification and rectification of black spots on the NHs. Further, it highlights the strengths and weaknesses of the policies based on the outcomes of the audit conducted to review the road safety status on Indian Highways. This study also recommends the measures to improve the safety at black spots locations. Krantikumar V. Mhetre, Road safety, crash hot-spot, and crash cold-spot identification on a rural national highway in maharashtra, India: The study deals with road safety, crash hot-spot, and crash cold-spot identification on a rural national highway NH-48 in Maharashtra, India. Crash data from 2016 to 2020 of the NH-48 is considered for this study. There are three separate scenarios: 2016–2018 as scenario-1, 2017–2019 as scenario-2, and 2018–2020 as scenario-3, for which the crash hot-spots and crash-cold spots are identified. The comparison and analysis of crash hot-spots and crash cold-spots identified over the three scenarios are presented to understand the major hot-spots. It was observed that in all 3 scenarios, the chainage wise sections 592.24 km–611.5 km, and 712 km–725 km are performing excellent as cold-spots, since they do not have any hot-spots in between them. Whereas, the sections 611.5 km–629 km, and 679.5 km–707 km have 0 cold-spots in scenario-2, and scenario-3. The fall in the number of crash hot-spots every year in all three scenarios is 49.68 % in scenario 2 and 20.25 % in scenario 3. The rise in the number of crash cold-spots every year in all three scenarios is 46.42 % in scenario 2 and 48.78 % in scenario 3. Overall, the rise in the crash cold-spots and the fall in the crash hot-spots indicate that the highway is performing well in achieving road safety.
Dinesh K. Yadav, Mitigation of Blackspots on Highways by the Application of Safe System Approach: With increase in traffic volume across the globe traffic safety has come into highlight and become a major concern. Apparently, with due increase in traffic volume resulting in higher road accidents which considerably causes negative impact on economic growth, public health and general welfare of well-being. In the present scenario challenges are faced to mitigate the blackspots and by making road users aware with road safety parameters which may results in less road fatalities. The root cause of an accidents intends to perception, intellection emotion and violation. The approach towards this research is to get minimal setback/casualties of the road. In order to gain the best possible course of action, the stretch of 8 KM of National highway (NH-66) situated in a plain terrain in the district of Alapphuza, Kerala India. To begin with, accident data has been collected from NHAI office and Police station of above location with proper analysis by Accident Severity Index (ASI) method has been carried out.

Adding to an idea, location of Black Spot has been identified by ASI method. Based on Severity of accident short term and long-term measures has been adopted. Eventually, after analyzing short term measures 10 black spot location along with the estimate has been worked out.Xudong Wang, Anti-circulant dynamic mode decomposition with sparsity-promoting for highway traffic dynamics analysis: Highway traffic state data collected from a network of sensors can be considered as a high-dimensional nonlinear dynamical system. In this paper, we develop a novel data-driven method–anti-circulant dynamic mode decomposition with sparsity-promoting (circDMDsp)–to study the dynamics of highway traffic speed data. Particularly, circDMDsp addresses several issues that hinder the application of existing DMD models: limited spatial dimension, presence of both recurrent and non-recurrent patterns, high level of noise, and known mode stability. The proposed circDMDsp framework allows us to numerically extract spatial–temporal coherent structures with physical meanings/interpretations: the dynamic modes reflect coherent spatial bases, and the corresponding temporal patterns capture the temporal oscillation/evolution of these dynamic modes. Our result based on Seattle highway loop detector data showcases that traffic speed data is governed by a set of periodic components, e.g., mean pattern, daily pattern, and weekly pattern, and each of them has a unique spatial structure. The spatiotemporal patterns can also be used to recover/denoise observed data and predict future values at any timestamp by extrapolating the temporal Vandermonde matrix. Our experiments also demonstrate that the proposed circDMDsp framework is more accurate and robust in data reconstruction and prediction than other DMD-based models.

Hongjun Cui, Identifying accident black spots based on the accident spacing distribution: The identification of accident black spots is of great significance for the prevention of traffic accidents. Commonly used accident black spot identification methods divide road sections for the analysis of accident data, the direct result of which is the splitting of accident black spots, which affects the results. This paper is based on three years of traffic accident data from the Beijing–Harbin Expressway, including the time and location of traffic accidents, form of the accident fatalities, severe injuries, slight injuries, and property damage only (PDO). To avoid road division effects, an identification method based on the accident spacing distribution is established by using quality control theory. The results show that the average number of accidents per kilometer by the method proposed in this paper is 42, which is much higher than 10, identified by other identification methods. The method proposed in this paper improves the accuracy of the identification results. This method avoids the problem of road segmentation found in other common methods and can more accurately reflect the spatial distribution of traffic accidents. Thus making the identification of accidents more scientific and accurate.

Rohit R. Salgude, Investigation for effect of weak electric and magnetic fields at black spots on concrete pavement: Roads are valuable assets worldwide that must be kept in good condition with minimum maintenance to safeguard against accident. From the literature review and the field observations, it is quite evident that geo-fields are one of the parameters which is responsible for damaging the road surface and hence further increasing the possibility of accidents. Present study is an attempt to provide a detailed insight into the performance of the road segment when subjected to geo-fields. For the same accident data of the Mumbai-Pune expressway, over six years from 2016 to 2021 has been used. Based on this data 46 accident black spots were segregated for investigation. An automated method is used to measure the pavement roughness index (PRI). On these spots, the quality of pavement is determined using the non– destructive test of Ultra Sonic Pulse Velocity (UPV). Geo-fields are measured in terms of electric and magnetic fields at these black spots. Data has been analyzed using Karl Pearson's correlation coefficient and linear regression models are developed for the average number of road accidents ($\bar{A}$) with respect to PRI, UPV and Geo-fields. The mathematical models developed may provide a useful link between road accidents, geo-fields, and pavement surface conditions. It will also help transport authorities not only to predict the number of accidents at particular spots envisaged on existing expressway but will also enable them to design pavements appropriately for the detrimental effects of weak electric and magnetic fields.

Ari Sandhyavitri, Three Strategies Reducing Accident Rates at Black Spots and Black Sites Road in Riau Province, Indonesia: This paper aimed to (i) identify black spots and black sites road within the east cross highway of Sumatra, Ujung Tanjung \x96 Bagan Batu, Indonesia, (ii) analyze its traffic accidents anatomy, and (iii) recommend appropriate strategy for reducing the accident rates within this road section. In the period of 2009-2011, it was identified that, the black spot area (1 km of the road length) within this highway was located at KM 36-37 road section. The black sites area (6 kms) was located at Balam Jaya to Balai Jaya. The numbers of traffic accident occurrences at the black site area were 36 events for 3 years period. The traffic accidents were caused by; human errors (66.67%), vehicle failures (11.11%) and, poor of the existing road technical conditions (22.22%). After implementing 3 strategies encompassing: (i) educating road user, (ii) improving safer road strategy, and (iii) improving road safety and technical specifications, the number of accident rates decreased by 50% in 2014.

Ellen Oettinger White, Unclear territory: Clear zones, roadside trees, and collaboration in state highway agencies: The American Association of State Highway and Transportation Officials (AASHTO) issues guidance for highway agencies to maintain clear zones adjacent to the roadbed, free of trees, to reduce the severity of run-off-the-road crashes. Some departments of transportation (DOTs) are clearing trees beyond the standard clear zone for road safety, creating friction between units of different disciplines.

Following an analysis of roadside tree literature, I use semi-structured interviews with agency staff to illuminate how perceptions of trees—either as safety hazards or as beneficial environmental assets—are considered by practitioners at state highway agencies.

Results indicate that engineering leadership understands roadside tree management as a nuanced issue. The benefits of trees are understood by most staff though are rarely a sufficient counterweight for perceived safety issues. Maintenance staff are motivated more by budgets or contracts than by research or federal guidance. An interdisciplinary staff structure, robust communication practices, and stronger environmental policy can improve DOT collaboration.

Shawon Aziz, A Meta-analysis of the methodologies practiced worldwide for the identification of Road Accident Black Spots: An accident Black spot (often synonymously known as a crash hotspot) is a section of road where the frequency of occurrence of several types of road accidents or a particular type of road accident is comparatively higher than other similar sections on the road. Accidents may occur on such sections of a road due to several factors such as faults in engineering design, failures in traffic rule enforcement, rash driving etc. but road accidents repeatedly occur at a location due to faults and inconsistencies in design which lead creation of an ambiguous road environment that fails to provide a positive guidance to road users. For rectifying of such road sections, it is important to identify such locations based on likelihood of occurrence of road accidents and past accident history. This paper intends to conduct a critical appraisal of the various methodologies practiced worldwide for the identification of road accident black spots and discusses their merits and demerits. The paper summarizes the key elements in the definitions of road accident Black spots and black road sections of different countries that are a part of protocol of their respective government policies. The paper at last discusses a meta-analysis of the inferences drawn out from these definitions for road accidents.

Nazneen, Determinants of traffic related atmospheric particulate matter concentrations and their associated health risk at a highway toll plaza in India: People working at toll plazas are continuously exposed to high pollutant concentrations due to traffic congestion at toll booths. However, there are fewer studies available which focus on toll workers' exposures. Therefore, a study was conducted at a toll plaza on a busy national highway (NH) in India to assess black carbon (BC), particulate matter with aerodynamic diameter ≤2.5 µm (PM2.5), and ultrafine particles (UFP) concentrations and their associated health risks on the toll workers inside toll cabin and kerbside. Higher BC (34 µg m^{-3} vs. 18 µg m^{-3}) and PM2.5 (86 µg m^{-3} vs. 79 µg m^{-3}) concentrations were observed inside the cabin than at kerbside. On the contrary, UFP concentrations were higher at the kerbside (22,790 pt cm^{-3}) than in-cabin (18525 pt cm^{-3}). All pollutant concentrations were higher during evening hours than in

the morning hours. BC and PM2.5 concentrations were found to be higher during the weekdays. Positive correlations were found between traffic volume and all pollutant concentrations. Negative correlations were observed for solar radiation and boundary layer height with pollutant concentrations. Additionally, it was found that the health risk of toll workers was higher (risk quotient, RQ range: ∼2–5) than the prescribed limit (RQ < 1). The present study demonstrates that there is a need to control personal exposure to pollutants in the workplaces, especially locations with traffic proximity.
Jinfen Zhang, A two-stage black-spot identification model for inland waterway transportation: Inland shipping plays a significant role in the integrated transport system. Maritime safety has been one of the top concerns due to its high-risk characteristics. The historical accident data is treated as a valuable source for identifying the riskiest waters (also called black-spots) where special attention is necessary. In view of this, a two-stage black-spot identification model is proposed in this paper to identify and locate waterways with higher accident rates. In stage 1, the dynamic segmentation and equivalent accident number methods are proposed to identify the preliminarily black-spots. In stage 2, Density-Based Spatial Clustering of Applications with Noise (DBSCAN) algorithm is introduced to pinpoint the precise locations of the detailed black-spots based on the results from the first step. The model is further applied to the Jiangsu section of the Yangtze River based on the historical accident data between 2012 and 2016. The results show that altogether 12 preliminary black-spots and 5 detailed black-spots are identified in the investigated waters. This research provides helpful reference for optimizing the allocations of search and rescue resource as well as differentiated safety management of black-spot waters.
Sujata Basu, Evaluation of risk factors for road accidents under mixed traffic: Case study on Indian highways: This paper presents an evaluation of risk factors for highway crashes under mixed traffic conditions. The basis of selecting study sites was abutting land use, roadway, and traffic characteristics. Accordingly, the study selected thirteen segments on the existing highway network in the state of West Bengal of India, covering a wide spectrum of such road attributes. A systematic investigation based on site-specific accident data to capture the highway sections' safety features revealed that the crash rate has steadily increased for years with traffic regardless of roadway category and conditions. A number of risk factors that affect road accidents were identified; they are mid-block access, pavement and shoulder conditions, vehicle involvement, time of day, and road configuration, i.e., two and multi-lane. The empirical observation indicates that the crash rate is relatively lower on multi-lane highways; however, the severity of any crash on such a road is relatively high. Notably, the crash frequencies on such roads are less during daylight hours due to the lane-based unidirectional traffic movement. This is quite the opposite during nighttime when drivers exhibit an inability to meet traffic contingencies, thereby increasing crash risk. The majority of crashes on two-lane highways are, on the other hand, due to unsafe driving manoeuvers. The study also observed that frequent mid-block accesses and poor shoulder conditions reduce scopes to rectify driving errors and increase crash risk as a consequence. The paper subsequently suggests proactive approaches to identify safety deficits at the time of planning and designing.
Hikaru Kimura, Decision-Making Based on Reinforcement Learning and Model Predictive Control Considering Space Generation for Highway On-Ramp Merging: Reducing traffic accidents pertaining to autonomous vehicles has garnered attention. Merging on a highway is one of the most challenging problems that must be addressed for the realization of autonomous vehicles. It is difficult because an agent must decide where to merge in a complex and ever-changing environment. Merging with congested highway traffic involves significant interaction with vehicles in the main lane. If there is no space for the autonomous vehicle to merge, it needs to work on vehicles in the main lane to create space and subsequently decide to merge or not. Reinforcement learning (RL) is a promising method for solving decision-making problems. However, it is difficult to guarantee the safety of the controller obtained using RL. Therefore, we propose a combined method in which decision-making is performed by RL and vehicle control by model predictive control (MPC) to ensure safety. The performance of the proposed system is tested by simulations. The proposed system made appropriate decisions

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according to the situation, and by controlling the vehicle in consideration of collision avoidance constraints, it showed a high merge success rate evenin a crowded situation.
Beatrice Rosso, Quantification and characterization of additives, plasticizers, and small micro-plastics (5–100 μm) in highway storm-water runoff: Highway storm-water (HSW) runoff is a significant pathway for transferring microplastics from land-based sources to the other surrounding environmental compartments. Small microplastics (SMPs, 5–100 μm), additives, plasticizers, natural, and nonplastic synthetic fibers, together with other components of micro-litter (APFs), were assessed in HSW samples via Micro-FTIR; oleo-extraction and purification procedures previously developed were optimized to accomplish this goal. The distribution of SMPs and APFs observed in distinct HSW runoff varied significantly since rainfall events may play a crucial role in the concentration and distribution of these pollutants. The SMPs' abundance varied from 11932 ± 151 to 18966 ± 191 SMPs/L. The dominating polymers were vinyl ester (VE), polyamide 6 (PA6), fluorocarbon, and polyester (PES). The APFs' concentrations ranged from 12825 ± 157 to 96425 ± 430 APFs/L. Most APFs originated from vehicle and tire wear (e.g., Dioctyl adipate or 5-Methyl-1H-benzotriazole). Other sources of these pollutants might be pipes, highway signs, packaging from garbage debris, road marking paints, atmospheric deposition, and other inputs. Assessing SMPs in HSW runoff can help evaluating the potential threat they may represent to receiving water bodies and air compartments. Besides, APFs in HSW runoff may be efficient proxies of macro- and microplastic pollution.
Sergey Naidenko, The effect of highway on spatial distribution and daily activity of mammals: The Russian Far East is a unique location that may be considered a hot spot of biodiversity in Russia. In 2010, a new illuminated highway for high-speed traffic was built on its territory. The aim of this study was to evaluate the impact of this highway on the distribution and activity of various mammalian species. We set up camera traps in five lines near the road and obtained photos of 1372 passes of various animals. In total, 15 species of wild mammals were captured by camera traps. Animals preferred to stay far away from the road. This highway became a serious barrier separating the local populations of ungulates and carnivores. Only domestic animals and Amur wild cat used the underpasses more often than other areas. The distance from the road did not affect the daily activity of the mammals.
Bo Yu , Quantifying drivers' visual perception to analyze accident-prone locations on two-lane mountain highways: Owing to constrained topography and road geometry, mountainous highways are subjected to frequent traffic accidents, and these crashes have relatively high mortality rates. In middle and high mountains, most roads are two-lane highways. Most two-lane mountain highways are located in rural areas in China, where traffic volume is relatively small; namely, traffic accidents are mainly related to the design of roads, rather than the impact of traffic flow. Previous studies primarily focused on the relationship between actual road geometry and traffic safety. However, some scholars put forward that there was a significant discrepancy between actual and visual perceived information. Drivers greatly depend on what they perceived by their vision to determine driving behavior. Thus, in this paper drivers' visual lane model was established to quantify drivers' visual perception. To further explore drivers' perception of horizontal and vertical alignments, the visual lane model was projected onto horizontal and vertical planes in drivers' vision respectively. The length and curvature of the visual curve were extracted as shape parameters of drivers' visual lane models. Real vehicle driving tests were conducted on typical two-lane mountain highway sections of G318 in Tibet, China. Then the differences of visual perception at black spots and accident-free locations were analyzed and compared. In horizontal and vertical projections of visual lane model, there were 9 shape parameters have significant differences between accident-prone and accident-free locations. A probabilistic neural network (PNN) was formed to identify accident-prone locations on two-lane mountain highways. This study will lay a foundation for the improvement of traffic safety on mountain highways based on the quantification of drivers' visual perception, during the phase of both road design and reconstruction, and can also make a contribution to the automatic driving technique.

Wilson Ogutu Ochieng, RFID-based location based services framework for alerting on black spots for accident prevention: The need of developing systems that address traffic matters such as traffic control and accidents has led to the development of a number of techniques, methods and tools to address road usability issues. Many automated models have been proposed and applied in different scenarios such as road oddities. Despite of the advantages of these models the major problem of road accidents continue to pose problem globally. This has created the need to come up with more user-effective approaches to address road accidents. Main objective of this research therefore is to identify and address the gap in Location Based Services (LBS). A model that combines RFID and GPS technology to provide Location Based Services via audio alerts to drivers as they approach black spots is presented. The model provides location based services to drivers as they approach black spots causing them to adjust their driving accordingly (i.e. speeding, overtaking). Since LBS technologies have different limitations, most researchers have focused on addressing accuracy limitation by proposing hybrid technologies. Accuracy requirement varies depending on application area. The analysis of the different technologies revealed that in vehicle transportation medium accuracy is effective. This research focused on availability aspect which is a key requirement in LBS. To achieve this a model made up of RFID & GPS is formulated. Higher availability of significant alerts at black spots is registered through simulation as compared to alerts when the technologies are applied separately. Black spot accidents are therefore managed due to safer driving around black spots. This can lead to reduction in exposure to accidents, likelihood of occurrence and impact in the event of an incident. Usability metrics is used to determine effectiveness of the model.
S.M. Sohel Mahmud, Using a surrogate safety approach to prioritize hazardous segments in a rural highway in a developing country: Road safety is a global concern particularly in developing countries where some road sections are disproportionately more vulnerable in terms of the frequency and severity of crashes. Other than using historical crash data based reactive approaches, those sections need to be identified proactively, so that mitigation measures can be applied. Moreover, those approaches are sometimes questioned mainly due to data reliability issues in developing countries. The study reported here is aimed at highlighting the applicability of traffic conflict techniques as surrogate safety measures to identify those sections of a rural highway in a developing country, which are most likely at risk. An adapted framework is demonstrated to identify traffic conflicts using combined surrogate indicators acknowledging the limited resources and facilities in developing countries. A new model is put forwarded using a count data modelling approach. Both fixed and random parameters model derivatives have been explored as an alternative methodological approach to relate the factors affecting the number and probability of conflicts. The partial effects of individual independent variables were estimated to gain a better insight of their impact. The results show that the model can predict high risk segments in terms of probability of conflicts as well as safety risk, as well as prioritize road sections according to the likelihood of their safety level. The model provides a less expensive alternative to the collection of historical crash data in order to identify hazardous road locations or black spots on two-lane highways in developing countries.
Mehmet Ali Dereli, A new model for determining the traffic accident black spots using GIS-aided spatial statistical methods: Traffic accidents are one of the important problems in our country as it in the world. The World Health Organization case reports published in 2015 stated that approximately 1.25 million people died each year and more than 50 million people injured as a result of traffic accidents in the world. Considering this situation, it is seen that traffic accidents are mostly human originated and one of the major problems that is negatively affecting life. In this context, many investments and many studies have been performed on the determination of traffic accident black spots to reduce traffic accidents.
The current study aimed to get a descriptive model for determining the traffic accident black spots using model-based spatial statistical methods. These methods are Poisson regression, Negative Binomial regression and Empirical Bayesian method. The ultimate goal of this study was to build a

model that allowed evaluating all the methods together in Geographic Information Systems (GIS) which is quite widely used nowadays.
In the present study, the data were obtained from 300 thousand traffic accidents occurred on 2408 different state roads during the years from 2005 to 2013 from the General Directorate of Highways. The state roads of Turkey were divided into 32,107 sub-segments with the length of 1 km. Based on the study results, 126 sub-segments were determined as traffic accident black spots depending on the method used. According to comparison of the methods used in the present study, the Empirical Bayesian method provided the best results in terms of accuracy and consistency.
Linfei Chen, Landslide susceptibility assessment using weights-of-evidence model and cluster analysis along the highways in the Hubei section of the Three Gorges Reservoir Area: Landslide susceptibility assessment has become the focus of geological disaster research to strengthen disaster prevention and mitigation. Landslide disasters frequently occur in the Hubei section of the Three Gorges Reservoir Area (TGRA), with some potential landslides located along the highway, which brings risks to highway engineering, maintenance and transportation. In this paper, a comprehensive landslide susceptibility evaluation indicator framework with three dimensions and 12 factors was established, and an integrated approach was applied to evaluate the landslide susceptibility level, which combined weights-of-evidence model, seven clustering algorithms, three quality evaluation indices and the elbow method. To validate the effectiveness of the methods, five objective measures were employed for evaluation. The 69 samples along the highway were used for training, and another 30 samples were collected for validation. The results showed that the landslide susceptibility level of potential landslides can be effectively predicted by K-means algorithm. It was found that the landslide susceptibility for each cluster had significant differences, which were mainly reflected in natural induced factors, followed by human induced factors, while the slope structure showed little differences; the areas with low landslide susceptibility appeared sheet distribution, while the areas with high landslide susceptibility showed zonal distribution along the Yangtze River and its tributaries. This study developed a comprehensive indicator system and method for landslide susceptibility assessment along highways and provided a reference for the risk evaluation and prevention management.
Lien-Wu Chen, Exploring spatiotemporal mobilities of highway traffic flows for precise travel time estimation and prediction based on electronic toll collection data: In this paper, we propose a travel time estimation and prediction (TTEP) framework to enhance the driving efficiency on highways through the Internet of Vehicles (IoV). Highway travel time estimation and prediction are important for the drivers in a long-distance traveling. The accurate travel time information on highways is the key to improve the efficiency of transportation systems. When current flow status is collected through the IoV, TTEP can accurately estimate and predict highway travel time by the proposed weighted root-mean-square similarity (Weighted-RMSS) method. In addition, when current flow status is unavailable at the present time, we propose the multiple slope-based linear regression (Multi-SBLR) method to predict highway travel time only using historical traffic data. Furthermore, the spatiotemporal mobilities of vehicles on highways are analyzed and explored to improve the prediction accuracy of the proposed Weighted-RMSS and Multi-SBLR methods. To verify the feasibility and superiority of TTEP, we adopt the open Electronic Toll Collection data of highways in Taiwan to evaluate the prediction accuracy of our approaches. Experimental results show that our approaches outperform existing methods and can significantly reduce the prediction errors of highway travel time. In particular, we further implement the Android-based and web-based systems of TTEP to predict and compare travel time at different departure times and locations for highway drivers.
Hiroshi Wakabayashi , Sustainable Traffic Safety Management at Accident Black Spots Combined with Drivers' Psychology and Vehicle Engineering Using Eye Mark Recorder: This paper proposes an integrated approach for sustainable traffic safety management at accident blackspots, including a mechanism that tracks the occurrence of accidents from the moment of drivers' vision to actual accident occurrence, via vehicle behavior. An accident black spot can become a "vicious circle" of

accident occurrence and safety countermeasures, where a safety countermeasure is repeatedly performed, but its effect soon fades each time. For such a spot, implementation of a safety countermeasure from only the highway point of view has no sustainability. Therefore, to be effective as one of the next-generation safety countermeasures, the method must integrate considerations from traffic engineering, drivers' psychology, and vehicle behavior. This paper proposes and discusses a next-generation, integrated traffic safety management method and an explanation of a mechanism that tracks accident occurrence where drivers watch first and then how vehicles behave and lastly what accident risk increases as the series of event.

Maen Ghadi, A comparative analysis of black spot identification methods and road accident segmentation methods: Indicating road safety-related aspects in the phase of planning and operating is always a challenging task for experts. The success of any method applied in identifying a high-risk location or black spot (BS) on the road should depend fundamentally on how data is organized into specific homogeneous segments. The appropriate combination of black spot identification (BSID) method and segmentation method contributes significantly to the reduction in false positive (a site involved in safety investigation while it is not needed) and false negative (not involving a site in safety investigation while it is needed) cases in identifying BS segments. The purpose of this research is to study and compare the effect of methodological diversity of road network segmentation on the performance of different BSID methods. To do this, four commonly applied BS methods (empirical Bayesian (EB), excess EB, accident frequency, and accident ratio) have been evaluated against four different segmentation methods (spatial clustering, constant length, constant traffic volume, and the standard Highway Safety Manual segmentation method). Two evaluations have been used to compare the performance of the methods. The approach first evaluates the segmentation methods based on the accuracy of the developed safety performance function (SPF). The second evaluation applies consistency tests to compare the joint performances of the BS methods and segmentation methods. In conclusion, BSID methods showed a significant change in their performance depending on the different segmentation method applied. In general, the EB method has surpassed the other BSID methods in case of all segmentation approaches.

Andrea Bisignano, Field calibration of a low-cost sensors network to assess traffic-related air pollution along the Brenner highway: This paper presents the results of a field campaign aiming at testing the ability of a network of low-cost electro-chemical sensors to measure nitrogen dioxide concentration levels alongside one of the major Italian highway arteries. The results of a double on-field calibration, allowing for investigating the performance of the sensors under a broad range of weather conditions, are first shown and discussed. Different regression models are tested and their performance is widely assessed. Then, the measurements of the calibrated sensors are analyzed during a year-long field campaign, testing their performance against reference air quality stations and paying particular attention to different statistical indices. Results show a satisfactory performance of the low-cost sensors, highlighting their suitability to complement measurements from standard air quality stations, to reach a wider spatial coverage and to monitor pollutant concentrations in critical situations, when standard measurements are usually not feasible. Moreover, the dataset available from the year-long field campaign allows to extensively investigate nitrogen dioxide concentrations alongside the highway, pointing out in particular the strict relationship between pollutant concentration patterns and meteorological phenomena typical of Alpine valleys, such as daily-periodic thermally-driven wind systems.

III. STUDY AREA

BLACK SPOT LOCATION – GRAM RAGHOGARH (WAREHOUSE) (KM 25+900 TO KM 26+400), INDORE BETUL ROAD – NH-59A, POLICE STATION BAROTHA, DISTRICT DEWAS INTRODUCTION

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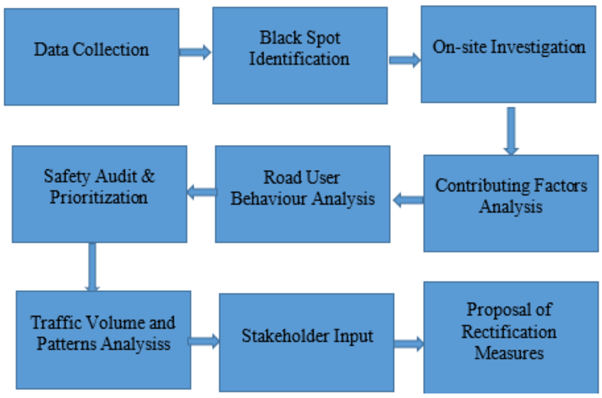
Considering the number of casualties and fatalities in road accidents on National Highways, it is of great concern to reduce the mishaps from occurring again and again as it is leading to not only loss of life and property but also impeding the economic growth of the country.

As per definition given in Ministry's OM issued vide RW/NH/15017/109/2015-P&M (RSCE) dated 28.10.2015, a Black Spot is a stretch of road of about 500m in length in which either 5 road accidents in all three years put together involving fatalities / grievous injuries took place during the last 3 calendar years or 10 fatalities in all three years put together took place during the last three calendar years. The Supreme Court of India has directed the Concerned Authorities to notify all such Black Spot locations on various types of Road. The rectification of the notified Blacks spots is also being monitored directly by the Supreme Court.

Office of Executive Engineer P.W.D. - NH Division, Indore (M.P.), has identified 4nos. of Black Spots out of the notified Black spots on Indore - Betul road, NH-59A and Khargone – Barwani road, NH-347B and invited bids from the Road Safety Experts for preparation of design estimate for carrying out long term measures including cautionary measures and/or short term measures on these 4 numbers Black Spots. After the due process the work has been assigned to Resotech Consultancy Services Pvt. Ltd., Indore, as per the work order Letter No./1437/SAC/NH/Black- Spot/Pkg-2/2020-21, dated 13.07.2020. These Black Spots are located under P.W.D. - NH Division, Indore (M.P.).

FLOW CHART



PRESENT SITUATION

The stretch under this Black Spot location is an open area. There is an existing curve of radius 400m. Existing carriageway width is 7.0m only. Just ahead of the curve at Ch 26+250 in the transition portion, there exists a warehouse (Samruddhi Warehouse & Processing Unit) on RHS of the main carriageway. The existing carriageway width is 7.0m with earthen shoulder varying from 0.85 to 1.3m only. The reason for accidents may be the inadequate with of the shoulders and Obstruction of Sight Distance (Visibility) on curve due to dense vegetation on inner side of the curve. Besides this, it is seen that the provision of entry / exit of the warehouse is directly on the Main Carriageway and not through service road or acceleration/deceleration lanes. Another reason is over-speeding of the vehicles.

Fig : Location Map of Gram Raghogarh Black Spot, Km 25+900 to Km 26+400, NH-59A

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COLLECTION OF FIELD DATA

Detailed topographical survey has been done by us in a length of 1.0km covering the entire curve stretch. A base plan showing the existing position is attached in Annexure-A1.

ISSUES IDENTIFIED

From the Road Safety Audit conducted, the following issues have been identified:

It is seen that existing carriageway width is 7.0m with earthen shoulder varying from 0.85 to 1.3m only;

Site distance is obstructed because of dense vegetation on the inner side of the Horizontal curve;

There is an existing Warehouse just ahead of the curve at Ch 26+250 on RHS, provision of whose entry / exit is directly on the existing main carriageway;

RECTIFICATIONS MEASURES

The details obtained from the field topographical survey have been studied for analysis of the existing situation and formulating of rectification measures for the black spot.

Suggested Short Term Improvement Proposals are as follows:-

Metal Beam Crash Barrier (MBCB) to be installed on the Outer Edge of the Right Hand Horizontal Curve;

Required Road Safety Signs as per IRC: 67-2012;

Required Road Markings as per IRC: 35-2015 and IRC: 99-2018;

A Plan showing the Short Term improvement Proposal is attached at Annexure-A1.

Cost of Short Term Improvement Proposals:-

The cost of the above mentioned improvement proposals (Without Service Road) has been worked out on the basis of MPPWD SOR effective from 29.08.2017 and it amounts to Rs
16.94 Lakh (including GST @ of 6% and other percentage charges).

IV. METHODS AND PROCEDURE SUGGESTED FOR RECTIFICATION OF BLACK SPOT

Improvement for Gram Raghogarh (Warehouse) Location

TRAFFIC SIGNS, MARKINGS & OTHER ROAD APPURTENANCES

Retro-reflectorised Traffic signs - Providing and fixing of retro-reflectorized cautionary, mandatory and informatory sign board as per IRC 67- 2012 made of high intensity Micro- Prismatic Grade Sheeting (Type XI) vide clause 801.3.3 fixed over Aluminium composite material sheet with thermoplastic core of Low density polyethylene (LDPE) between two thick skins/sheets of aluminium with overall thickness of 4mm and aluminium skin of thickness 0.3 on both side, the ACM shall
conform to Table 800-1 of specification and High Intensity Micro Prismatic Grade Sheeting shall conform to Table 800-3 of specification. The printing on the high intensity grade sheeting shall conform to Clause 801.3.7 with water based latex optimized transparent ink as specified by the sheeting manufacturer, supported on a mild steel angle iron post 75 mm x 75 mm x 6 mm firmly fixed to ground by means of properly designed foundation with M15 grade concrete 450x450x600mm. The ACM sheet shall be fixed to the post with four minimum four number breakaway bolts.

Informatory sign

i) Information Sign 800 mm x 600 mm rectangular
ii) Route Marker Sign 600mm x 450 mm rectangular

Cautionary/Warning Sign

i) Equilateral Triangular 900 mm
ii) Octagon *STOP* sign 900 mm
iii) Chevron Sign Boards 500mm x 600mm

Mandatory / Regulatory sign

i) 600 mm dia circular sign
ii) Hazard marker sign board - 300mmx900mm rectangular

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Direction and Place Identification signs with size more than 0.9 sqm size board.

Providing and fixing of retro-reflectorised cautionary, mandatory and informatory sign board as per IRC 67-2010 made of high intensity Micro-Prismatic Grade Sheeting (Type XI) vide clause 801.3.3 fixed over Aluminium composite material sheet with thermoplastic core of Low density polyethylene (LDPE) between two thick skins/sheets of aluminium with overall thickness of 4mm and aluminium skin of thickness 0.3 on both side, the ACM shall conform to Table 800-1 of specification and High Intensity Micro Prismatic Grade SHeeting shall conform to Table 800-3 of specification. Theprinting on the high intensity grade sheeting shall conform to clause 801.3.7 with water based latex optimized transparent ink as specified by the sheeting manufacturer, supported on a mild steel angle iron post 75 mm x 75 mm x 6 mm firmly fixed to ground by means of properlydesigned foundation with M15 grade concrete 450x450x600mm. The ACM sheet shall be fixed to the post with four minimum four number breakway bolts.Providing and laying of hot applied thermoplastic compound 2.5 mm thick including reflectorising glass beads @ 250 gms /sqm area thickness of 2.5 mm isexclusive of surface applied galss beads as IRC 35 the finishing surface to be level uniform and free from streaks and holes all complete as per clause 803 specifications.Transverse Bar Marking 15mm heightTransverse Bar Marking 5mm height

Metal Beam Crash Barrier

Metal Beam Crash Barrier; Type -A, "W" : Metal Beam Crash Barrier (Providing and erecting a "W" metal beam crash barrier comprising of 3mm thick corrugated sheet metal beam rail, 70cm above road / ground level, fixed on ISMC series channel vertical post, 150x75x5 mm spaced 2m centre to centre, 1.8m high. 1.1m below ground / rpad level, all steel parts and fittings to conform to IS: 1367 and IS: 1364, metal beam rail to be fixed on vertical post with a spacer of channel section 150 x 75 x 5 mm, 330 mm long complete as per clause 811)Providing and fixing retro-reflective stickers (Engineering grade) of size 10 cm x 5 cm on MBCBs and other structures as per MoRTH Cl No. 801 and as per approval of Engineer- in- Charge.

Road Markers/Road Stud with Lense Reflector

Providing and fixing of road stud 100 x 100 mm, die cast in aluminium, resistant to corrosive effect of salt and grit, fitted with lense reflectors, installed in concrete or asphalt surface by drilling hole 30 mm upto a depth of 60 mm and bedded in a suitable bituminous grout mortar, all as per BS 873 part 4:1973.SITC of Crystal control Road warning Blinker system with solar panel module with 300mmLED Module of minimum 190 Nos.,Blinker Units, Charging circuit, suitable SMF Rechargeable Battery(12 Volt,), including wiring, connections etc. complete in all respect.

ACCIDENTS WITH VEHICLES FROM THE SAME DIRECTION

This accident type is usually not very common on road sections between junctions. However, the accident type occurs in hilly sections where the difference in speed between different vehicles is great.

COUNTERMEASURES

Add an extra lane: Construct climbing lanes on hilly sections.

Divided four-lane road: Construct a divided four-lane road if the traffic volume is high enough to justify this.

EFFECTS

Climbing lanes can be particularly useful where there is a mix of slow and faster traffic, such as on the uphill side of a steep gradient. Advance signing, for example, “Climbing lane 1000 m ahead”, can persuade some drivers to be patient and to wait for a safer opportunity to overtake. In that case, a positive effect can be reached even before the climbing lane.

On long and steep gradients, heavy vehicles are driving slowly even downwards. Provided the traffic volume is high, a four-lane section divided by a barrier or guardrails can be effective to reduce the number of accidents related to hitting from behind. At the same time, head-on collisions will be avoided and accidents related to overtaking will be reduced. On the other hand, the number of single-accidents where vehicles hit the barrier or guardrails will be increased.

CONSIDERATIONS

With climbing lanes a clear definition of where overtaking is permitted, and where it is not, is essential. This should be done with traffic signs and with distinct lane and centerline markings. It is also essential that signs and markings are well maintained, especially at the start and end points.

The start and end points of a divided section has to be chosen in such a way that the visual guidance is clear. It is also important that the end points (terminals) of the barriers and guardrails are safely designed.

ACCIDENTS WITH VEHICLES FROM OPPOSITE DIRECTIONS

This accident type implies that one of the drivers intersects the centerline without overtaking.

This type of accident can be the result of incorrect position on the road because of deficient road markings or potholes and worn pavement due to bad maintenance. It can also depend on a driver that takes a short cut in a curve.

COUNTER MEASURES

Maintenance: Renew the horizontal markings and/or the pavement. Widening the road: Construct paved shoulders, widen the driving-lanes.

Separate the directions: Install median, concrete barriers or guardrails.

EFFECTS

The horizontal markings should generally be renewed every year. The safety effect of new horizontal markings could be a reduction of accidents if centerlines and edge-lines are renewed at the same time. The speed, however, will usually increase.

Increasing the width up to normal standard has a positive effect on both number and severity of accidents. The effect of widening already existing shoulders is uncertain.

If the directions are separated by a median wide enough to avoid over-running or by a barrier, head-on collisions can be reduced by almost up to 100 %. On the other hand, other types of accidents can increase, such as hitting from behind or single vehicles hitting the barrier. However, the severity is usually lower for those kinds of accidents.

CONSIDERATIONS

The start and end points of a divided section has to be chosen in such a way that the visual guidance is clear. It is also important that the terminals of the barriers and guardrails are safely designed.

OVERTAKING

Accidents related to overtaking could be between two vehicles in the same direction or between two vehicles in opposite directions.

In both cases, the distance to the oncoming vehicle was too short, either because the sight distance was too short due to a curve or a crest, or because the driver that made the overtaking misjudged the distance to the oncoming vehicle.

COUNTERMEASURES

Increase sight distance: Make sure that sufficient sight distance for overtaking is provided at reasonable intervals along a road section.

Add an extra lane: Construct climbing lanes on hilly sections.

Divided four-lane road: Construct a divided four-lane road if the traffic volume is high enough.

EFFECTS

A general improvement of the alignment along a road can reduce the number of accidents substantially, depending on the difference in alignment before and after.

Climbing lanes can be particularly useful where there is a mix of slow and faster traffic such as the uphill side of a steep gradient. Advance signing, for example, “Climbing lane 1000 m ahead”, can persuade some drivers to be patient and to wait for a safer opportunity to overtake. In that case a positive effect can be obtained even before the climbing lane.

Provided the traffic volume and the number of over-takings are high, a four-lane section divided by a barrier or guardrails can be effective to reduce the number of accidents related to overtaking. At the same time, head-on collisions will be avoided. On the other hand, the number of single-accidents, where vehicles hit the barriers or guardrails will probably be increased.

Considerations

With climbing lanes a clear definition of where overtaking is permitted, and where it is not, is essential. This should be done with traffic signs and with distinctive lane and centerline markings. It is also essential that signs and markings are well maintained, especially at the start and end points.

The start and end points of a divided section has to be chosen in such a way that the visual guidance is clear. It is also important that the terminals of the barriers and guardrails are safely designed.

Junctions

Single vehicle accidents

This accident type could occur when single vehicles continue straight on from the third leg in a T-junction or when single vehicles hit signs or traffic islands in a junction.

Countermeasures

Increase the visibility of the junction, especially from the secondary road approach.

Warning signs: Install warning signs saying that there is a junction ahead.

Speed limit: Change the speed limit to 70 km/h or 50 km/h through the junction.

Rumble strips: Apply rumble strips in order to increase the driver's attention and to reduce speed.

If there are many accidents during dark hours, install road lighting.

Effects

Traffic islands in the secondary road normally have a small safety effect in four-leg junctions.

A local speed limit through the junction will reduce the number of accidents and also the severity.

Lighting has a double effect. Firstly, it announces the junction in general and secondly, it makes it easier to observe traffic islands and signs as well as other vehicles etc.

Accidents with vehicles from same direction

This accident type could happen when one vehicle hits another from behind, for example, when the first vehicle has slowed down because of a stop or yield sign, traffic signals or turning movements.

Countermeasures

Visibility: Increase the visibility of the junction in order to make drivers aware of that such actions can be taken by other drivers.

Warning signs: Install warning signs saying that there is a junction ahead.

Speed limit: Change the speed limit to 70 km/h or 50 km/h through the junction.

Channelization: Provide separate lanes for left-turning and/or right-turning vehicles.

Effects

A local speed limit through the junction will reduce the number of accidents and also the severity.

A separate lane for left-turning vehicles has a positive safety effect, especially in 4-leg junctions. A separate lane for right-turning vehicles has normally no safety effect.

Considerations

When a separate lane for left-turning vehicles is used, a median, designed to give shelter for vehicles waiting in the left-turning lane, should be constructed.

Accidents with vehicles from adjacent directions

This type involves accidents between vehicles in the main road and vehicles entering from the secondary road.

Countermeasures

Speed limit: Reduce the speed limit to 70 km/h or 50 km/h through the junction.

Traffic control: If there is no regulation, install yield-sign or stop-sign in the

	approach of the secondary road. If the junction is yield- regulated, change it to stop-regulated.
Signalization:	If there is regulation, install traffic signals.
Visibility:	Make sure that the junction is visible in all approaches and that there is enough sight distance. It is important that there are no billboards, advertisement signs, etc. obstructing the sight from the secondary road towards the main road.
Lighting:	If there are many accidents during dark hours, install road lighting.
Junction design:	Increase the angle between the intersecting roads. Divide a four-leg junction: Change a four-leg junction into two three-leg junctions. Modern roundabout: If the traffic volume is similar on all approaching roads, consider reconstruction to a "modern" roundabout.
Grade separation:	If the traffic volumes are high, consider grade separation.

Effects

A local speed limit through the junction will reduce the number of accidents and also the severity.
A change from yield to stop regulation is effective in rural areas.
Modern, traffic regulated, signals have a rather good safety effect. Time-regulated signals might increase the number of accidents.
Changing a four-leg junction into two three-leg junctions normally has a good effect on accident severity, especially if the percentage of vehicles from the secondary road is high.

Considerations

The angle between the main road and the secondary road should be close to 90°.

ACCIDENTS WITH VEHICLES FROM OPPOSITE DIRECTIONS

This type involves mainly accidents with vehicles turning to the left from the main road.

Countermeasures

Channelization: Separate lane for left-turning.

Effects

Separate lane for left-turning vehicles has a positive safety effect, especially in four-leg junctions.

Considerations

When a separate lane for left-turning vehicles is used, a median, designed to give shelter for vehicles waiting in the left-turning lane, should be constructed.

ACCIDENTS WITH PEDESTRIANS

These are normally accidents in junctions between motor vehicles and pedestrians, when the pedestrians are crossing one of the junction legs.

Countermeasures

Marked pedestrian crossing: Pedestrian crossings marked with vertical signs and horizontal markings.

Channelization:	Install fences to lead the pedestrians to safe crossing locations.
Secure low speed:	Install speed reduction devices, such as rumble-strips, before at-grade pedestrian crossings. In urban areas speed humps can be used.
Signalization:	Traffic signals will separate pedestrians from motor traffic in time. Traffic signals could introduce hazards of a different kind if vehicle speeds are relatively high in the approaches to the crossing. Therefore, approaching traffic must have adequate visibility and time to stop when required.
Grade separation:	If the number of pedestrians and/or the traffic volume is high or if the number of children and elderly is significant, a grade-separated crossing should be considered.

Effects

The effect of marked pedestrian crossings is uncertain. The best effect is achieved if the marked crossing is combined with speed reducing devices.

Grade separation (over- and underpasses) is very effective, if it is used by pedestrians.

Considerations

When a marked pedestrian crossing is provided, the pedestrians could get a false feeling of safety when using it. Therefore, it is essential that the location is visible for the drivers and that a low speed is ensured.

The use of grade-separated crossings is very much depending on the location. The location should be where it is convenient for the pedestrians.

Road Safety Engineering measures for enhancement of road safety

• Safety aspect of Engineering measures related to roads is more misunderstood than it is under stood.
• Road safety through engineering measures is not 'Removing congestion on roads'.
• Road safety through engineering measures demands holistic approach and balancing in every step.
• Road safety through engineering measures has close linkage to road user psychology and socio economic / cultural milieu of the region.
• An inspired and motivated approach by all stake holders is required to bring about road safety through engineering measures.

Coordinated efforts by agencies responsible for managing different factors

• Road user education should make users aware of and skilled enough to use the road infrastructure appropriately with due consideration to fellow road users
• Enforcement should provide enough deterrence against irresponsible use of road infrastructure and negligent use of road to the detriment of fellow users.
• Road infrastructure and road side environment should guide the users into desirable paths, should prevent undesirable movements and be forgiving in case of unintentional mistakes.
• Vehicle should facilitate safe movement and protect the inmates in case of any crash

V. Conclusion

The Safe Systems Approach (SSA) aims to prevent deaths and serious injuries in road systems by tailoring the environment to human characteristics and preparing road users for traffic tasks. The Netherlands promotes Sustainable Safety and Sweden's Vision Zero policy, aiming to reduce road crashes by 50% by 2020. Engineering interventions focus on improving the road environment, focusing on the interaction between humans and road users. Road engineering should help users cope with the road by providing better signage, road markings, footpaths, pedestrian crossings, speed control devices, and channelization or segregation. Blackspot improvement programmes identify where road crashes are occurring and investigate them to determine local risk factors. Although road crash data is not comprehensive, it is crucial to identify locations with an above-average number of road crashes for investigation and treatment.

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