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A Review on the Study of Different Black Spot Identification Methods

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Abstract - *Research on the different black spot (BS) identification methodology is receiving growing interest due to the need to significantly reduce road accidents, therefore, make Roads safer and black spot-free. Numerous Black spot identification methods are developed under the different principles and techniques, but one method possibly can not fit at another scenario because of its input and different result based on shapes, size, and area. Therefore, this research then carries out an extensive literature review of different Black spot identification methods and their supportive technology to capture, analyze and simulate the appropriateness of different conditions, parameters, suitability, feasibility, and accuracy. The study identified various methods of Blackspot identification based on different principles, and different techniques and tools employed by considering different types of accidental and traffic data. The paper concludes that each BS identification method has its individual advantages and limitations.*

Key Words: **Accident Black spots, Highway, GIS, accident rates, Black spot identification methods**.

1. INTRODUCTION

The role of road transport in terms of the movements of both passengers and freight in India is very significant. Since the independence of India, demand for passenger and freight transport in the road sector has grown rapidly. With the increasing shift of traffic from other modes (viz. rail, water) to the road, the road safety problems have been unprecedently growing. As consequence, the number of motor vehicles on road increased spectacularly which causing major social and transportation problems such as death and economic losses.

World Health Organization (WHO) estimated that the road accident is a prominent cause of death for the age group of 5-29. It is found that the world suffering thirteen death per hour as a consequence of road accidents and alone India accounts for 11 % death of total world road accident death (WHO, 2021). The government of India reported that in the year 2019 around 1,51,113 persons died, and 4,51,361 people were injured (MORTH, 2019).

This tremendous human and economic losses required to be noticed by concern governmental bodies and the research community to provide effective solutions. This can be established by taking multidisciplinary approaches to understand issues and deliver a comprehensive solution. The transportation engineer is primarily involved in the issue as numerous features of the road affect the safety of the vehicles and the road user.

Mostly, the black spot is the first and most important step of road safety management. The black spot is a phrase used in road safety management that represents the place with a high rate of accidents are concentrated. Mostly black spot defines the location where many accidents have happened, and risks (severe, major, and minor) are engaged in those accidents. The cause of the Accidental black spot is normally complicated and consist of numerous factors. A previous research study showed that the key factors can be considered into four separates categories such as human factors, the vehicle, the roadway, and the environment (Dinsamo, 2018). The black spot study and its various methods are used to find out the black spot at the road section and to treat the identified spots with different countermeasures.

There are several methods developed by different researchers to identify the black spot and hazardous road sections. The different methods produced different results based on shapes, size, and area. There are many techniques to identify hazardous location occurrence areas. Overall, pieces of literature and research concentrated mostly on one type of road or condition at each time, but the various road characteristics affect the success and accuracy of the applied method. This infers that the one method possibly can not fit at another scenario. In response to the above arguments, this research paper then has the centre objective to comprehensively review the various methods based on different parameters and techniques. This would help in the selection process of the BS identification method and will address the research question that the "How different black spot identification methods can help at different scenarios".

To intimate what follows, the next section reviews different methods and approaches of blackspot identification. Findings from the review are analyzed, compared, and discussed in section. The last section concludes the paper.

2. THE CONCEPT OF BLACK SPOT

The primary goal of the road safety improvement strategy is to accurately identify the BS location. Different methods are available to identify the BS, each of them has a distinct

accuracy. Over the period, various BS methods have been employed as identification criteria of black spot, attempt to approach the real definition of the BS. Many definitions of accident black spots are available however, present research emphasizes that there is no comprehensive and universally quoted definition of what is accepted as a black spot (Geurts and Wets, 2003). Thus, black spots are defined in different ways by several scholars, transportation agencies, engineering teams, researchers, and regional safety boards. Black spot definition is mostly identified under 1. Numerical definitions. 2. Statistical definitions. 3. Model-based definitions.

3. RESEARCH METHOD

A review of various Black spot identification techniques previously employed by researchers is carried out. There are several identification methods available, and several approaches are applied in different situations due to actual requirements. It must be noted that the different developed methodologies of black spot identification are means slightly different things to researchers in a different context, for instance, BS methods can be classified based on linear and nonlinear theory approach, and the experiential learning approach. (Yuan et al., 2020).

(Dawei and Xiansheng, 2015) classified methods into accident number method, accident rate method and integrated method. Similarly, all BS methods can be classified based on various principles, techniques, or accident-related data input. Literature related to the method of black spot were reviewed to identify their appropriateness on different conditions. Different criteria for using those techniques were assessed and compared to decide on which one of them will be able to address BS accurately and without difficulty.

4. LITERATURE REVIEW

This part of the paper reviews the findings emanating from the academic literature conducted. The section is divided the literature review findings into different parts based on their type. The existing black spot identification methods include different statistical methods, accident number methods, neural network methods, conventional and GIS technology-based models, etc.

4.1 Accident number methods

There are some methods identified as accident number method such as accident frequency method, equivalent traffic accidents number method, cumulative frequency method (Dawei and Xiansheng, 2015). While the accident frequency method is simply based on the number of accidents that happened at one location. The Location with the highest accident number is ranked black spot but the method ignores other traffic factors. Whilst considering the Equivalent accidents number method, various severity index and weightage methods are developed under the principle of assigning equivalent weightage to accidental parameters.

(Thoker et al., 2018) studied four 17 km stretches of NH44 each, by using both primary and secondary data. The author used 14 years of accidental statistics from the nearby police station to find the accident patterns. Meanwhile, primary data of traffic volume count and road survey collected as supportive data during studying of accident data. Various patterns are identified, and results are concluded in this study after analyzing primary and secondary data together. It is observed that the overall rate of accidents is increasing year by year as traffic volume increases. The frequency of accidents was more on the last stretch compared to the other 3 stretches. However, diversion of road and reduction of traffic volume showed a significant drop in road accidents. The authors concluded that the primary and secondary data collection can provide an adequate amount of information to understand the accidental causes at a particular stretch. However, the detailed study of an individual black spot is not possible alone.

(Vambere et al., 2021) used Severity index method, Accident density method, and Analytical hierarchy process to identify black spots and their various causing variables independently. The accident density method was performed to find the area where the highest number of accidents occurred. The severity Index helped to determine the cause of the accident and their severity-based ranking. The methodology was performed by using the secondary data collected from the NHAI including the nature of the accident, the severity of an accident, and other accident-related details. The employed methodology helped to understand the different problems causing accidents. Analytical hierarchy process identified that the speeding of vehicles, rear end of vehicles, skidding of vehicles as a prominent reason for an accident. Further, a reconnaissance survey and other primary data were collected before providing final appropriate countermeasures for all identified black spots.

(Mathew et al., 2020) used Severity index method for identification and prioritization of Blackspot on state highway 08. The accidental spots are identified by MoRTH specification while considering accidental data from the nearby police stations. The MoRTH specification implies that the "accident black spot as a stretch of 500m road in which either five accidents (involving grievous injuries/fatalities) or ten fatalities occur over the last three calendar years". Further, the identified black spots are ranked by utilizing the Severity index method which provides more priority to fatal accidents and negates accidents having property loss.

(Krishna and Jalegar, 2017) studied Black spots and accident investigation on NH 44. The accident frequency method and severity index method were used to identify the frequency of accidents on different stenches. The Accident rate and frequency were calculated by dividing the total number of accidents in the selected section by the length of the road. Stenches with higher Accident frequency rates were considered for detailed black spot investigation. The different types of trends studied on selected stretches such as accidents based on traffic volume count, annually and monthly accidental variation trends, yearly severity-based injury trends were identified and analyzed. Further, primary data of accidental area collected such as Average Surface Texture Depth, inventory survey and subjective study of each accident. The final countermeasure was provided by analyzing all subjective and objective aspects. This study was found to be more precise as a detailed qualitative study of

each accident case performed but required enormous qualitative data, and financial, labour, and time resources.

4.2 Accident Rate method

Safety factors, the Accident rate per lakh vehicle kilometers and the critical crash rate are the most widely used methods of the Accident rate method (Dawei and Xiansheng, 2015). While considering the accident rate per lakh vehicle kilometers method, the traffic volume of the road and its length consider but it ignores the severity of the accident. In this method, if the accident rate crosses the specific index, then it considers a black spot. The critical rate method is a better method than others to show priority which finds the black spot section if one section of road crosses the critical rate.

(Apparao et al., 2013) used GIS technology to identify the Black Spots with the help of the Critical Crash Rate Method. The author defined the location as a black spot when that location's crash rate is more than the critical crash rate ratio of 1.5. In this study, all secondary accidental data attributes, and Ground Control Points (GCP) assigned to the Survey of India topographical map and geo-referencing of raster data were done. ArcGIS 9.3 was used for the complete GIS database input and georeferencing process. Further, the GIS database was used for spatial and traffic density study. The case study concluded that the Critical Crash Rate method is a flexible statistical test method to accommodate effectively on any four-lane highways. The crash ratio result was found to be helpful to identify traffic-related trends such as Black spot prioritization, day-wise or season wise accident pattern variation etc.

4.3 Fuzzy logic

It is a mathematical approach that is applied to show uncertain and imprecise information. Based on the Fuzzy logic concept various approaches are developed such as Fuzzy Multicriteria Decision Making (FMCDM), Fuzzy Rule-Based System (FRBS), Fuzzy C-Means clustering. All such approaches are either used independently or with some other methods and technology to identify BS and level of safety.

(Al-Omari et al., 2020) identified BS by using Fuzzy logic and GIS technology. Fatality and GIS-based spatial analysis helped to study accidental fatalities. The study developed Weighted Overlay Method and Fuzzy Overlay Method based framework to predict BS and Point Density (PD) method is used to verify BS.

(Murata and Cakici, 2016) developed a framework based on the Fuzzy evaluation method to determine the safety levels of black spots. The framework used cluster analysis to identify black spots and further the safety level of black spots is identified by utilizing Shannon Entropy and fuzzy logic approaches. The primary and secondary data such as accident record, traffic volume count, spot speed and geometrical and physical conditions are gathered as a parameter for demining the entropy values of black spots. Based on the entropy values of eleven black spots, the level of safety was determined from safety level first to the fourth level. Further, the framework of the Shannon Entropy approach was validated with the truth value method and the chi-square test methods. The study concluded that the Shannon Entropy and fuzzy logic approaches are very effective to determine the level of traffic safety at a specific location.

4.4 Neural network approach

The Artificial Neural network (ANN) is the advancement in the field of machine learning which is inspired by the working of the human brain neurons signals. It helps to self-learn the pattern of multi-source data from past traffic accidents. There are numerous studies carried out where a Neural network is used independently or with other methods to identify the black spots.

(Fan et al., 2019) developed a method based on a deep neural network to identify complex black spots in urban areas. Ten road accident factors and features of black spot locations are employed to perform an analysis. The research performed two different methods to identify the black spot. Firstly, the Support vector machine method was used to identify the black spot. The SVM has a capability to solve small sample nonlinear high dimensional machine learning accident patterns. Spatial nuclear density and average accident nuclear density was used to detect black segments then the spatial coordinates of accidents are matched with black segment and Black spots are identified. The author concluded that while adding four types of road section flow periods, the precision and recall rate of SVM and DNN increased substantially. An increasing amount of complex traffic data is posing a barrier for accurate and Real-time black spot identification. So, Focus must be given to the improvement of the method to handle large complex data with greater accuracy.

(Tanprasert et al., 2020) have developed a model based on semantic segmentation, distance pixel accumulation, and neural network. As a prominent feature of the presented model, it does not require any traffic or accidental data which is very helpful for developing countries where extensive black spot data is unavailable. In this research, while identifying black spot and their safety level, the surrounding of the road in the form of images was considered. This technique required data in the form of geographical coordinates of black spot, google street view images as a basic data input used for image pre-processing in the semantic segmentation and distance-aware pixel accumulation stages. Finally, the filtering process removed irrelevant object classes and retained 28 relevant components. The filtered vectors were used for the neural network learning model network to identify complex patterns. In this way, the procedure provided results for road safety predictions of black spots. The research concluded that this technique is well capable of black spot identification and classification with full surrounding environment awareness. The 69.91% accuracy was achieved for a road safety prediction from images, but the accuracy can be increased if the complete data set is available.

4.5 Subjective approach

This is a Subjective Black Spot Identification Method where data for BS identification is collected by considering views and experiences of road users and nearby residents. It is not dependable on historical accidental data. There are various mixed approaches developed by scholars where the Subjective approach is used with other methods and techniques.

(Kowtanapanich et al., 2005) developed a Subjective nature approach known as an Accident Public Participation Program (APPP). This framework assisted a black spot identification process where available accidental data is limited. The accident data of black spots collected from nearby residents helped to increase the involvement of the local community who suffered from nearby accidental spots. The APPP framework employed a regular public informed information approach and public participation tactics for subjective data collection. All gathered information was stored in a GIS-based database management system to accumulate, update, retrieve, and compare. GIS-based DMS graphically (spatially) showed data for analysis of black spot identification process.

The collected information was stored in the subjective form and the result could be biased hence subjective information was converted into quantifiable data by the statistical quality control method. This method determined the safety index and critical value to identify the black spots. As black spot identified based on subjective approach, the employed APPP model validated with accident data and all identified blackspots in APPP model validated against Rate Quality Control Method. To check the effectiveness and accuracy of the APPP model, the validation process was carried out all between identified blackspots in the APPP model against Rate Quality Control Method. The research concluded that the compared results showed statistically significant agreement between the public input data and historical accident data. And if a nearby residence identifies the accident location, then the accident rate is high.

4.7 Statistical models

Statistical models are generally identified as a mathematical relationship between one or more random variables and other non-random variables. Various accidental models have been used for black spot study such as Regression methods, Poisson distribution, Chi-Squared test, etc. (Desai and Patel, 2010) developed a regression analysis model for accident predictions Based on Linear regression techniques. The model performed a success rate and better goodness-off.

(Reddy et al., 2017) used Weighted severity Index and Chi-Square test to identify and study the black spot patterns on the Nandyal Mandal area of Andhra Pradesh. The study used seven years of accidental data from police stations. The WSI method identified 10 Black spots with the highest WSI of 559 at Nandyal – Atmakur road. The study used statistical analysis of accidents by employing the Chi-squared test method. The Chi-squared test was used to check the independence between accident severity and different time frame such as yearly, monthly, weakly. It also studied independence between accident severity and attributes like age group and vehicle types. Moreover, the Chi-squared test for goodness of fit was used to analyse the pattern of whether accidents are occurring more at a particular hour of the day or month of the year or day of the month. Countermeasure provided after identifying and studying all outcome and accidental patterns. The study concluded that the WSI method is effective to identify black spots and the Chi-squared test method is significantly effective to identify different patterns related to accident severity and other attributes.

(Dinsamo, 2018) developed an accidental prediction statistical model (a type of Generalized Linear Model (GLM)) by using available geometric and traffic characteristics. The 20 black spots are identified with the help of the point weightage method and three years of police station data. All necessary traffic data such as traffic volume study, spot speed and site investigation survey were performed. The Negative binomial regression analysis was employed with SPSS software and the result concluded that the traffic volume, spot speed, U-turns, and access points are identified as important factors for road accidents. These logical factors are employed in the developed final accident prediction model. The Pearson Chi-square test was used as a goodness-of-fit measure to check the relevance of the developed model.

4.8 Other findings

There are numerous techniques and supportive technology that have been implemented in the BS identification framework. The Application of GIS technology is highly utilized in the BS identification process by graphic method modelling techniques. In this domain, Spatial and traffic density study or Kernel density methods are other extensively employed methods to find Black spots or analyze the prediction models. Besides, intersection analysis, segments analysis, clusters analysis, density-analysis, pattern analysis, and spatial analysis are carried out by the GIS (Erdogan et al., 2008).

(Parmar et al., 2018) used GIS technology based QGIS software for Mapping and geospatial analysis for BS identification on urban roads. Different primary and secondary data, accident spot coordinates collected, and Linear referencing and datasheet prepared. Qgis 2.18 software created a buffer layer with the help of the heat map plugin and google Maps was used as a base layer. The created buffer layer showed the intensity of the accidents with the respective locations and according to MoRTH's definition BS are identified. Apart from the attempt to identify BS, land use patterns and monthly accident variations and high-density accident spots are studied. Overall Results concluded successful identification, evaluation, and countermeasures.

(Anchan et al., 2015) proposed an approach based on Remote Sensing and GIS Technology to identify and detailed analysis of black spots and further development of countermeasures. Remote sensing and GIS technology are used to generate maps which are further utilized for spatial and non-spatial data analysis. Additionally, the database and other collected data were utilized for yearly accident analysis, overlay Analysis, vehicle-based analysis, buffer zone analysis. The research concluded that the developed framework

between RS and GIS is more interoperable than the available conventional method as GIS-RS has a strong geo-referencing ability. The given framework provided more accurate data to identify the black spots and it helped in the countermeasure's development process.

Firefly Clustering Algorithm method is another example of GIS application tools where Firefly Clustering Algorithm and GIS are used to identify the black spots by providing a reference guide for the improvement of accidents in complex urban roads (Yuan et al., 2020). Besides, the Poisson regression model, negative binomial regression, negative binomial regression model, are used for crash-frequency analysis and accident prediction models. (Dinsamo, 2018).

Table -1: Extract of BS identification methods [5], [6],[19].

Method	Description	Advantages	Disadvantages
Accident frequency method	It Ranks black spots based on the number of accidents that occurred. Suitable for similar sections with low traffic.	The process is simple to compute, and the results are simply clear.	Do not consider different road, severity, and traffic conditions. Traffic volume affects accuracy.
Equivalent accident number method	The degree of severity of the accidents is considered. Accident severity is calculated by assigning Weightages to the type of casualty.	The method has social benefits. Help to analyse the severity of injury and death rate.	Do not take traffic volume and the length of the section. It is challenging to use to ascertain the weightage values.
Accident rate method	Consider the relation of road accidents number, volume, and road length.	Fully consider Traffic volume and road section.	Accident severity is not considered.
Critical rate method	Consider the traffic volume of a section to check the crash rate to the critical crash rate.	Helpful for BS prioritizatio n and analyses different accident patterns.	As critical rate changes database should be updated.
Synthesis matrix method	The degree of the risky section shows BS by using accident number and accident rate as criteria.	Method process is easy to use and flexible.	Do not have criteria so identification criteria are subjective. Do not consider severity.
Quality control method	Accident numbers are taken into Poisson distribution to find the accident rate. It is based on a hypothesis.	All traffic conditions are taken into account.	The severity of the accident is not considered. Required a lot of different data.
Fuzzy evaluation method	It uses multiple accident parameters or criteria in a mathematical model for decision-making problems.	Flexible and can be used in various conditions. No accurate data is required.	No systematic approach. Indexing is subjective.
Subjective experience method	Use views and experience of nearby road residence and road users for data collection	Useful where accident data is not available or not proper.	Subjective in nature, time-consuming.
Neural network method	It uses a machine learning concept to self-learn multi-layer accident and road data input to identify BS or accident, prediction models.	It can appraise accident patterns comprehens ively. Consider a wide range of accident data.	Results are not directly related.
Regression methods	It is based on mathematical model which checks relationship of different variables.	Different factors are considered.	Required various variable and accident data.

5. CONCLUSIONS

1. Understanding the influence of different approaches, techniques and parameters on the BS identification process while carrying out a detailed evaluation of previously employed methods have been argued by this paper.

2. The literature review was revealed that the success and precision of an applied BS identification approach are to some extend based on different available variables and parameters. Therefore, while selecting the suitable method for BS identification, the availability of the following parameters needs to be considered- A. Area (Urban, Non-Urban area). B. Type of Road (Highways, small roads, intersections). C. Types of data available (Accident data, traffic data, road condition).

3. After a careful appraisal of all the methods, the study identified that each BS identification method has its individual advantages and Limitation, even in the applicable conditions. While considering neural network and Fuzzy logic, extensive accident and traffic data is required but accident number methods are required one type of data. Further, most of the methods are considered either accident or traffic data. Even quality control method is considered various geometric and traffic parameters but evades severity study.

4. It is found that most of the approaches are a mix of different methods and techniques. To check the significance of the model as a Goodness-of-fit test, the chi-square test was extensively used among different testing approaches by researchers.

5. Since the advancements in technology, researchers are developing new comprehensive crash detection and BS identification models based on neural network and fuzzy logic. GIS technology is extensively utilized with the BS identification methods, especially for accident density analysis.

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