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Identification of Grey Spot for Accident Prevention through Road Safety Audit

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Abstract: -

Road safety continues to be a major global concern, with traffic accidents posing significant risks to public health and safety. Traditional methods of managing road safety have mainly concentrated on identifying black spots, which are areas with a high frequency of accidents. However, this reactive approach often fails to address potential risks in areas that have not yet experienced significant incidents. This study introduces the concept of grey spots, which are road sections that show potential safety risks but have not yet become black spots.

The research aims to identify grey spots along an 11.7-kilometer road with two lanes in both directions, which is an important route due to its proximity to primary schools, a college, and a hospital. The road experiences heavy traffic, especially during peak hours, as it is used by students, parents, and healthcare users. This study will use a mixed-methods approach, including environmental observation and a questionnaire survey targeting road users, to conduct a comprehensive road safety audit.

The environmental observations will focus on identifying existing road hazards, such as inadequate signage, potholes, and pedestrian infrastructure issues. Concurrently, the questionnaire will gather data on users' experiences and perceptions of safety along the road. The findings will help identify grey spots and form the basis for recommending targeted safety interventions.

By shifting the focus from reactive accident management to proactive risk identification, this study contributes to understanding road safety dynamics and emphasizes the importance of addressing grey spots. The results are expected to provide valuable insights for policymakers and road safety authorities, ultimately improving safety for all road users and reducing the incidence of accidents.

Keywords*:* Grey spot, Black spot, Road Safety Audit

1. Introduction

1.1 Introduction

Road Safety Audit (RSA) is a systematic process for evaluating the safety performance of road infrastructure projects at various stages of their development. It involves a comprehensive review of proposed or existing road designs, considering factors such as geometric layout, traffic flow, signage, and environmental conditions. The primary objective of RSA is to identify potential safety hazards and recommend mitigating measures to minimize the risk of accidents and injuries for all road users. [1]

A black spot is a specific location on a road or intersection with a significantly higher number of traffic accidents than other similar locations.

These spots are identified based on accident data collected over a defined period, typically 3 to 5 years.

Number of Accidents:

Urban Areas: 3 to 5 accidents within a single year, or 10+ accidents over 3 to 5 years.

Rural Areas: 3 accidents within a single year, or 5+ accidents over 3 to 5 years. [2]

A grey spot is a location on a road or intersection that, based on current data trends and predictive analysis over 1 to 2 years, is at risk of becoming a black spot shortly if no preventive actions are taken.

Grey spots are characterized by emerging patterns of safety concerns that may indicate the potential for increased accident frequency or severity.

The issue of road safety is a growing global concern, as millions of lives are lost and severe injuries are caused by traffic accidents each year. Governments and transportation authorities have traditionally focused on identifying and addressing high-accident areas, known as black spots. Black spot programs have been successful in reducing accidents by targeting these dangerous locations for improvement. However, the identification of black spots is a reactive approach that relies on the collection of crash data over time before interventions are put in place. This delay in addressing potential safety issues often results in avoidable accidents.

Considering the shortcomings in identifying black spots, a new preventive idea called grey spot has appeared in discussions about road safety. A grey spot denotes a specific area or part of a road system where there are potential dangers, but the number of accidents has not surpassed the threshold for being classified as a black spot. These areas might show subtle signs of safety issues, like subpar road layout, insufficient signage, or restricted visibility, but have not led to numerous documented crashes yet.

Instead of waiting for accidents to happen and then identifying the problem areas, grey spots aim to proactively identify potential risks. The objective is to recognize and resolve potential dangers before they lead to actual accidents. This proactive approach is crucial for modern traffic safety management, as it enables a forward-thinking approach to preventing accidents, in line with the vision of creating safer and more intelligent road systems.

Grey areas are discovered through road safety audits (RSAs), which involve a thorough evaluation of road infrastructure, traffic patterns, and user actions. RSAs allow auditors to analyze elements such as road layout, effectiveness of signage, safety for pedestrians and cyclists, and general road quality to pinpoint areas with potential hazards. By using this auditing method, grey areas can be identified and addressed early on, thus avoiding accidents that could happen in the future.

The idea of grey spots is becoming more popular as cities grow, more cars are on the road, and advanced road technologies are advancing quickly. As traffic increases and new roads are built, it's crucial to be able to identify potential safety issues early on. Grey spots are a new focus in road safety that goes beyond just reacting to known dangers and instead aims to actively manage risks. By addressing grey spots, road safety evaluations not only help reduce future accidents but also lead to long-lasting infrastructure improvements that make roads safer for everyone.

1.2 Background of grey spot

For a long time, road safety has been a major concern for governments, urban planners, and researchers globally. Traditionally, efforts to reduce road accidents have concentrated on identifying black spots, which are specific locations with a high frequency of crashes and injuries. Black spots are usually identified using historical crash data, which informs targeted interventions to enhance safety in these areas. However, this reactive approach addresses hazards only after accidents have occurred. [3]

To improve road safety further, a proactive approach is needed—one that identifies potential risks before they result in accidents. This is where the concept of grey spots comes in. Unlike black spots, grey spots represent locations that may not have a significant history of accidents yet but display risk factors that could lead to future crashes if not addressed. These risk factors might include poor road design, insufficient signage, lack of pedestrian infrastructure, or environmental conditions that compromise road safety under certain circumstances (e.g., during heavy rain or at night).

The concept of grey spots is relatively new and evolving in the field of road safety. It originates from the understanding that some road hazards go unnoticed or unaddressed until they cause significant harm. Grey spots aim to identify those hidden or emerging risks, making them a crucial focus for preventive safety measures.

Identifying grey spots through road safety audits (RSAs) allows transportation authorities to recognize and mitigate potential hazards before accidents occur, significantly improving road safety outcomes.

RSAs offer a systematic method to evaluate the safety performance of road networks. By combining expert analysis with on-site inspections, auditors can identify not only existing safety problems but also potential future risks. These future risks, classified as grey spots, often go unnoticed when focusing solely on black spot analysis, which heavily relies on past accident data. The identification of grey spots requires a more nuanced approach, considering factors such as road geometry, traffic volume, human behavior, and environmental conditions.

As cities and transportation networks expand, especially with the introduction of smart road technologies and sustainable infrastructure, the need to proactively address grey spots becomes even more urgent. Addressing these risks early can prevent accidents, save lives, and reduce the economic and social costs associated with road traffic crashes.

1.3 Problem Statement

Road safety is still a major issue worldwide, as traffic accidents cause a considerable number of deaths and injuries annually. Researchers have conducted several studies to pinpoint and reduce black spots, which are areas with a high accident rate. They have also created different techniques to assess and enhance the safety of these accident-prone areas through road safety audits. These audits usually use past crash data to identify black spots, which means they are a reactive method for preventing accidents.

Black spots are important for identifying dangerous areas, but they only focus on road safety after accidents have already happened. This reactive approach means that new, emerging risks might not be detected until serious accidents occur. Despite the extensive research on black spots and the effectiveness of road safety audits in finding them, there is a significant gap in proactively identifying potential accident risks in areas where crashes are not yet frequent

In this study, a new concept called "grey spots" is introduced as a response to a safety gap. Like "black spots," grey spots are road segments that exhibit early indications of safety risks, which could result in accidents if not dealt with. Unlike black spots, grey spots can be identified through safety audits before accidents happen, enabling a proactive approach to road safety.

This research aims to address the current gap in literature and practice by emphasizing proactive risk identification over-reactive measures. It will explore using "grey spots" as an innovative approach to accident prevention. The study will showcase how road safety audits can identify these grey spots and how addressing them can lead to sustained improvements in road safety.

2. Objectives

2.1 Main Objective:

- Establish clear and standardized criteria for defining and identifying grey spots based on accident trends and predictive indicators over a 1 to 2-year period.

2.2 Major Objectives

- To identify potential grey spots in a selected study area through a comprehensive road safety audit, focusing on areas with subtle safety risks not yet classified as black spots.
- To assess the effectiveness of road safety audits in identifying grey spots and evaluating their potential contribution to future accident prevention.
- To analyze the factors contributing to grey spots, such as poor signage, inadequate road design, or insufficient pedestrian infrastructure, that could increase accident risk.
- To recommend proactive countermeasures for grey spot locations identified in the study area, aiming to prevent future accidents before they occur.
- To contribute to the existing body of road safety research by filling the gap between black spot analysis and the early detection of road hazards through grey spot identification.

2.3 Significance of the study

This research presents the new idea of grey areas in road safety, addressing a significant gap in current studies that mainly concentrate on black spots. Unlike black spots, which are identified after accidents happen, grey spots are locations that currently have few accidents but still pose potential safety risks. Proactively identifying grey spots through road safety audits has several important benefits for both academic research and practical road safety management

This study introduces the concept of the "grey spot" to advance road safety research beyond reactive measures. It opens the door for future studies to investigate new aspects of accident prevention, urging a transition from addressing current hazards to identifying potential risks before accidents happen.

The research aims to improve road safety audits by showing how they can be used to identify areas with potential safety issues, making the audit process more thorough and proactive. This approach could lead to a significant decrease in accidents by addressing risk factors early on, which may not be reflected in current accident data.

Additionally, the study offers practical recommendations for policymakers, transportation authorities, and urban planners by focusing on these areas with potential safety issues. The insights from the study can help in developing proactive safety measures and policies, ultimately contributing to the creation of safer road networks and reducing the occurrence of future accidents.

3. Literature Review

The research on the Cebu South Coastal Road (CSCR)-N840 Highway in the Philippines aims to pinpoint high-risk areas using the Accident Point Weightage (APW) method along with heat mapping techniques in QGIS. Two notable locations identified are at 10.2 km (APW 106.4) and 11.4 km (APW 101.4), where severe and fatal incidents have largely resulted from sharp curves, intersections, and high traffic volumes, especially in the Talisay section. The study highlights issues such as inadequate road design, 13 junctions, 7 intersections, and 6 curves, alongside driver-related factors like speeding and fatigue. The scarcity of historical accident data and inconsistent reporting poses additional challenges for analysis. Proposed solutions involve engineering enhancements like widening curves, boosting visibility at junctions, and installing appropriate signage to rectify design deficiencies. Incorporating technology, such as automated traffic monitoring systems and GIS-based heat mapping, can help facilitate real-time assessments to focus on accident hotspots. Immediate actions like strict speed enforcement and targeted safety awareness campaigns, paired with long-term strategies including road safety audits and projects to address black spots, are deemed essential. The study concludes that a holistic strategy integrating engineering, technology, law enforcement, and education can greatly enhance road safety and decrease accidents on the CSCR-N840 Highway. [4]

The research on the NH-3 highway between Nashik and Mumbai in Maharashtra, India, examined a 96.9 km section with the Accident Severity Index (ASI) to pinpoint accident-prone areas. Key locations, notably the Sinnar Road Junction, experienced high accident rates due to speeding, vehicle skidding, and loss of driver control, especially on straight stretches and sharp turns. Challenges identified include poor road conditions, insufficient crash barriers, and flawed geometric design, exacerbated by human errors such as reckless driving. Additionally, inconsistent data collection from law enforcement hinders comprehensive accident analysis. To address these issues, the study suggests engineering improvements like better road design, installing crash barriers, and enhancing road markings, alongside real-time monitoring tools like GPS and GIS systems. Short-term actions, including speed management and stricter law enforcement, should complement long-term strategies like regular safety audits and infrastructure upgrades to reduce accidents on NH-3 effectively. [5]

The document analyzes various black spot identification techniques: Sliding Window (SLW), Spatial Auto-Correlation (SPA), and Empirical Bayesian (EB), through case studies on urban low-speed and high-speed roads. In low-speed urban areas, crashes frequently cluster around intersections, making the SPA method effective due to its clustering approach using Maron's index. SLW, with its fixed window, struggles here, resulting in inaccuracies. Conversely, on high-speed roads like Hungary's Motorway M3, crashes are more dispersed, where SLW outperforms SPA by identifying these patterns through a threshold-based method. The EB method

emphasizes the significance of speed in crash distribution, particularly on high-speed roads, which is less affected by traffic volume. The document identifies challenges, including each method's limitations and lack of detailed speed data, suggesting that combining SLW, SPA, and EB methods, along with integrating speed sensitivity, could improve black spot identification across various road types. Future efforts should aim for adaptable methods that consider comprehensive speed and traffic data. [6]

The research investigates road traffic accidents and highlights hazardous areas along Pakistan's Lahore-Islamabad Highway (M-2). Case studies pinpoint the Salt Range (223–234 km) as a significant danger zone due to its steep gradients and sharp turns, which often lead to brake malfunctions. The primary factor contributing to these incidents is human error (66.8%), followed by vehicle-related issues (25.6%) and environmental influences (7.6%). Major concerns include a high incidence of fatal accidents (35.3%), as well as problems such as drowsy driving (27.9%) and negligent driving (24.6%). The Collision Point Weightage (APW) method serves to rank these dangerous spots effectively, but its application is limited solely to this highway, making it less relevant for other areas. Proposed solutions comprise building underpasses for pedestrians and animals, installing rumble strips in steep sections, advocating for regular tire checks, and introducing alerts for drowsy drivers. Additionally, raising public awareness is essential for enhancing road safety. The study emphasizes the need to tackle human behavior and improve road infrastructure to lower accident rates, while also suggesting that future research should explore broader applications of these findings. [7]

The research evaluates road safety and identifies high-risk areas in Hyderabad, India, through a Road Safety Audit (RSA) and identifying hazardous spots. A rural road section from Rallaguda Bridge to Vardhaman College of Engineering was assessed using the iRAP tool, which assigned safety star ratings based on aspects like road design, intersection safety, and facilities for vulnerable road users. For example, dangerous intersections were particularly problematic for vehicles and motorcycles, while pedestrian crossings represented the greatest danger for foot traffic. Black spots, such as the road from Paradise to Karachi Bakery and other sites, were marked based on weighted indices and accident severity. Key issues included inadequate pedestrian facilities, unsafe intersections, and minimal amenities for cyclists. The study suggested strategies like better speed control, the addition of roundabouts, improved visibility, rumble strips, and enhanced pedestrian infrastructure with features like zebra crossings and street lighting to reduce dangers. It concludes that improving infrastructure, implementing traffic calming strategies, and tackling significant risk factors can enhance road safety, though ongoing monitoring and additional research are required for wider relevance. [8]

This study examines crash prediction models (CPMs) and their role in detecting high-risk areas to enhance road safety. Various case studies showcase the application of these models, such as Poisson distribution models in Denmark, which correlate crash rates with factors like speed limits and road types. However, they face challenges with data over-dispersion. Negative binomial models used in rural Ghana reveal the influence of traffic density and road length, while random effect models in Malaysia evaluate intersection crash rates while considering unmeasured factors. Key challenges include the limitations of conventional CPMs in adopting modern technology, biases in evaluations caused by Regression to the Mean (RTM), and selection bias from subjective variables. To overcome these, advanced methods such as the Empirical Bayes (EB) approach can adjust for RTM, and integrating diverse models can improve accuracy, ultimately making black spot identification and crash mitigation more effective. Future research should prioritize technological integration and localized safety factors. [9]

This research investigates the shortcomings of road infrastructure and their effects on traffic safety, focusing on Bojongsari Street in Purbalingga as a case study. The key findings highlight several issues, including inadequate stopping and passing sight distances, poor pavement conditions characterized by both longitudinal and transverse cracking, and notable drop-offs on lanes or shoulders. Moreover, the lack of essential road signage—such as speed limit signs, warning signs, and traffic signals—worsens safety hazards. Additional challenges include excessive vehicle speeds, insufficient road shoulder widths, and deviations from standard design practices, resulting in a high incidence of accidents. To tackle these problems, the study suggests improvements like widening road shoulders to at least 150 cm, repairing pavement defects and drop-offs, and installing vital road signage and traffic signals. In conclusion, the research emphasizes that thorough road safety assessments and infrastructure

improvements are crucial for reducing risks and enhancing traffic safety in rural areas with high accident rates. [10]

This research focuses on identifying high-risk areas and conducting a Road Safety Audit (RSA) for a segment of State Highway 27, extending about 11 km from Marimata Square to Shri Vaishnav University. The study employed the Accident Point Weightage (APW) method to pinpoint locations most prone to accidents, including Luv-Kush Square and Aurobindo T-junction. Key issues identified include encroachments that decrease the effective width of the road, unauthorized median openings, limited visibility at curves, insufficient signage, and traffic congestion stemming from poorly designed intersections and blind spots. These problems frequently contribute to over speeding and traffic accidents. Proposed solutions encompass installing speed enforcement cameras, positioning convex mirrors at blind spots, repairing damaged road medians, removing encroachments, and improving intersections to facilitate smoother traffic flow. The study also suggests introducing service lanes to ease congestion. In conclusion, it asserts that implementing an RSA and addressing the identified black spots with suitable measures can greatly lower the incidence of traffic accidents and improve overall road safety. [11]

The examination of road safety on NH-76 between Udaipur and Chittorgarh revealed several critical factors contributing to accidents. These include unauthorized openings in medians, inadequate road maintenance, and poor visibility of road markings. The analysis utilized accident severity index (ASI) values to pinpoint high-risk areas, with the segment between chainage 300+000 to 302+000 identified as particularly dangerous due to its elevated ASI. Key challenges involved peak-hour traffic congestion, accidents between heavy commercial vehicles and two-wheelers, and insufficient infrastructure, especially during monsoon conditions. Proposed solutions aim to close unauthorized median openings, enhance road markings and signage, and introduce underpasses, railings, and flyovers. The study emphasized that addressing these factors through specific measures could greatly reduce accident rates and enhance overall road safety. Additionally, it recommended implementing IRC guidelines for signage and crossings, optimizing access management, and increasing public awareness of road safety issues. [12]

The assessment of road safety policies in Asian nations highlights both significant challenges and potential opportunities. Various case studies showcase effective measures, including Brunei's holistic safe system framework, Vietnam's compulsory helmet law demonstrating high compliance, and Tamil Nadu's efforts to decrease ambulance response times. Despite these successes, issues persist, such as a lack of sufficient road safety data, elevated fatality rates among vulnerable road users (VRUs), and inadequate enforcement of traffic regulations. Suggested solutions encompass cost-effective strategies like enhanced helmet enforcement, awareness campaigns, and improvements in infrastructure for non-motorized transportation. The study emphasizes that to meet the new Decade of Action for Road Safety goal of a 50% reduction in fatalities by 2030, there is a need for strong governance, intersectoral collaboration, and the sharing of successful practices across different regions. [13]

The research on the Hulasur-Basavakalyana road in Karnataka aims to identify and address blackspots—sections of the road that frequently experience accidents. Utilizing crash data from 2017 to 2019, the study pinpointed six blackspots, mainly located in areas with dense development. The identified hazards stemmed from insufficient pedestrian amenities, numerous median openings, and unclear road markings. Key challenges included managing pedestrian crowding, visibility limitations, and inadequate signage. Proposed solutions included implementing traffic calming features such as speed bumps and rumble strips, enhancing road markings, closing dangerous median openings, and adding pedestrian infrastructure like footpaths. The study concludes that the adoption of these mitigation strategies could greatly improve safety, decrease accident rates, and create a more forgiving road environment for all users. [14]

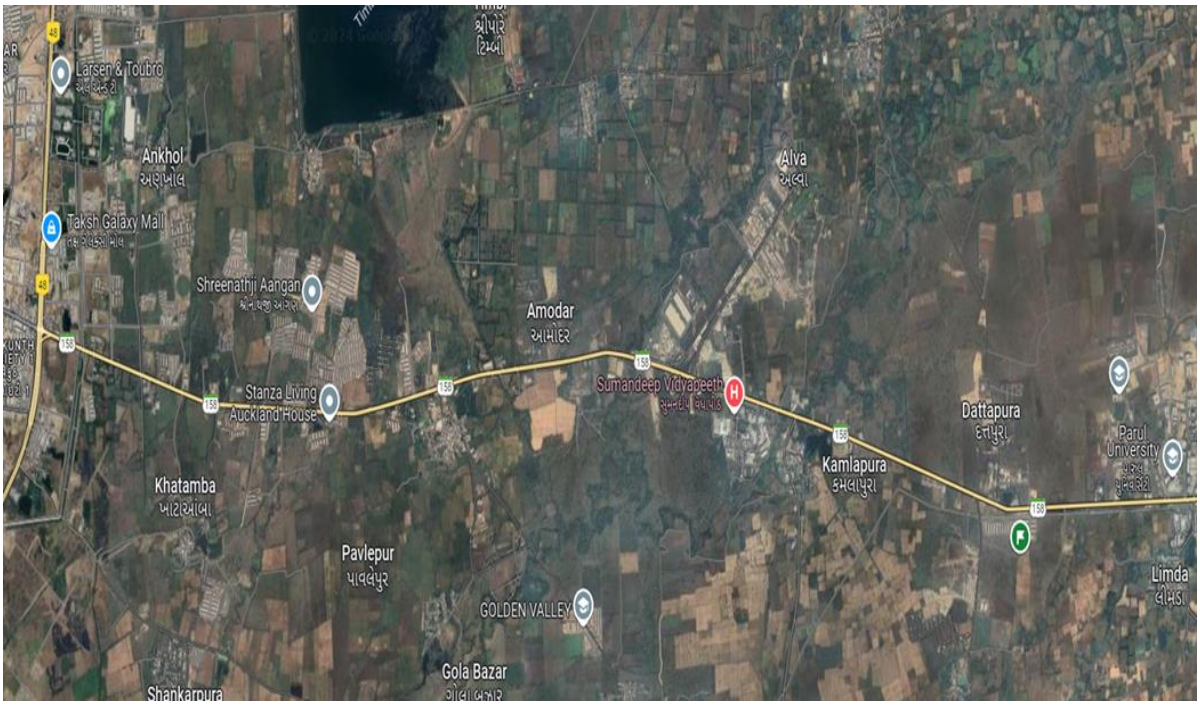
The research provides a critical analysis of how accident-prone areas, referred to as black spots, are identified and mitigated across various road networks worldwide, utilizing multiple approaches. It presents a case study from India that employs three years of crash data for specific road segments to pinpoint high-risk areas through a proactive, data-driven method. The study highlights challenges faced globally, including dependence on historical accident statistics, inconsistencies in definitions, and differing local risk factors, which complicate comparative

analyses and implementation efforts. Proposed solutions include the adoption of hybrid models that integrate statistical and non-accident-based techniques, such as the sliding window method or predictive modelling, to improve accuracy. The conclusion stresses the need for standardized definitions and methodologies at the international level to resolve uncertainties and enhance road safety. [15]

This study aims to identify and rank accident-prone areas in Amman, Jordan, by analyzing 30 road segments across seven intersections over a period from 2014 to 2016. It utilized methods like accident frequency, severity index, and rate calculations. The segment located between Al-Zamakhshre and Interchange Al-Shfaa was deemed the safest, while the route from Jordan University to Yajoz Street was identified as the most hazardous. Challenges faced included a lack of adequate traffic and accident data, methodological issues such as overlooking varying traffic volumes, and the fact that human errors were responsible for over 90% of accidents, complicating mitigation efforts solely through design. Proposed solutions involved improving traffic data collection, enforcing traffic regulations, upgrading infrastructure, and using advanced models like Empirical Bayes to gain a better understanding of high-risk areas. The results emphasize the need to tackle both infrastructural and behavioral aspects of road safety, highlighting that pinpointing black spots is an essential step in reducing traffic accidents in Jordan. [16]

4. Case Study

Vadodara – Gujarat along Waghodia road from waghodia bridge to Parul University.



Waghodia road from Waghodia Bridge to Parul University has 2 lanes two way with 11.7 Km This road is located in a heavily populated area with a lot of foot and vehicle traffic because of its close proximity to important facilities like elementary schools, a college, and a hospital.

Institutes that provide social services along Waghodia

- Gujarat public school
- Daroda public school
- Amicus International School
- Sumadeep collage and Sumadeep Hospital

Parul University and Sevashram hospital

The road faces heavy traffic, particularly during peak hours when students, parents, patients, staff, and visitors are commuting to and from schools and the hospital. This increased movement makes it more challenging to avoid accidents because of the higher number of interactions between vehicles and pedestrians.

The choice to use this road as the focus of identifying areas of concern is motivated by the pressing requirement to improve safety for everyone using the road. The high volume of traffic, the presence of people who are especially at risk on the road (like children and the elderly), and insufficient safety measures in specific locations create an excellent situation for examining potential dangers.

The study aims to conduct comprehensive road safety audits on this specific section of road to identify areas with potential risks that could lead to future accidents. This proactive approach is crucial for implementing effective safety measures to reduce accidents and ensure safer travel for everyone using this busy thoroughfare.

5. Discussion

This study emphasises the importance of actively identifying grey spots as a vital approach to enhancing road safety, shifting away from the traditional emphasis on black spots. Through thorough road safety audits, the study highlights how grey spot analysis can uncover emerging hazards such as insufficient signage, poor road design, and inadequate pedestrian facilities, which could lead to accidents if not promptly addressed.

The results underline the necessity of moving from reactive to proactive strategies in traffic management. By focusing on grey spots, policymakers and urban planners can implement specific measures that not only lower the risk of accidents but also improve the overall safety and efficiency of transportation networks. This strategy aligns with the greater goal of developing smart, sustainable transportation systems that prioritize user safety.

Moreover, the study points out the importance of merging qualitative feedback from road users with quantitative information about road conditions to provide a comprehensive view of road safety. The proactive identification and resolution of grey spots can help reduce the social and economic impacts of traffic accidents while promoting a culture of safety and awareness among road users.

Future studies might investigate the incorporation of advanced technologies, such as AI-powered predictive models and real-time monitoring systems, to enhance the methods for identifying grey spots. By expanding on this foundational research, the concept of grey spots can be integrated into contemporary road safety strategies, ultimately saving lives and ensuring safer travel for everyone.

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