

Advancement of technology in road safety: Review

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Abstract: Road traffic crashes remain a persistent global health crisis with road users facing an acute and rising risk of death. Due to high rate of fatalities on the road, the United Nations Decade of Action for Road Safety 2021-2030 stipulates that member countries need to halve the number of fatalities in their respective countries. This is a clear call that countries all over the world need to prioritise road safety, and the advancement of technology in this regard play a vital role as it could counteract factors contributing to road traffic accidents. This study attempts to examine the advancement of technology in road safety, challenges and opportunities. This qualitative article adopted the non-empirical research design: Systematic review. This study is completely based on the secondary data. A systematic review was done in detail for the collected literature. The key findings indicate that technology has improved road safety all over the world and assisted road traffic authorities in curbing fatalities on the road. The findings further indicate that misuse of technology by road users contribute to distraction on the road which lead to fatalities. Based on the findings, the researcher recommended that technology should be improved in the road traffic authorities and be maintained to assist in getting accurate results and ensure compliance to the rules of the road. It is accordingly recommended that training should be provided to law enforcement officials to have knowledge and skills about technology.

Keywords: Technology, Road Safety, Challenges, Opportunities, Law Enforcement and South Africa

Introduction

Road traffic accidents impose significant financial burdens on economies and cause severe emotional distress within societies. The urgency for road safety research has escalated, especially in light of the rapid evolution in transportation concepts and technology. These developments present new challenges but also open up opportunities for road safety researchers and practitioners (Haghani, 2020). Consequently, it is anticipated that the research landscape in this field will undergo rapid changes in the coming years, necessitating further exploration of the role of technology in enhancing road safety. While challenges persist, continued research could lead to effective strategies to reduce traffic accidents. Road safety remains a global issue, with the World Health Organization identifying road traffic injuries as the eighth leading cause of death worldwide across all age groups (Institute of Electrical & Electronics Engineers, 2023). Additionally, many regions, particularly low- and middle-income countries, lack the technological infrastructure needed to ensure safer roadways, where fatality rates are higher. Therefore, providing access to advanced road safety technologies is crucial for making roads safer globally. Technologies such as body-worn cameras, speed cameras, and breathalyzer testing equipment have proven effective in improving road safety by regulating traffic, apprehending offenders, and enhancing overall safety. Recent studies suggest that the root problem often lies not in drivers' abilities but in their choices, highlighting the importance of understanding the motivations behind risky behaviors. Since transportation is indispensable for any country's existence and development, roadways play a critical role in national growth. However, they also bring significant dangers to society (Deekshith, 2023). The current situation calls for innovative solutions to address these challenges, especially as the world becomes increasingly fast-paced with new technologies. These advancements have the potential to make driving and roads safer by reducing the incidence of traffic accidents. Improving transportation and leveraging technology has consistently shown promise in addressing road safety issues (Deekshith, 2023). This article focuses on exploring the advancements in technology related to road safety, examining both the challenges

and opportunities in reducing road traffic accidents, and proposing practical solutions based on international standards and practices

Problem Statement

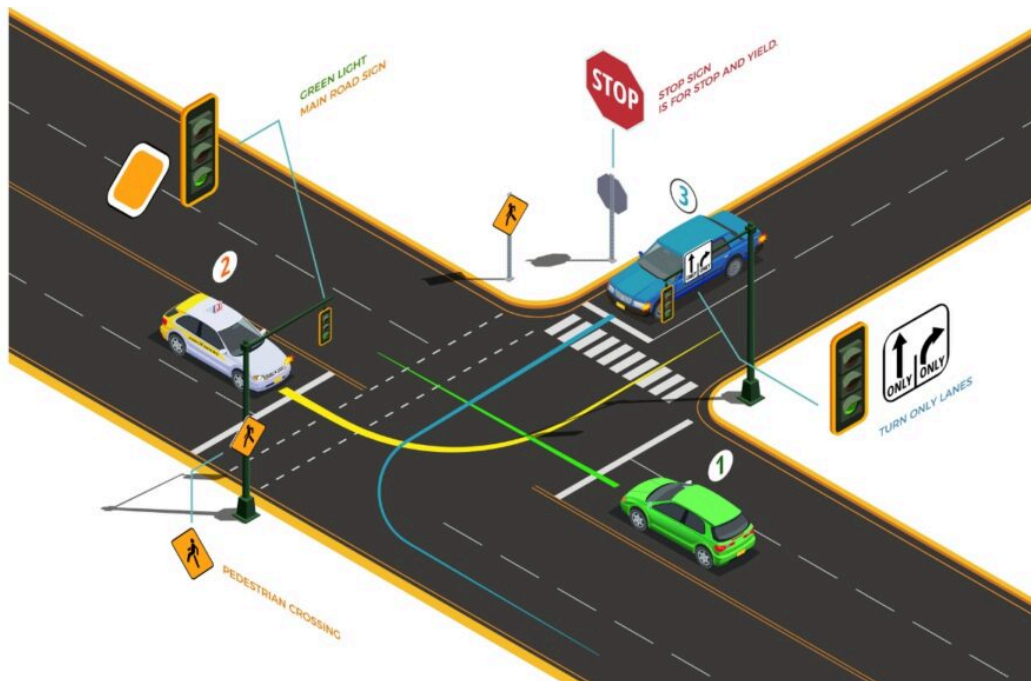
Traditionally, road safety research has focused on the idea that accidents result from a failure to manage the perceptual and motor skills needed for safe driving, with efforts aimed at enhancing drivers' abilities. However, between 1 December 2022 and 11 January 2023, 1,451 people lost their lives on South African roads (Road Traffic Management Corporation, 2023). The rate of road traffic fatalities in South Africa remains alarmingly high, imposing a significant burden on families, society, and the economy through lost productivity, diminished skills, and the emotional and financial toll on survivors and bereaved families who are left without providers. A major factor contributing to this issue is the lack of technological systems in road safety, which leads to widespread non-compliance among road users. To bring about meaningful and lasting improvements in road safety, it is crucial to address these challenges comprehensively. Priority should be given to significantly reducing the high percentage of road users who do not comply with traffic regulations, and the South African government must advance the use of technology to decrease the number of fatalities on the roads.

Methodology

The research employed a qualitative methodology, gathering material from relevant sources and evaluating it within its context without relying on quantitative methods. The researcher conducted a literature review from January to September, spanning a nine-month period, focusing on challenges in recruiting new members and the professional crises within law enforcement agencies. Given the nature of the data required for this study, the research predominantly utilized secondary data sources to compile relevant information. During this process, documented and historical data were extracted from pertinent publications, magazines, government gazettes, and other sources. The collected data were then condensed and critically examined through content and contextual analysis, leading to the extraction of relevant and useful information. This approach employed deductive synthesis, with the synthesized analytical findings presented in various sections of the study, aligned with the discourse's stated objectives.

Technology in road safety

The global increase in the number of vehicles on the roads is causing significant challenges, including unmanageable traffic congestion and a substantial rise in environmental pollution. It's evident that effective traffic management systems are essential to streamline the flow of traffic (Infosys BPM, 2024). Currently, road safety management systems primarily rely on manual data collection, visual inspections, and subjective expert judgments, which are often costly, time-consuming, and prone to inefficiencies due to underreporting, poor data quality, and corruption within the traffic environment (Torbaghan, Sasidharan, and Muchanga-Hvelplund, 2022). However, various innovations have the potential to enhance data collection and analysis, thereby improving road safety. The adoption of new technologies such as smart traffic lights, advanced traffic control systems, artificial intelligence, telematics, and automotive technologies can significantly reduce road accidents and improve safety (United Nations Institute for Training and Research, 2019). Additionally, mobile networks and fast data transmission solutions can be utilized to gather information on vehicles, road conditions, and provide real-time weather updates and warnings. In the 21st century, traffic policing must embrace technology to enhance road safety. It is crucial for traffic authorities to prioritize the use of reliable technologies to capture data and monitor road activities accurately. Digital technologies, including Artificial Intelligence (AI), Machine Learning, Image Processing, Internet of Things (IoT), Smartphone applications, Geographic Information Systems (GIS), Global Positioning Systems (GPS), drones, social media, virtual reality, simulators, radar, sensors, and big data, offer valuable tools for analysing road safety factors, such as road user behaviour, road conditions, and the operational environment (Torbaghan et al., 2022). The findings indicate that digital technologies like AI, Image Processing, and IoT have been extensively applied to improve road safety by automatically capturing and analysing data, thereby minimizing the risk of human error.



Artificial Intelligence in automobiles

Artificial Intelligence (AI) is quickly transforming the automotive sector and revolutionizing road safety. AI technologies are being integrated into vehicles, making driving safer than ever before. These intelligent systems are becoming more advanced, enabling cars to drive autonomously, detect potential hazards, and provide real-time assistance to drivers (Emerging India Analytics, 2023). The concept of self-driving cars, once seen as a distant possibility, has now become a reality due to advancements in AI technology. These smart vehicles use sensors,

cameras, and software algorithms to navigate roads without human intervention. The ability of these systems to process vast amounts of data and make split-second decisions has greatly reduced the risk of accidents caused by human error. AI is now used in nearly every aspect of vehicle manufacturing (Schroer, 2024). Examples of AI applications in the automotive industry include industrial robots assembling vehicles and autonomous cars navigating traffic using machine learning and computer vision. One of the primary benefits of AI in automobiles is the enhancement of safety and security features. AI-powered collision avoidance systems play a significant role in preventing accidents. By constantly monitoring the environment and analysing sensor data, these systems can identify potential collision hazards, issue warnings, or even take actions to avoid accidents. The Driver Fatigue Monitoring System is designed to prevent accidents by detecting when a driver is tired or drowsy and alerting them to take a break, helping to protect both the driver and others on the road. Additionally, AI can help drivers make informed decisions by communicating with them about the vehicle's condition, even when the car is not functioning optimally. AI-powered driving support systems offer a comprehensive solution to the critical issue of road safety. These systems use a combination of sensor technologies, including LIDAR (Light Detection and Ranging), radar, and high-resolution cameras, paired with advanced AI algorithms (Sharma, 2023). Moreover, AI processes real-time data from these sensors to perform essential functions like automatic emergency braking, lane-keeping assistance, and adaptive cruise control. This technology is particularly effective in reducing accidents caused by human errors, such as distraction or poor judgment. While many safety measures are in place to reduce the frequency and severity of accidents such as airbags, seatbelts, rollover protection, and speed regulations AI and deep learning in autonomous vehicles offer an increasingly vital life-saving role (Ranganathan, 2022). In conclusion, technology holds immense potential for enhancing road safety and reducing accident rates. Innovations like Advanced Driver Assistance Systems (ADAS), vehicle connectivity, AI, and educational tools are contributing to the development of safer roads. It is essential for governments, car manufacturers, and industry stakeholders to continue investing in these technologies to achieve a future where road accidents are minimized and road safety is significantly improved.

Technological devices in road safety

Body worn camera

In response to increasing demands for greater police accountability in South Africa, Cape Town law enforcement officers are being outfitted with body-worn cameras and in-vehicle cameras featuring Automated Number Plate Recognition (ANPR) technology (BusinessTech, 2023). This initiative is a pioneering effort in South Africa and is part of Cape Town's R860 million safety technology investment over the next three years to enhance city safety. This year (2023-2024), the city plans to equip 800 law enforcement officers with bodycams and install 290 dashboard-mounted cameras, also known as 'dashcams,' in their vehicles. Body-worn cameras are devices that can be worn by officers to record videos, audio, and capture images of people or locations. These cameras document events involving law enforcement officers, as well as interactions between officers and the public (Norden, 2024). Typically, these devices are worn on the officer's uniform torso, but they can also be attached to the chest, helmet, or hat. The cameras often come with a small touch screen and operate on the Android system. Depending on the circumstances, the recorded footage can be transmitted to a control centre using 3G/4G, Wi-Fi, or Bluetooth technology, enhancing their functionality and convenience. Research indicates that the presence of these cameras can decrease the likelihood of confrontations and, in cases where incidents do occur, provide crucial evidence for police investigations and legal proceedings (National Highways, 2022). Traffic officials play a vital role in ensuring public safety and maintaining smooth road network operations. They are often the first responders to incidents, assisting in clearing obstructions, managing broken-down vehicles, or supporting emergency services. However, despite their primary role of helping, they increasingly face abuse, including verbal assaults, threats, and physical attacks, while performing their duties. During on-the-ground law enforcement activities, it is not unusual for officers to encounter confrontations, whether they are issuing parking tickets, enforcing rules, or managing crowds during protests, which can sometimes escalate into riots. In the age of social media, anyone can broadcast events and share personal views on controversial situations (Hytera, 2024). To accurately document what transpired, the officers' first-person recordings, including video and audio, become crucial evidence in legal trials. To enhance transparency, deter violence, and improve trial efficiency, more governments and public safety organizations around the world are advocating for or enacting legislation to require the use of technologies like body-worn cameras (Mzenkandaba, 2023). As a critical tool for law enforcement globally, body cameras provide trustworthy visual and audio evidence that verifies events, records statements and behaviour, and boosts transparency with the community (Safe Fleet, 2023). Additionally, these cameras are praised for their ability to enhance transparency, accountability, public trust, and safety by deterring illegal activities. There is substantial evidence showing a significant reduction in attacks on law enforcement officers following the introduction of these cameras, and they provide valuable evidence for legal

proceedings. Moreover, these devices could help combat corruption on the roads and ensure consistent enforcement of the law, thereby contributing to road safety and protecting both law enforcement officials and the public

Breathalyser testing equipment

Alcohol remains the most widely consumed substance in many countries, including South Africa, and it is a leading factor in addiction. Individuals whether drivers or pedestrians who have high blood alcohol levels are significantly more likely to be involved in road traffic accidents. This results in more vehicle crashes, property damage, injuries, and fatalities. Consequently, incorporating routine breath tests for corporate fleet drivers, alongside comprehensive vehicle tracking and data monitoring, becomes not only a sensible choice but a prudent investment (Teltonika, 2024). The dangers associated with drinking and driving are numerous: slower reaction times, impaired coordination, diminished concentration, reduced vision, and poor judgment. Unfortunately, alcohol consumption or driving under the influence has been a well-known roadway hazard since the early days of the automobile industry. This issue leads to increased insurance premiums, higher taxes, and various human, medical, and property-related costs. Additionally, the emotional toll on family, friends, and colleagues includes grief, sadness, anger, and even thoughts of revenge. A breathalyser is a diagnostic tool that measures the alcohol content in a person's exhaled breath, which can be used to estimate blood alcohol concentration (BAC) and determine how much alcohol is present in the bloodstream (Medical News Today, 2023). The use of breathalysers can significantly reduce the number of motor vehicle accidents involving drivers impaired by alcohol, as these devices measure the alcohol concentration in a person's breath to determine if they are too intoxicated to drive safely. The combination of drinking and driving is highly dangerous, putting road users at considerable risk of being involved in traffic accidents. Initially, drivers are screened for alcohol impairment at the roadside using a portable device. If the test is positive, a more formal breath test is conducted at a police station (National Library of Medicine, 2024). Police officers can stop motorists and administer breath tests at the scene of an accident if they suspect that the driver may be under the influence of alcohol or if the driver commits a traffic violation. Driving under the influence of alcohol or drugs is one of the most prevalent causes of road accidents, and random screenings are crucial for identifying offenders and removing them from the roads immediately (Drager, 2024). Given the statistics showing that breathalysers are effective, it is essential for enforcement officials to adopt these safety measures to enhance road safety (Yousif, Alali, Aldakhi & Zohdy, 2021). Implementing such measures would contribute to improved road safety while simultaneously fostering a culture of road safety and accident prevention strategies.

Speed camera

Drivers traveling at higher speeds have less time to perceive and respond to their surroundings, resulting in longer stopping distances and more severe crashes. These collisions tend to cause greater injuries to the vehicle's occupants and any pedestrians or cyclists involved (Royal Society for the Prevention of Accidents, 2021). Additionally, elevated speeds intensify the severity of injuries in accidents, with approximately two-thirds of fatal or injury-causing crashes occurring on roads with higher speed limits. Various studies have established a link between a driver's chosen speed and the seriousness of accidents, suggesting that higher speeds increase the likelihood of crashes. This raises the question: what strategies are most effective in reducing speed-related accidents? Speed cameras are widely regarded as a critical tool in decreasing road traffic accidents. Addressing traffic-related deaths and injuries is a significant global public health concern. Road Traffic Authorities must pinpoint accident hotspots and install speed cameras, as many incidents result from excessive speed. Speed enforcement equipment is deployed following specific guidelines and is monitored by a Traffic Officer designated under Section 3 of the Road Traffic Act 93 of 1996 or a Traffic Warden declared a peace officer under Section 334 of the Criminal Procedure Act, Act 51 of 1977. Increased enforcement, including automated speed limit enforcement, is a common approach to enhancing speed compliance and reducing average speeds. Countries have adopted camera-based enforcement systems, such as spot speed cameras, which monitor speed at a specific location, or section control systems, which automatically enforce speed limits based on the average speed over a road segment (Vadeby, 2023). Lowering speeds and enhancing compliance are essential for improving road safety, as these factors are integral to many Safe System interventions. Speed cameras have proven effective in promoting speed compliance and decreasing the number of fatalities and serious injuries (Vadeby & Howard, 2024). These cameras are crucial to road safety, as many drivers adhere to speed limits when they are aware of cameras or the presence of law enforcement. Various methods have been employed to curb speeding, including speed humps, setting speed limits, and using speed cameras. However, speed cameras are considered a highly cost-effective way to control vehicle speeds and reduce road accidents (World Health Organisation, 2017). Numerous countries have adopted this technology to lower crash rates, and automated traffic enforcement systems—mechanical devices that automatically record violations—capture both vehicle and driver information when a traffic offense occurs (Al-Masaeid, Mujalli & Al-Haj, 2020). This

technology enables the recording of violator information, and after processing the data, the vehicle and driver can be identified, allowing for the issuance of appropriate penalties

Misuse of technology in road safety

Each year, approximately 1.19 million people lose their lives due to road traffic accidents, making road traffic injuries the leading cause of death for children and young adults aged 5–29 years. Notably, 92% of these fatalities occur in low- and middle-income countries, despite these regions having only around 60% of the world's vehicles (World Health Organisation, 2023). Moreover, more than half of all road traffic fatalities involve vulnerable road users, such as pedestrians, cyclists, and motorcyclists. These accidents impose significant economic costs, with most countries losing about 3% of their gross domestic product due to road traffic crashes. In response, the United Nations General Assembly has set a goal to halve global road traffic deaths and injuries by 2030 (A/RES/74/299). Consequently, countries worldwide are prioritizing road safety and implementing comprehensive measures to improve road traffic systems, including enhancing vehicle safety, upgrading road infrastructure, and promoting better driving practices (World Health Organisation, 2018).

Accidents can happen in an instant, which is why it is crucial to stay focused on driving, keeping your eyes on the road, your hands on the wheel, and your mind on the task at hand to ensure the safety of yourself and others, including cyclists and pedestrians (Supa Quick, 2019). According to the 2018 International Transport Forum's (ITF) Annual Road Safety Report, South Africa has one of the highest road crash rates globally, with distraction increasingly identified as a significant road safety issue. The Road Traffic Management Corporation (RTMC) of South Africa highlighted in its February 2016 report that inattentiveness and distracted driving have become leading causes of single-vehicle crashes, particularly among young people (Supa Quick, 2019).

While modern technology has significantly enhanced driving safety through innovations such as automatic braking systems and advanced airbag technology, which have prevented countless accidents and saved lives (Knowles Law Firm, 2022), it has also contributed to an increased risk of accidents. Technology's dual impact on road safety is evident, as it has both reduced and exacerbated the number of traffic accidents over time. Distractions from smartphones and dashboard infotainment systems, as well as over-reliance on driver-assistive technologies, can lead to slower reaction times and poor decision-making while driving. Globally, distracted road users are a significant factor in the high rate of traffic accidents, a problem that is also prevalent in South Africa, where many road users lose their lives due to distraction (Modipa, 2022). The failure of road users to adhere to traffic regulations concerning the use of cell phones, driving or walking while impaired, and other distractions is a significant issue in South Africa. Road users must remain focused on the road, adhere to traffic laws, and avoid distractions that could result in fatalities, as is often the case on South African roads (Modipa, 2023).

Distractions occur when drivers or pedestrians shift their focus from the road, often due to the use of technology, which is illegal while driving as it hampers their concentration. For instance, using a phone for talking, texting, or browsing reduces a road user's ability to maintain lane discipline, recognize changes, and respond promptly. Additionally, drivers engaged in phone conversations are more likely to speed or maintain inconsistent speeds (Youth for Road Safety, 2022). Texting while driving, even at low speeds, is extremely hazardous due to delayed reaction times and difficulties in maintaining lane positions and assessing traffic conditions. Distracted driving encompasses activities like sending texts, talking on a phone, using a navigation system, and eating while driving or walking. Such distractions contribute significantly to the high incidence of road fatalities. Despite being illegal, distracted driving does not carry the same societal stigma as drunk driving. Many drivers routinely engage in non-driving-related tasks using increasingly complex and accessible technological devices (Allianz, 2023). The widespread use of mobile phones and onboard computers, particularly smartphones, has become a normal part of daily life, and with the growing number of potential distractions in modern vehicles, road users are increasingly at risk of traffic accidents

Findings and discussions

Advancement of technology in road safety

The key findings revealed that technological systems globally have been effective in promoting road safety, including tools such as body-worn cameras, speed cameras, and breathalyser testing equipment. These systems facilitate traffic management, law enforcement, and overall road safety enhancement. Various innovations present opportunities to improve the collection and analysis of data to further enhance road safety measures. The implementation of advanced technologies, such as smart traffic lights, traffic control systems, artificial intelligence,

telematics, and automotive technology, plays a significant role in preventing and reducing road-related accidents, thus improving road safety (United Nations Institute for Training and Research, 2019).

Digital technologies like Artificial Intelligence (AI), Machine Learning, Image Processing, Internet of Things (IoT), smartphone applications, Geographic Information Systems (GIS), Global Positioning Systems (GPS), drones, social media, virtual reality, simulators, radar, sensors, and big data are valuable tools for identifying and analysing road safety factors, including road user behaviour, road conditions, and the operating environment (Emerging India Analytics, 2023). The findings suggest that digital technologies such as AI, image processing, and IoT have been extensively utilized to improve road safety, largely due to their ability to automatically collect and analyse data, thereby reducing the likelihood of human error (Torbaghan et al., 2022). Technology holds significant potential to enhance road safety and reduce the frequency of accidents. Innovations such as Advanced Driver Assistance Systems (ADAS), vehicle connectivity, AI, and educational resources are playing a crucial role in creating safer road environments. It is essential for governments, car manufacturers, and industry stakeholders to continue investing in these technologies to achieve a future where road safety is maximized, and accidents are minimized.

Misuse of technology in road safety

The findings show that the misuse of technology by road users contributes to distractions that can lead to fatal accidents. While technology has improved road safety in many aspects, it has also, in some instances, increased the risk of car accidents. Consequently, technology has had a dual impact on the frequency of road traffic accidents, leading to both increases and decreases over time. For example, drivers may become distracted by smartphones or dashboard infotainment systems. Additionally, reliance on driver-assistive technologies can cause drivers to become overly relaxed, resulting in slower reaction times and poorer decision-making while driving. When drivers or pedestrians use their phones for activities such as talking, texting, or browsing the internet, their ability to maintain their lane, respond to changes, and react in a timely manner is significantly reduced. Moreover, drivers engaged in phone conversations are more likely to speed and exhibit inconsistent driving behaviours (Youth for Road Safety, 2022).

Although these technological systems are intended to enhance safety, they can inadvertently promote over-reliance, leading drivers to engage in distracted driving with the mistaken belief that the technology will compensate for their inattention. This false sense of security can potentially increase the likelihood of accidents since these systems are not infallible and still require the driver's full attention (Steinberg Law Firm, 2024). Additionally, some safety systems may introduce new hazards, such as emergency braking systems misinterpreting cues and causing rear-end collisions when the driver had the situation under control.

Conclusion and recommendations

This article aims to analyse the advancements in technology related to road safety, focusing on both the challenges and opportunities that could be leveraged to reduce the number of road traffic accidents. The article acknowledges that South African law enforcement agencies have a robust legislative framework and effective strategies for decreasing the high rate of road fatalities. With consistent enforcement of laws by officials and adherence to road rules by users, many lives could be saved. Factors such as human behaviour, vehicle conditions, and environmental aspects contribute significantly to road fatalities. The introduction of technology in road safety has the potential to greatly reduce traffic accidents worldwide, though it also brings disadvantages, including distractions like texting while driving, in-car infotainment systems, and risks such as cyber-attacks.

Technology is becoming a crucial ally in the global effort to reduce road traffic accidents, with research highlighting its vital role in achieving the United Nations Decade of Action for Road Safety goals, where member states are tasked with halving their road fatalities from 2021 to 2030. Innovations such as advanced driver assistance systems (ADAS), which include features like collision alerts, automatic emergency braking, and blind-spot monitoring, are designed to prevent accidents through warning signals and automatic interventions when necessary. If these technologies are successfully implemented with the support of law enforcement, the 2030 target can be achieved.

Based on the findings, the researcher recommends enhancing and maintaining technology within the traffic environment to ensure accurate results and compliance with road safety regulations. It is also suggested that law enforcement officials receive training to develop the knowledge and skills necessary to effectively use technological devices in law enforcement and to support the technology already installed on roads. Furthermore, road users should avoid using technological devices while driving, as these distractions are a major cause of road traffic accidents. Road safety is a shared responsibility, and all stakeholders must actively contribute to ensuring a safe and secure traffic environment.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy.

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