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Research Article **Open Access**

Unveiling the impact of speed control cameras on urban crashes in Tabriz city, Iran: A GIS-based analysis

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Abstract

Background: Crashes in Iran annually lead to devastating consequences, resulting in loss of life and significant property damage. To mitigate these impacts, the deployment of fixed and mobile speed control cameras has been adopted as a strategy to regulate traffic and improve road safety.

Objectives: The aim of this study was to examine the behavior of drivers when approaching speed control cameras and their influence on crash occurrence.

Methods: Fatal crash data from three consecutive years (2020-2022) were collected and analyzed using the Geographic Information System (GIS) in Tabriz City. Approximately 27 speed cameras located in crash-spots were investigated within 100-meter sections, both preceding and following the cameras.

Results: The results showed a significant reduction in fatal crashes within a 500-meter radius before the speed control cameras. However, crashes were more frequent within distances ranging from 500 to 1000 meters before the cameras, primarily occurring during the night. After passing the cameras, daily crashes increased, with incidents primarily involving pedestrians due to driver inattention occurring within the 500-meter range after the camera's location.

Conclusion: The present study not only emphasizes the potential of speed control cameras in promoting safer driving behaviors, but also stresses the importance of conducting further investigations on drivers' behaviors after passing the speed control cameras to enhance road safety measures.

Keywords: Speed control cameras, Fatal crashes, GIS, Spatial analysis.

Introduction

Health institutions are concerned about road accidents, causing significant health issues and 1.3 million fatalities in low- and middle-income nations in 2019.[1] Factors contributing to these accidents include speeding, inadequate infrastructure, non-compliance with traffic regulations, and insufficient enforcement of safety measures. These accidents have significant impacts on families, society, and the economy, including healthcare costs and productivity loss.[2] Iran faces significant challenges in road traffic accidents, resulting in fatalities, injuries, and economic losses annually.[3,4] In the past three years (2020-2022), nearly 350 individuals in our city, Tabriz, have lost their lives in crashes, and over 11,000 people have been injured or disabled. Various factors can contribute to causing a traffic accident,[5] with human errors being a significant aspect.[6] Negligence in addressing these errors can diminish the overall enjoyment of driving. Among these errors, speeding stands out as the most significant, intensifying crashes and often resulting in fatalities.[7,8]

As a result, speed limits are implemented in many countries to control vehicle speeds.[9] Numerous studies have identified excessive speed as the primary factor contributing to the severity of injuries.[10,11] Exceeding the speed limit is considered risky and accident-prone driving.[12,13] High speed reduces the driver's field of vision, decreases reaction time and decision-making ability, and increases the intensity of collisions, resulting in more severe injuries.[14–16]

One solution for speed management on main roads is the use of speed control cameras, which can manage driver behaviors and promote calmness.[17] Installing speed cameras throughout the network is a costly measure for road safety.[18] Research has been conducted on the impact of speed cameras on reducing crashes and fatal injuries, demonstrating their significant influence on driver behavior and safety within the camera enforcement area.[19,20] Notably, a study by Shahab Hasni Nasab et al. in 2018 divided the camera installation area into three sections: the pre-camera zone, the central zone, and the post-camera zone, and collected data related to drivers' speeds in these three sections, revealing a lack of consistency and association among driving speeds in these zones.[21]

In another study conducted by Christie et al. in 2003, a controlled before-and-after study compared two methods to assess the effectiveness of mobile speed cameras:[22] a radial approach and a linear approach. The locations where speed cameras were installed showed fewer injuries within a radius of up to 300 meters in the radial study and up to 500 meters in the linear study. The route-based method proved to be the best approach for measuring effectiveness within distances of up to 500 meters, showing a 51% reduction in injuries from crashes.[23]

However, it is evident from the research conducted that the positive effects of fixed-speed cameras increase as drivers approach them and decrease as they move away.[24,25] However, safety management planners need to know these distances and determine the effective range of speed control cameras. Necessary measures should be taken in this regard. The most prominent innovation in this article is determining the effective range of speed cameras by examining 100-meter sections in 20 segments, assessing the impact of active or inactive speed cameras, and analyzing the time pattern of crashes in these 20 segments.

Objectives

This present study was conducted to answer the question of how many meters are in the safe zone for speed control cameras, and what is the time pattern of crashes in different segments, and does the activation or deactivation of speed cameras have any effect on driving crashes?

Methods

The study adopted a retrospective observational design to analyze the distribution of traffic accidents in relation to the installation of speed control cameras. The design involved collecting historical data on traffic accidents that occurred within a specified radius (1000 meters) of speed camera locations in Tabriz city over the past three years. The aim of the study was to assess the impact of these speed control measures on accident rates by comparing accident data before and after the installation of the cameras. Moreover, this study focused on both linear and radial routes to provide a comprehensive analysis of accident patterns in the vicinity of the speed cameras. The study process is shown in Figure 1.

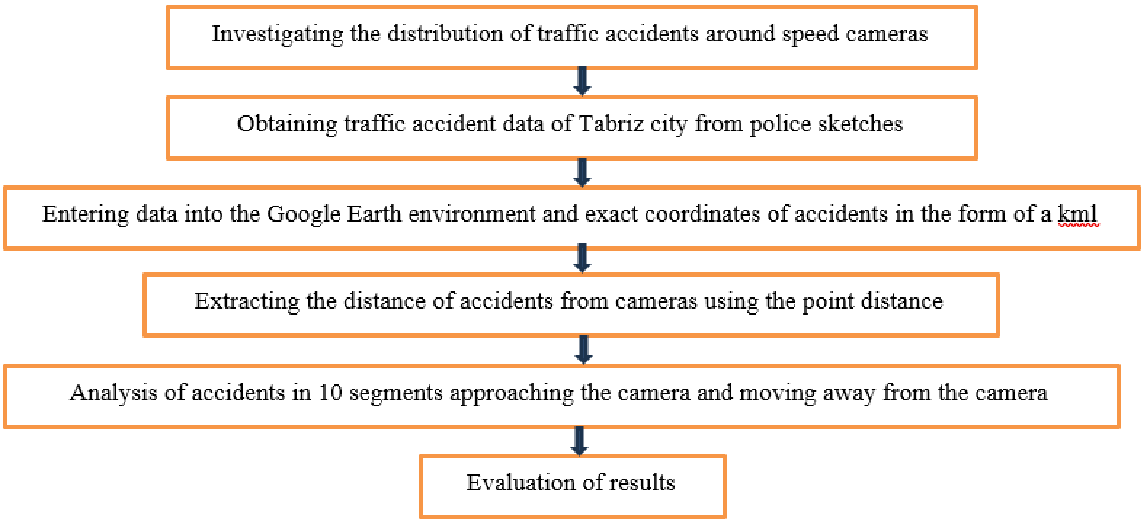

Figure 1. Study process

There are various methods and approaches for determining the safe zone of speed control cameras. In this study, the crashes of the past three years (2020–2022) in Tabriz city were obtained from the road maps of East Azerbaijan province and entered into the GIS database. The geographical positions of 27 speed control cameras were also separately added to the GIS as individual layers. Using the point distance function, distances ranging from 100 meters to 1000 meters from the speed cameras were scanned in 100-meter intervals, and the crashes that occurred within these radii were extracted. Then, considering the distance-response to crashes, the crashes associated with each camera within the calculated radii, both before and after the camera, were linearly analyzed. Both before and after the camera specifically refer to data points collected at various distances before a vehicle reaches the camera location and after it passes the camera.

Outliers were removed, and ultimately, after extracting the accident status within the mentioned radii, variables such as camera activation or deactivation, temporal patterns of crashes in camera zones, and spatial and temporal analysis were conducted, and suitable suggestions were made. In this study, the point distance function was applied to assess the radial distances of accidents on the map. Given that speed control cameras operate linearly, influencing only the area along their path, data points outside this path were excluded after identifying the spatial boundaries of camera-related incidents. Figure 2 depicts the number of crashes on linear and radial routes within a 1000-meter radius of speed cameras in Tabriz City.

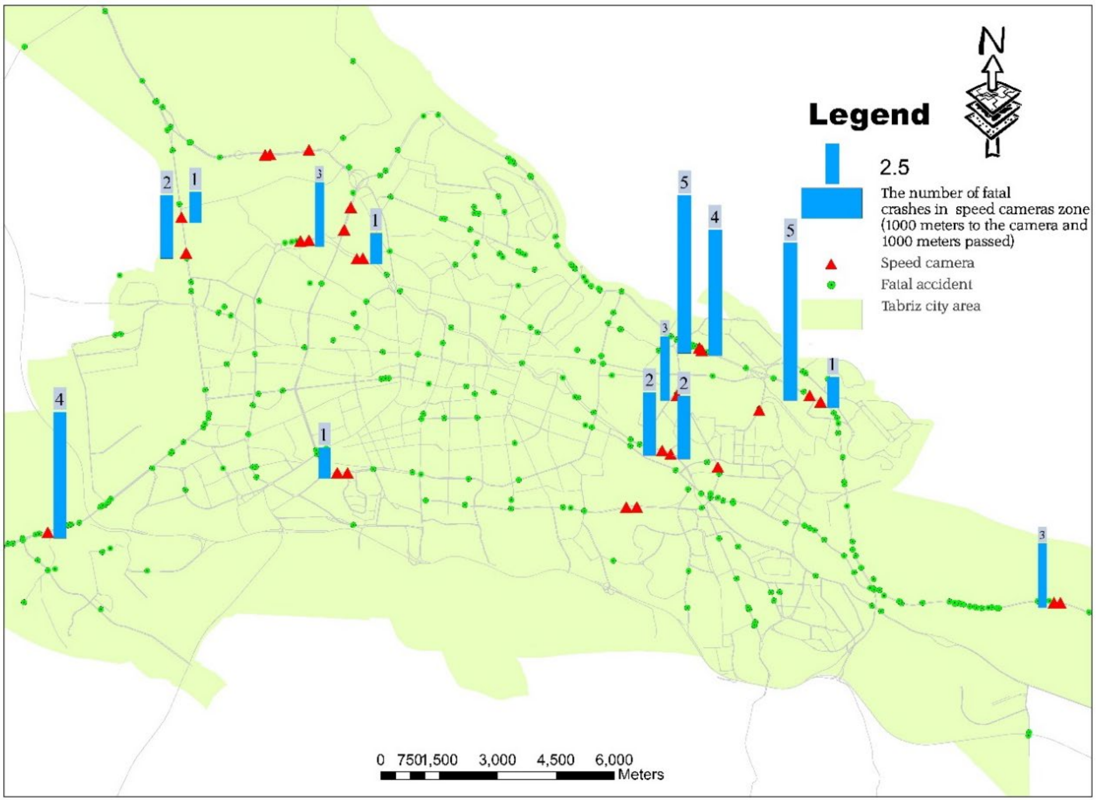

Figure 2. Number of Crashes on linear and radial routes within a 1000-meter radius of speed cameras in Tabriz city

Statistical analysis

The analysis primarily included descriptive statistics to describe the relationship between the installation of speed cameras and the rate of crashes in the areas adjacent to the cameras. The collected data, consisting of the number of reported crashes within the camera limits, underwent basic statistical treatment. Descriptive analyses, such as frequency distributions, were employed to compare crash rates before and after the installation of speed control cameras.

Ethical considerations

The study strictly adhered to ethical standards throughout its execution. The study was conducted in accordance with the Declaration of Helsinki. Consent and necessary permissions were obtained for the collection and utilization of historical crash data. To protect individuals' identities involved in these crashes, all personal identifiers were removed from the dataset, ensuring anonymity and confidentiality. Institutional Review Board approval (code: IR.TBZMED.REC.1398.1012) was obtained.

Results

There was a total of 300 fatal crashes that occurred in Tabriz City between 2020 and 2022. All the data in Table 1 pertains to accidents that occurred after the installation of the cameras. Through two investigations, both linear and radial, it was found that within a 1000-meter radius of speed cameras, 138 fatal crashes occurred. After software analysis by GIS (Geographic Information System), crashes that passed through the camera's route and those that were not on the same lane were eliminated. Eventually, 37 crashes within the 1000-meter radius of the camera and 1000 meters beyond it were selected and analyzed.

Table 1. Summary of Crash Counts and Camera Status within Specified Buffer Zone

Crash Information	Number
Number of Crashes within a 1000-meter radius of speed cameras	138
Number of Crashes within a 2000-meter buffer zone of speed cameras	37
Number of Crashes in the remaining 1000-meter buffer zone before the camera	19
Number of Crashes in the past 1000-meter buffer zone from the camera	18
Number of nighttime Crashes within a 2000-meter buffer zone of cameras	20
Number of daytime Crashes within a 2000-meter buffer zone of cameras	17
Camera Status	
Number of active cameras	15
Number of inactive cameras	12

*This table presents the counts of crashes within specific buffer zones around speed cameras, along with the operational status of the cameras. Additionally, it includes the distribution of crashes during daytime and nighttime within the defined buffer zones.

The present study aimed to evaluate the effectiveness of the speed cameras by analyzing the distribution of accidents within the specified radial distances. The emphasis is on comparing these distances to assess the impact of the speed cameras on accident rates. Information related to the speed cameras in Tabriz City was obtained from the Tabriz Traffic Organization. After identifying their locations on the map, the remaining 1000 meters before each camera and the past 1000 meters after each camera were divided into 100-meter sections, and crashes within each section were determined using the 100-meter intervals. Figures 3 to 5 depict information about fatal crashes in Tabriz city within a certain range before and after the camera locations.

As observed in Figures 3 to 5, there were no fatal crashes in the first five segments leading up to the speed cameras (500 meters remaining). The highest number of fatal crashes occurred in the sixth segment, which is 600 meters from the speed cameras. Additionally, there is a decreasing trend in the number of crashes from the sixth segment to the tenth segment, which are within 500 meters of the speed cameras.

Based on this information and Figures 3 to 5, the 500-meter segments within the speed camera range are more significant than the 100-meter segments. Therefore, we can focus on the four 500-meter segments within the speed camera range. In the segments beyond the cameras, the highest number of crashes occurred within a range of 100 to 200 meters after passing the camera, precisely when vehicles accelerate after the camera.

The pattern of crashes around active cameras closely resembles the overall pattern of crashes within the speed camera zones, with clear divisions into 500-meter segments. The number of crashes decreases progressively from the 600-meter mark to the 1000-meter mark, and the 200-meter segment immediately after passing the speed cameras shows the highest number of crashes. In the vicinity of inactive cameras, there have been relatively fewer crashes compared to active cameras.

The time chart indicates a significant relationship between crashes before reaching the camera and those occurring after the camera. More crashes occurred before reaching the camera, mostly during the night, while crashes after the camera were more prevalent during daylight hours. The types and causes of crashes in the two sections before and after the camera, which had the highest number of fatal crashes, were examined in Table 2.

The highest number of crashes occurred in Section 6, 500–600 meters before the camera, and Section 2, 100–200 meters after the camera. Upon examining the causes of crashes in these areas, it was found that the majority of crashes in Section 6 were rollovers or collisions with obstacles, accounting for 66.6% of the total crashes. The primary cause of these types of crashes was speeding, accounting for 66.6% of the cases.

In section 2, after passing the camera, the highest number of crashes involved pedestrians, accounting for 80% of the total crashes. The primary cause of these pedestrian-related crashes was drivers failing to pay attention to the road ahead. This analysis highlights the need for measures to address speeding and improve driver attentiveness in order to reduce crashes in Section 6. Additionally, efforts should be made to enhance pedestrian safety and promote driver awareness of pedestrians in Section 2.

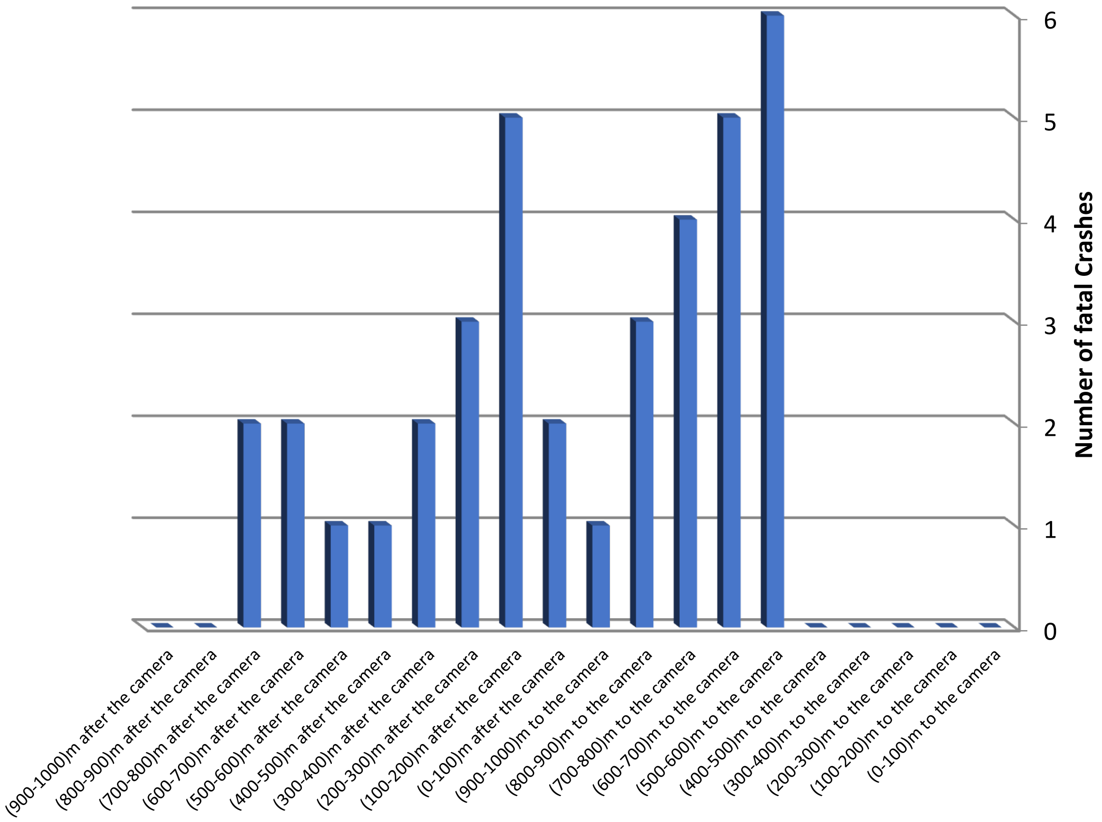

Figure 3. Total number of fatal crashes in Tabriz city (2020-2022) within 1000 meters before and 1000 meters after the camera location

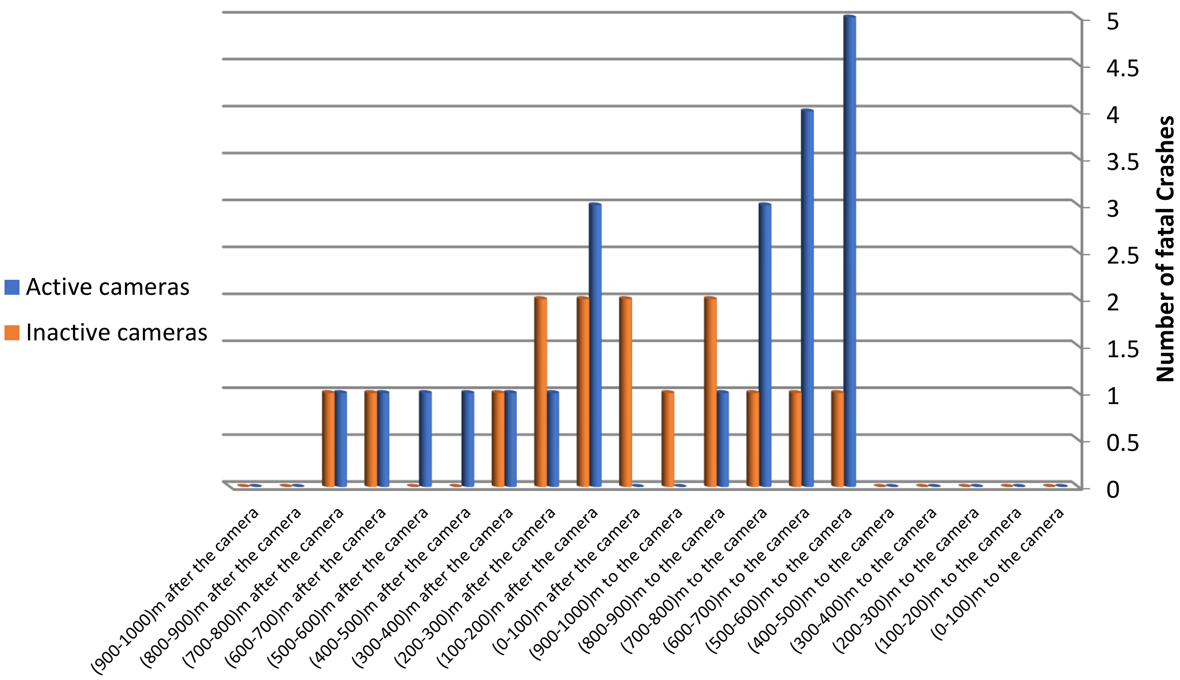

Figure 4. Number of fatal crashes in Tabriz city (2020–2022) within a 1000-meter range before and after active and inactive cameras

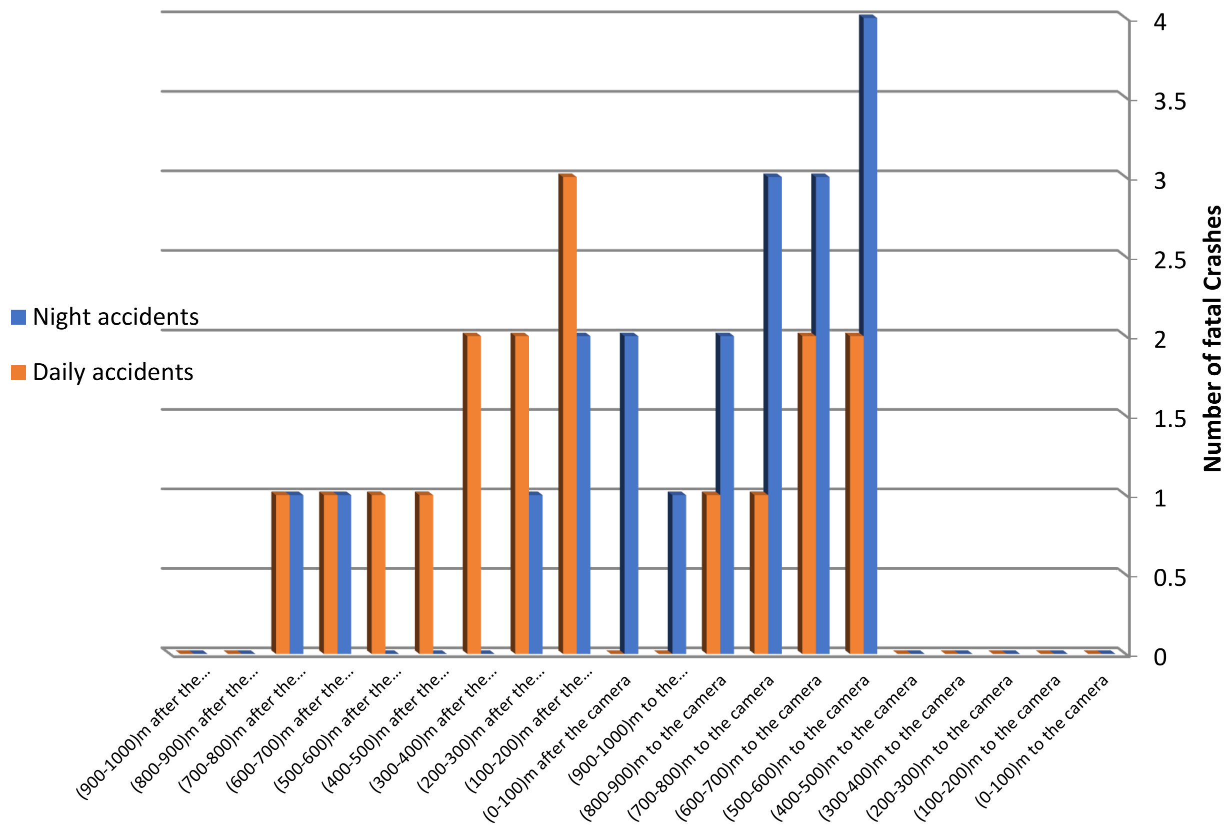

Figure 5. Number of fatal crashes in the city of Tabriz (2020–2022) within a range of 1000 meters before and 1000 meters after speed cameras

Table 2. Crash Characteristics and Counts in Segments Relative to Speed Cameras

Name of the segment	Number of Crashes	Excessive speed	Lack of attention to the front	Dealing with a passerby	Obstacle collision and overturning
500-600 meters before the camera	6	4	2	2	4
100-200 meters after passing the camera	5	1	4	4	1

*This table presents the frequency of different crash characteristics observed within specific segments relative to the position of speed cameras. The segments are identified based on their distance before and after the camera location.

Discussion

The most pivotal finding of this study lies in the demonstrable impact of speed cameras on reducing accidents within the vicinity of Tabriz City. Specifically, the comprehensive evaluation of crashes occurring within a 500-meter radius of these cameras revealed a significant reduction in accidents preceding their locations. This emphasizes the crucial role speed cameras play in promoting road safety by compelling drivers to moderate their speed as they approach these devices.

The alignment of our findings with prior studies in the field fortifies the argument for the effectiveness of speed cameras in curbing excessive speeding.[26–28] These congruent results reinforce the established behavior among drivers: a tendency to slow down as they approach the camera and, potentially, to resume higher speeds after passing it.[27,28]

This consistency in driver behavior stands as persuasive evidence of the impact that speed cameras have on influencing how drivers behave, ultimately encouraging safer practices behind the wheel. Earlier studies have consistently observed similar fluctuations in driving behavior around speed camera locations, emphasizing the pivotal role these cameras play in cultivating responsible driving habits and mitigating the risks associated with speeding-related accidents.

Moreover, the observed pattern of deceleration near camera sites and potential acceleration afterward underscores the need for continued monitoring and strategic placement of these devices. By maintaining a presence that influences driver behavior positively, speed cameras contribute not only to immediate speed reduction but also to the cultivation of long-term safer driving habits, thereby reducing the likelihood of accidents caused by excessive speeding. This consistency across multiple studies bolsters the argument for the sustained use and implementation of speed cameras as an effective tool in promoting road safety.

While affirming the positive impact of speed cameras, this study highlights areas where their effectiveness could be further enhanced. One intriguing possibility lies in the integration of short-range radar technology with speed cameras.[29] This amalgamation has the potential to significantly bolster speed limit enforcement by allowing more precise detection of speeding vehicles in closer proximity to the cameras. Such technological advancements hold promise in fortifying the efficacy of speed cameras, ensuring that safer driving speeds are maintained within designated areas.

Moreover, the proposal to periodically replace inactive cameras with operational ones introduces an innovative strategy.[26,28] The primary goal is to perpetuate a perception of continual enforcement, fostering a sustained sense of accountability among drivers. If implemented effectively, this approach could potentially strengthen compliance with speed regulations, even in the absence of immediate enforcement. By creating a persistent awareness of monitoring, it aims to instill long-term responsible driving behavior, ultimately contributing to enhanced road safety.

These proposed enhancements underscore the evolving nature of speed camera technology and enforcement strategies. Embracing technological advancements and adopting innovative deployment strategies can significantly augment the efficacy of speed cameras, making them not just a short-term deterrent but a sustained influencer of driver behavior. The integration of advanced radar systems and strategic camera replacement strategies represents proactive steps toward fostering a culture of consistent compliance with speed regulations, thus promoting enduring road safety.

Despite the valuable contributions of this study, it is important to acknowledge its inherent limitations. Visibility issues surrounding speed cameras and the potential for post-camera distractions represent areas that require further investigation. These factors could significantly impact driver behavior and might contribute to crashes, indicating the need for a more comprehensive study aimed at understanding these dynamics in depth. A more nuanced exploration could facilitate the development of targeted interventions or improvements in camera placement and design to mitigate these potential issues and enhance overall road safety.

Furthermore, the application of these study findings holds substantial implications for policymaking. The research suggests the importance of maintaining speed cameras, even when inactive, in accident-prone areas to leverage their inherent deterrent effect. Policymakers can utilize these findings to inform strategic decisions regarding the placement and maintenance practices of speed cameras.

By recognizing the sustained impact of inactive cameras on influencing driver behavior, policymakers can adopt a proactive approach. They can strategically place these cameras in high-risk zones, not solely for active enforcement but also to perpetuate the perception of ongoing monitoring. This approach aligns with the study's findings, aiming to instill a sense of accountability among drivers and foster continued adherence to speed regulations, contributing to long-term road safety goals.

Looking ahead, future studies should delve deeper into post-camera zones, evaluating driver behavior and distractions in these areas. Additionally, exploring the role of visibility and mental preoccupation in influencing driver actions can further enhance our understanding of speed camera effectiveness.

Conclusions

The findings from this study affirm the significant impact of speed control cameras in reducing crashes, particularly before vehicles reach the camera locations. Distinct patterns emerged within segmented sections around the cameras, highlighting higher crash rates in the 500 to 1000-meter range before the cameras and a significant decrease beyond this point. Lighting conditions and camera activation status further influenced crash occurrences, indicating a complex interplay of factors.

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Competing interests

The authors declare that they have no competing interests.

Abbreviations

Geographic Information System: GIS.

Authors' contributions

All authors read and approved the final manuscript. All authors take responsibility for the integrity of the data and the accuracy of the data analysis.

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Availability of data and materials

The data used in this study are available from the corresponding author on request.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki. Institutional Review Board approval (code: IR.TBZMED.REC.1398.1012) was obtained.

Consent for publication

By submitting this document, the authors declare their consent for the final accepted version of the manuscript to be considered for publication.

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