MAULANA AZAD NATIONAL INSTITUTE OF TECHNOLOGY
BHOPAL, INDIA, 462003

MINOR PROJECT REPORT ON

<u>Study on Pedestrian Safety</u>

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Session: 2023-2024

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CERTIFICATE

This is to be certified that this minor project report, "Study on Pedestrian Safety," is submitted by:

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The project work has been conducted under my supervision. I approve this project for submission of the Bachelor of Technology in the Department of Civil Engineering, Maulana Azad National Institute of Technology, Bhopal.

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ACKNOWLEDGEMENT

We would like to take this opportunity to express our heartfelt concern in words to all those people who have helped us in various ways to complete our project.

First, we would like to express our sincere thanks to Dr. K.K. Shukla, Director, MANIT Bhopal, and Dr. Mukul Kulshrestha, Head of Department, Department of Civil Engineering, MANIT Bhopal, for giving us this opportunity to undertake this project.

It gives us immense pleasure to express our deepest sense of gratitude and sincere thanks to our highly respected guide, Dr. Pritikana Das., Assistant Professor, Department of Civil Engineering, MANIT Bhopal.

We extend our sincere thanks to our faculty members and lab technicians for their help in completing the project work.

We also wish to express our indebtedness to our family and friends, whose blessings and support have always helped us.

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DECLARATION

We, hereby declare that the work being presented in this dissertation, entitled **"**Study on Pedestrian Safety,**"** submitted towards the fulfillment of requirements for the award of the degree of **Bachelor of Technology** in **Civil Engineering** at **Maulana Azad National Institute of Technology Bhopal,** is an authentic record of my work carried out under the supervision of **Dr. Pritikana Das**, Assistant Professor at the Department of Civil Engineering, at **MANIT Bhopal.**

The matter embodied in this dissertation report has not been submitted by me for the award of any other degree. Further, the technical details furnished in the various chapters in this report are purely relevant to the above project, and there is no deviation from the theoretical point of view for design, development, and implementation.

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ABSTRACT

The most vulnerable users of the road are pedestrians, who differ greatly from motorised users in that they have a greater degree of freedom in selecting their walking style. The most vulnerable users of the road are pedestrians, particularly when there is mixed traffic and traffic infrastructure that is intended for motorised vehicles. In addition, people travel at a moderate pace and can stop or slow down at any time, making the motion of pedestrians crossing the street incredibly uneven. In light of the varied traffic situations in urban midblocks and intersections, the purpose of this study is to define the gaps in past pedestrian safety studies and use the temporal proximity surrogate safety approach for measuring pedestrian safety in future.

This study provides a comprehensive review of the literature, including the impact of infrastructure modifications, traffic control measures, and public education campaigns on pedestrian safety. Also a mixed-methods approach, combining quantitative analysis of accident data with qualitative assessments of pedestrian behavior and perceptions have been highlighted in this report. Key factors contributing to pedestrian accidents, including vehicle speed, infrastructure design, and pedestrian behavior have been identified from the past literature.

Furthermore, this report explores the role of emerging technologies such as smart traffic systems, pedestrian detection sensors, and augmented reality applications in enhancing pedestrian safety. It investigates the potential of these technologies to provide real-time feedback to both pedestrians and drivers, thereby reducing the likelihood of accidents.

Table of Contents

CERTIFICATE	2
ACKNOWLEDGEMENT	3
DECLARATION	4
ABSTRACT	5
CHAPTER I: INTRODUCTION	
1.1. General:	9
1.2. Need of Study:	10
1.3. Objectives:	11
CHAPTER II: LITERATURE REVIEW	12
CHAPTER III: STUDY GAPS	
3.1 Study gaps in past literatures	27
CHAPTER IV: CONCLUSIONS	
4.1 Conclusions:	45
4.2 Scope for future work:	45
CHAPTER V: RECOMMENDATIONS	46
REFERENCES	47

TABLE OF FIGURES

Figure No.	Title of the figure	Page No.
2.3	Sorted value of k parameter with respect to post-impact kinematics	22
2.4	Pedestrian Crossing Speed by intersection control type	23
2.5(a)	Waiting time for pedestrians at intersections.	24
2.5(b)	Waiting time of pedestrians by intersection control type.	24

LIST OF TABLES

Table No.	Title of the table	Page No.
2.1	Number of Pedestrian Accidents	12
2.2	Summary of collision frequency models.	26
2.3	Studies identifying significant contribution to pedestrian severity	28

CHAPTER I: INTRODUCTION

1.1. General:

Pedestrian safety is a critical aspect of urban transportation systems, impacting the lives and well-being of millions of people around the world. As cities continue to grow and urbanize, the safety of pedestrians becomes increasingly important to ensure equitable access to transportation, promote active modes of travel, and create vibrant and livable communities. However, pedestrian accidents remain a significant public health concern, with thousands of fatalities and injuries occurring each year globally. Therefore, understanding the factors influencing pedestrian safety and implementing effective interventions is essential for creating safer and more inclusive urban environments.

The aim of this thesis is to comprehensively explore the topic of pedestrian safety, examining various aspects ranging from the underlying causes of pedestrian accidents to the effectiveness of interventions aimed at reducing these risks. By conducting a thorough review of existing literature and empirical analysis, this study seeks to provide valuable insights into pedestrian safety in urban areas.

Pedestrian accidents occur as a result of a complex interplay of factors, including vehicle speed, infrastructure design, pedestrian behavior, and traffic volume. High vehicle speeds significantly increase the likelihood and severity of pedestrian accidents, as faster-moving vehicles require longer stopping distances and pose a greater risk of injury in the event of a collision. Infrastructure design also plays a crucial role in pedestrian safety, with features such as crosswalks, sidewalks, pedestrian islands, and traffic calming measures influencing the interaction between pedestrians and vehicles. Furthermore, pedestrian behavior, such as jaywalking, distracted walking, and alcohol impairment, can contribute to the risk of accidents, highlighting the importance of education and enforcement strategies in promoting safe pedestrian behavior. Finally, traffic volume and congestion can impact pedestrian safety by increasing the complexity of interactions between pedestrians and vehicles, particularly at intersections and crosswalks.

In addition to understanding the factors contributing to pedestrian accidents, it is essential to evaluate the effectiveness of interventions aimed at improving pedestrian safety. Infrastructure modifications, such as installing traffic signals, crosswalk markings, pedestrian refuge islands, and traffic calming measures, have been shown to reduce pedestrian accidents by improving visibility, controlling vehicle speeds, and enhancing the overall pedestrian environment. Similarly, traffic control measures, including speed limits, pedestrian crossing signals, and enforcement of traffic laws, play a crucial role in promoting safe pedestrian behavior and reducing the risk of accidents. Moreover, public education campaigns aimed at raising awareness about pedestrian safety, sharing the road responsibly, and encouraging active transportation modes can help change attitudes and behaviors among both pedestrians and drivers.

Emerging technologies also hold promise for enhancing pedestrian safety in urban environments. Smart traffic systems, pedestrian detection sensors, and augmented reality applications have the potential to provide real-time feedback to pedestrians and drivers, alerting them to potential hazards and improving situational awareness on the road. By integrating these technologies with traditional safety measures, cities can create more resilient and responsive transportation systems that prioritize the safety and well-being of pedestrians.

1.2. Need of the Study:

In mixed traffic, pedestrians are the most vulnerable users of the roads. Therefore, pedestrian safety is essential for the following reasons:

- Protection of Vulnerable Road Users: Pedestrians, including children, elderly individuals, and people with disabilities, are among the most vulnerable road users. Ensuring their safety is essential to preventing fatalities and injuries on city streets.
- Promotion of Active Transportation: Safe walking environments encourage people to choose active modes of transportation, such as walking and cycling, leading to numerous health and environmental benefits.
- Enhancement of Urban Livability: Safe and walkable streets contribute to the overall livability of cities, fostering social interaction, community engagement, and economic vitality.
- Reduction of Traffic Congestion: By encouraging walking and cycling, pedestrian-friendly infrastructure can help alleviate traffic congestion and reduce the environmental impacts of motorized transportation.
- Equity and Social Justice: Access to safe pedestrian infrastructure is a matter of equity and social justice, ensuring that all members of society, regardless of age, income, or ability, can safely navigate their communities.
- Economic Benefits: Investing in pedestrian safety measures can yield significant economic benefits, including reduced healthcare costs, increased property values, and enhanced economic productivity.
- Sustainable Development Goals: Improving pedestrian safety aligns with the United Nations Sustainable Development Goals, particularly Goal 11 (Sustainable Cities and Communities) and Goal 3 (Good Health and Well-being), by promoting safer, healthier, and more sustainable urban environments.

By addressing these critical needs for pedestrian safety, cities can create safer and more sustainable urban environments that prioritize the well-being of all road users. Through research and evidence-based interventions, this study aims to study past studies and understand the advancement of pedestrian safety. Further study can be done using proactive safety assessment of pedestrians’ movement in mixed traffic scenarios.

1.3. Objectives:

To fulfill the aim of this study theTo fulfill the aim of this study the following objectives have been proposed have been proposed:

- To study past literature on pedestrian safety at national and international levels.
- To find the study gaps for future studies in this area.
- To identify the primary factors influencing pedestrian safety in urban environments from the past literature.
- To investigate the role of emerging technologies in enhancing pedestrian safety, such as smart traffic systems and pedestrian detection sensors, from past studies.

CHAPTER II: LITERATURE REVIEW

Fleig and Duffy (1967) studied pedestrians' behavior in New York City during the early 1960s. intersection and limited accident data at several urban intersections before and after the installation of pedestrian signals (4). Pedestrian behavior, rather than accidents, was used as a primary measure of the effectiveness of signals because of the problem of sample size and the necessary lead time.
The authors identified a number of pedestrian actions or violations as unsafe acts and determined the trends in these unsafe acts before and after the installation of a pedestrian signal with a Barnes dance (scramble) phasing. For the accident study, they analyzed the pedestrian accident data at a total of 11 intersections one year before and one year after the installation of the pedestrian signals (see table below (1.1)].

	No. of Pedestrian Accidents	
Intersection No.	1 Year Prior to Signal Installation	1 Year After Signal Installation
1	7	4
2	2	4
3	1	0
4	2	1
5	3	1
6	2	4
7	3	0
8	1	3
9	1	1
10	3	3
11	2	4
Total	27	25

TABLE 2.1

They found no significant reduction in the proportion of unsafe acts before and after the installation of pedestrian signals. Based on this evidence,. The authors concluded that pedestrian signals are not an effective method for reducing pedestrian accidents.

The number of pedestrian accidents at the 11 intersections studied was reduced slightly (27 versus 25) after the installation of the pedestrian signals. However, the small sample of intersections and the low number of accidents in the sample did not allow for a conclusive statistical analysis. This limitation was also recognized by the authors.

The use of several years of accident data, a large number of sites, and a better experimental design (1.e., use of randomized control sites, comparison sites, or trend analysis) would have greatly enhanced the experimental plan and could have resulted in some important findings relative to pedestrian signals and their effect on safety. Another way to have enhanced the study would have been to review each accident report carefully to omit any pedestrian accidents that are unrelated to the pedestrian signals. accidents that are attributable to unrelated factors For example. such as vehicle failure or drunk driving should be screened out in such an analysis. The authors do not report on any such screening effort. This study, however, is one of the few that attempted to analyze actual pedestrian accident data to assess the effectiveness of pedestrian signals. The study does not show any conclusive evidence about either a positive or a negative effect of pedestrian signals concerning accidents.

Mortimer (1973) compared the compliance rates of pedestrian crossings at intersections with and without pedestrian signals (5). His methodology consisted of (a) identifying similar signal-controlled intersections with and without pedestrian signal (WALK and DON'T WALK) indications, (b) collecting data at these intersections on pedestrian compliance as well as on the incidence of successful completion of the crossing, and (c) developing two types of hazard indices and other statistics on the pedestrian crossings. Mortimer found that better signal compliance was found at intersections with pedestrian signals than at those without them,Fewer illegal starts and more successful crossings were made at intersections with pedestrian signals than at those without pedestrian signals:Hazard-index values calculated for intersections with pedestrian signals were slightly lower than those calculated for intersections without pedestrian signals;Potentially serious pedestrian-vehicle conflicts were reduced substantially at intersections with pedestrian signals.The use of pedestrian crossings was instrumental in improving compliance and providing more information to pedestrians, which resulted in more comfortable crossings and fewer crossing hazards.

This study provides some useful information regarding pedestrian compliance, specifically in comparing intersections with and without pedestrian signals. However, without any known quantifiable relation between pedestrian compliance and accidents, the true effects of pedestrian signals on safety (i.e., pedestrian accidents) cannot be determined.

Skelton, Bruce, and Trenchard, (1976) studied the effectiveness of pelican crossings, conducted surveys at several sites in the city of New- castle-upon-Tyne and in a town in rural Northumber- land, England (6) Pelican crossings are pedes- trian-actuated crossings, used extensively in England, Australia, and some European countries, in which the pedestrian phase is initiated by a pedestrian push button. Zebra crossings are crossings that have alternate black and white stripes and are occasionally marked with flashing beacons. The study did not analyze any accident, operational, or compliance data but mainly focused on an opinion survey among pedestrians on the understanding and effectiveness of pelican crossings. The study concluded that the general public (pedestrians as well as drivers) lacked an understanding of how pelican crossings were designed to function. The study recommended that if the potential of the crossing devices is to be fully realized, significant operational and design improvements must be made.

The above study cannot necessarily be categorized as a safety study, since it does not deal with any accident or compliance data. However, it provides information relative to the effectiveness of new or Innovative control devices and public acceptability. The study suggests that adequate publicity and appropriate placement are necessary prerequisites to the successful use of any new control device. The message of these devices is completely received and understood by motorists and pedestrians if the intended purpose is to be achieved.

Inwood and Grayson(1979), in a study conducted for the **Transport and Road Research Laboratory, England,** analyzed injury accident data, pedestrian counts, and vehicle flows for lengths of road on and near pedestrian crossings (9). The prime objective of this study was to compare pedestrian accident rates at zebra and pelican crossings. The candidate crossings were located in similar conditions at sites throughout England and were selected based on good visibility and not being too close to busy intersections. The study showed no evidence of a difference in pedestrian accident rates between pelican and zebra crossings. However, pelican crossings tended to have a lower total injury accident rate than zebras when the road length in the vicinity of the crossings was taken into account.

It appears that push-button signals (pelicans) are not any more effective than pavement markings with flashing beacons (zebras) in reducing pedestrian accidents. However, when injury accidents are considered, pedestrian-actuated signal crossings are more effective than zebra crossings.

Williams (1978) discussed the evolution of the pelican concept in England and in Australia and summarized the findings and experiences of different researchers about safety, operation, and behavior (8). The discussion is primarily oriented toward a comparison with its predecessor, the zebra crossing. The author mentions that uncontrolled zebra crossings, originally introduced in 1951, were reported to cause delays and congestion in heavy vehicle and pedestrian flows. Pelican crossings present considerable advantages over appeared to zebra crossings. Williams also mentions that at least one study in Australia found that accidents decreased by 60 percent at a sample of pelican crossings that were originally zebra crossings.

Based on these findings, Williams suggests that it is not possible to conclude that pelican crossings significantly increase pedestrian safety. He mentions that, in most of the sites where positive safety benefits were indicated, the results appear to be masked by the presence of other factors. Several other countermeasures were installed at these sites (e.g., antiskid surfacing and guardrails), and the effects of these treatments are very difficult to isolate from the overall safety effect of the pelicans. Although the studies reported by Williams do not provide conclusive evidence of the positive safety benefits of pelican crossings, there was also no indication of any adverse effect of the devices.

Abrams and Smith (1977) in their effort to address the safety (and delay) aspects of pedestrian signals, analyzed three types of signal phasing (i.e., early release, late release, and scramble timing) (Figure 1 (7)]. The authors performed compliance studies in Sioux City, Iowa, and concluded that the early release of pedestrians may provide a measure of additional safety, but the benefits were not precisely determined; higher compliance rates associated with the late release technique are indicative of increased pedestrian safety; scramble timing has the capability of increasing pedestrian safety by eliminating pedestrian-vehicular conflict; however, violation rates for scramble timing were found to be higher, particularly on narrow streets.

The authors' postulated association between safety and compliance appears to be based primarily on judgmental factors as opposed to any specific data analysis. The higher violation rates at scramble-timed intersections (i.e., where an exclusive pedestrian phase exists with diagonal crossings permitted) are indicative of the higher pedestrian delay generally associated with these locations. This study provides useful information regarding pedestrian behavior and compliance relative to various pedestrian signal-timing schemes (i.e., early release, late release, standard, and scramble timing), which may or may not be indicative of pedestrian safety.

Sunny Singh (2023): This review of pedestrian safety begins with an overview, acknowledging comprehensive reviews available in earlier studies and directing readers to specific topics like traffic conflict measures, general traffic conflict modeling, and extreme value theory models for detailed information. Next, crash-based pedestrian safety studies are explored, which utilize traffic crash data to identify factors contributing to pedestrian injuries and fatalities. Representative studies, including Ammar et al. (2022), Bernhardt and Kockelman (2021), and Gooch et al. (2022), highlight various risk factors and high-risk behaviors observed in different regions. Following this, conflict-based pedestrian safety studies are examined, focusing on proactive approaches to assess vehicle-to-vehicle and vehicle-to-pedestrian conflicts. Studies by Zheng and Sayed (2020), Guo et al. (2020), and Santhosh et al. (2020) illustrate diverse methodologies employed to enhance pedestrian safety through conflict-based analysis. The review then delves into conflict data collection methods, discussing techniques such as driving simulators, video analytics, numerical simulations, LiDAR-based studies, and the utilization of autonomous vehicle data. Each method's strengths and limitations are outlined, emphasizing their contributions to understanding pedestrian safety. Furthermore, autonomous vehicle sensor data-based pedestrian safety studies are explored, highlighting research efforts that leverage AV data to analyze AV-pedestrian interactions. Studies by Kutela et al. (2022), Liu et al. (2021), and Beauchamp et al. (2022) offer insights into AV-VRU crashes, AV-pedestrian conflicts, and AV safety compared to human drivers. Lastly, traffic conflict measures for pedestrian safety are discussed, emphasizing the importance of selecting suitable measures to effectively capture vehicle-pedestrian interactions. Commonly adopted conflict indicators such as Post-Encroachment Time (PET) and Time to Collision (TTC) are highlighted, along with their theoretical justifications and applicability. The literature review concludes by identifying research gaps, including the reliance on crash-based statistical models, the increasing use of traffic conflict-based assessment frameworks, the variety of data collection methods, and the underutilization of autonomous vehicle data for corridor-level pedestrian safety analysis. These gaps serve as the motivation for the present study, which aims to address knowledge limitations and harness the potential of autonomous vehicle data for enhancing pedestrian safety analysis.

Jiaqi Chen (2016): This section underscores critical gaps in the current understanding of Vertical Flow Pedestrian Systems (VFPS) design parameters, particularly regarding pedestrian-friendly features. These identified gaps represent a significant opportunity for transformative upgrades in VFPS design within Toyota and Australia. By addressing these deficiencies, this research aims to revolutionize VFPS design practices, emphasizing pedestrian safety and comfort. Through rigorous parametric studies, this study seeks to comprehensively explore the intricacies of VFPS design and its impact on the pedestrian experience. By analyzing various parameters such as layout, signage, lighting, and accessibility, the research endeavors to generate profound insights into enhancing pedestrian-friendly infrastructure. Moreover, the study aims to advance knowledge surrounding pedestrian impact phenomena, shedding light on key factors influencing pedestrian safety in VFPS environments. By synthesizing this understanding, the research aims to pioneer innovative design concepts and establish comprehensive guidelines that align with relevant pedestrian safety standards. Ultimately, the outcomes of this research are poised to catalyze the development of VFPS that prioritize pedestrian needs, thereby fostering safer and more inclusive urban environments in Toyota and Australia.

D. Harwood, K. Bauer (2008): This paper synthesizes factors associated with varying levels of pedestrian crash risk based on an extensive literature review. Roadway characteristics are commonly considered in identifying areas of increased risk, but land use variables are often overlooked or generalized. Several studies highlight the significance of location variables and emphasize the importance of spatial analysis and novel statistical approaches in understanding pedestrian crash correlates. Further research delves into the spatial relationship between pedestrian injury rates and various land use, demographic, and geographic factors. Despite contradictions in some variables across studies, the cumulative evidence underscores the need to consider a wide range of variables in predictive models for pedestrian crash risk. Challenges remain, such as the lack of distinction between factors influencing crash frequency and pedestrian exposure. Additionally, studies focusing on specific population groups, such as children, reveal further complexities in the relationship between land use and pedestrian injury risk. Overall, the research highlights the intricate interplay between land use, demographic, and geographic characteristics in shaping pedestrian crash risk, emphasizing the need for comprehensive modeling approaches.

Rebecca L. Sanders, (2019): This review investigates the relationship between pedestrian safety and traffic speed, emphasising the crucial role of speed reduction in minimising pedestrian injuries. It delves into countermeasures spanning engineering, education, enforcement, and policy domains aimed at achieving this goal. Despite limited explicit studies on pedestrian safety countermeasures, insights from both academic and "grey" literature provide strategies for effectively reducing vehicle speeds in pedestrian-dense areas. Engineering interventions include traffic calming measures, while education campaigns promote safe pedestrian behaviour. Enforcement efforts entail strict implementation of speed limits and pedestrian right-of-way laws, complemented by policy initiatives like implementing lower speed limits in pedestrian-heavy zones. Integrating academic and "gray" literature offers a comprehensive understanding of traffic-speed management's importance in enhancing pedestrian safety. However, further research is necessary to assess the efficacy of these interventions and address gaps in the literature, ensuring comprehensive strategies for pedestrian safety in urban environments.

Fei, Ran(2014): This review segment addresses pedestrian detection and recognition, structured into two levels: the strategic level, concerning problem-solving philosophy, and the algorithmic level, providing computational approaches. Detection strategies are categorized into supervision-based and logic-based strategies. The former trains detectors to distinguish pedestrians and identify prototype pedestrians, while the latter defines rules for detection/identification. Algorithmic approaches are reviewed for detection and identification purposes, utilizing cognitive shape-based and texture and colour-based algorithms. OpenCV toolkit is predominantly used for experiments. Terminology clarification distinguishes between prototype pedestrians in detection (models of pedestrians) and identification (individuals detected in the system). The review also clarifies the focus on recognition and re-identification, highlighting the significance of algorithms in pedestrian detection and identification frameworks. The review emphasizes the interplay between strategic means and algorithmic support, influencing the processing flow of detection and identification methodologies.

Yee Mun Lee, Jim Uttley, Albert Solernou, Oscar Giles, Richard Romano, Gustav Markkula, Natasha Merat Institute for Transport Studies, University of Leeds, Leeds, UK(2019) This study investigated pedestrians' crossing behavior in a virtual reality environment. One aim was to develop a framework for evaluating external Human-Machine Interfaces (eHMI) used by automated vehicles for future studies. Pedestrians were provided with a series of two approaching cars, which were traveling at either 25mph, 30mph, or 35mph, with eight manipulated time gaps in between cars, where the second car either decelerated or kept pace. These stimuli were presented in 3 blocks. Pedestrians' task was to cross (or not) naturally between the approaching cars. Data from decelerating trials were analyzed. Results showed 51% of crossings happened before deceleration, 31% of crossings after the car had stopped, and only 18% of the crossings during deceleration, leaving a great margin for evaluating the effect of eHMI and changing pedestrian crossing behavior during deceleration. A learning effect was found, demonstrating a shift of decision-making across blocks, whereby crossing increasingly occurred during the approaching vehicle's deceleration, rather than after it had come to a full stop. Further analyses were conducted to investigate the effect of speed on initiation time, crossing time, and safety margin. This study provides guidelines for choosing the appropriate time gaps and speeds that may influence pedestrians' crossing decisions and behavior while presenting different designs of eHMI in future studies. The results also provide guidance on how to evaluate safety, efficiency/receptivity, and learning effects, when comparing different eHMI designs in VR experiments.

Sheila Clark, Courtney Coughenour, Kelly Bumgarner, Hanns de la Fuente-Mella, Chantel Reynolds, and James Abelar(2019) they found that drivers yielded more for pedestrians when they were carrying pedestrian crossing flags-PCFs at two mid-block crosswalks in Las Vegas, NV. While walking for transportation and/or recreation is affordable and sustainable, it is not without risk. Changes in the built environment, policy, individual behaviors, and technological advancements are essential to increasing road safety in America. Pedestrian crossing flags may be one affordable and simple way to improve pedestrian safety at mid-block crosswalks.

This study is not without limitations. Driver behavior was only observed on two mid-block crosswalks in Las Vegas, NV, thus limiting generalizability to other locations. Recreating this study in other geographical areas would assist in determining the efficacy of PCFs. All pedestrians in this study were female, so an examination of gender differences is also necessary. The cross-sectional nature of this study makes it impossible to determine how driver behavior may change over time as they become more accustomed to seeing the PCFs, i.e. the fade-out effect.

Er. Asif Yousuf Seh, Er. Sonu Ram, Dr. Pooja Sharma(2019) Pedestrian crossing behavior depends on the destination, age, education, physical condition, and overall awareness of the pedestrian. The issues associated with pedestrian crossing activities generally create considerable emotional concern within the community, especially when the community is reacting to an incident involving pedestrian injury. Pedestrian crossing safety relies on the judgment exercised by pedestrians and drivers. To interact safely requires an exchange of information between the pedestrian and the motorist. Although traffic control devices can help to promote an exchange of information, educating pedestrians and drivers is paramount to providing for a safe operation. The provision of visible cross markings must be installed in all the intersections. Considering the high density of pedestrian traffic all over the city, it should be provided to ensure safe pedestrian crossing. A median island with a median barrier must be provided at all the intersections to ensure safe pedestrian crossing. Street lighting around the crossing should be adequate so that cross marks are easily captured by the vehicle drivers to have to stop sight distance to avoid a collision. Management of existing physical infrastructure must be enhanced to enable more effective use of crosswalks. It is provided with better road markings, signs, traffic signals, canalization at intersections, turn restrictions and separation barriers, space for bus stops, and parking or waiting areas for public transport vehicles (buses, rickshaws, auto-rickshaws, taxis, etc.). Pedestrian crossing should be considered carefully in traffic engineering and planning of the intersections and midblocks.

Anna C. Hunter(2020) delves into pedestrian-involved accidents on Interstate highways in West Memphis, Arkansas, pinpointing barriers/fencing and overpass improvements as effective measures. It underscores the lack of pedestrian awareness regarding Interstate regulations, particularly at night, and identifies Ingram Boulevard as a crucial route lacking adequate pedestrian facilities. Proposed solutions advocate for upgrading Ingram Boulevard, alongside enhancing lighting and implementing driver signage. However, definitive recommendations are stymied by insufficient cost data and the necessity for further research.

To address these challenges, the study suggests future investigations focusing on pedestrian activity patterns, community feedback collection, and estimating crash reduction factors for Interstate pedestrian accidents. These endeavors promise to refine countermeasure selection and bolster safety measures effectively. Additionally, the study proposes comparing pedestrian and traffic counts during racing and non-racing seasons to ascertain the influence of casino activity on pedestrian demand for Interstate crossings. Community surveys would further gauge the potential utilization of proposed countermeasures, such as Ingram Boulevard overpass improvements. Ultimately, enhancing the body of literature on crash reduction factors for pedestrian-involved accidents on Interstates is deemed imperative. By amassing more accurate data and insights, these studies are poised to augment the efficacy of countermeasure selection processes and advance safety initiatives comprehensively.

Mojgan Rahimi(May 2019) in his research evaluates pedestrian Levels of Service (LOS) in downtown Walnut Creek using both quantitative calculations and qualitative observations across seven selected segments. Findings indicate that quantitative results generally rate pedestrian LOS one level higher than qualitative assessments, except for certain segments like Broadway Plaza East and West, and the Civic Drive to Lincoln Avenue section on Main Street. Environmental factors such as infrastructure aesthetics, safety perception, and amenities significantly influence pedestrians' perceptions, potentially leading to unpredictable outcomes. While quantitative data provide more predictable results based on measurements, qualitative observations highlight the emotional and perceptual aspects of the pedestrian experience. Future research suggests employing a Geographical Information System (GIS) to assess walkability, focusing on developing a walkability index considering parameters like residential density, connectivity, and environmental friendliness to enhance pedestrian-friendly infrastructure in downtown Walnut Creek.

Mariusz Ptak(May 2018)'s investigation addresses safety testing discrepancies in SUVs concerning pedestrian protection, particularly the differences in knee bending angles between leg form impactor tests and pedestrian dummies. Existing standard tests may inaccurately assess vehicle safety, potentially leading to severe pedestrian injuries. A new method was developed, incorporating post-impact pedestrian kinematics validation using ellipsoid-based parametric vehicle models. By analyzing linear and angular velocities of the pedestrian dummy, a new parameter, "k," was defined, enabling pre-evaluation of vehicle safety regarding pedestrian protection. Tests indicated that a kinematic criterion of k ≥ 1.7 rad/m ensures satisfactory pedestrian kinematics post-impact. This method allows for efficient safety evaluation without costly modifications to vehicle structures. Future research may focus on refining parameter k based on varying impact velocities and pedestrian positions during accidents, ensuring comprehensive safety assessments. Additionally, this method permits safety testing for vehicles not meeting certain regulatory requirements, offering flexibility in evaluation processes.

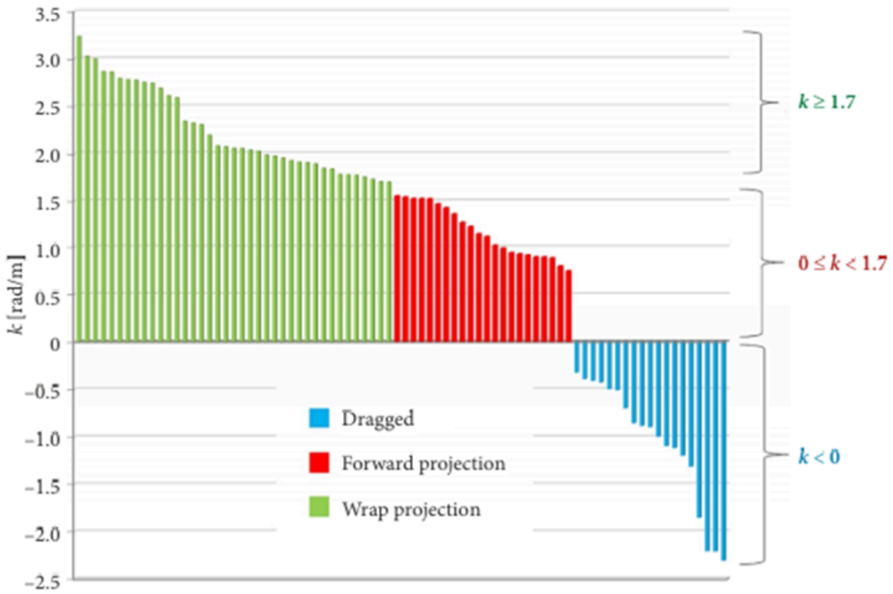

Figure 6. Sorted values of the k parameter with respect to post-impact pedestrian kinematics

FIG 2.3 SORTED VALUE OF k PARAMETER WITH RESPECT TO POST-IMPCAT KINEMATICS

Niaz Mahmud Zafri, Atikul Islam Rony and Neelopal Adri(2019) investigated pedestrian crossing behavior at intersections in Dhaka city, focusing on crossing speed and waiting time. The mean pedestrian crossing speed was 1.26 m/s, slightly exceeding the recommended design speed of 1.15 m/s. Crossing speed varied significantly based on intersection type, gender, age, crossing type, compliance behavior, and vehicle flow. Pedestrians generally preferred not to wait longer than 20 seconds. Intersection control type had the most significant impact on waiting time, with pedestrians waiting longer at traffic-controlled intersections compared to signalized and unsignalized ones. Male pedestrians tended to wait less than females, and waiting location also influenced waiting time. A multiple linear regression model highlighted the factors affecting crossing speed and waiting time. Recommendations include considering pedestrian crossing speed in signal phase timing and minimizing waiting time to 20-30 seconds. Future research should address the crossing behavior of disabled individuals to create more inclusive roadway designs. These findings are crucial for informing policies and interventions to enhance traffic safety through engineering, enforcement, and education measures.

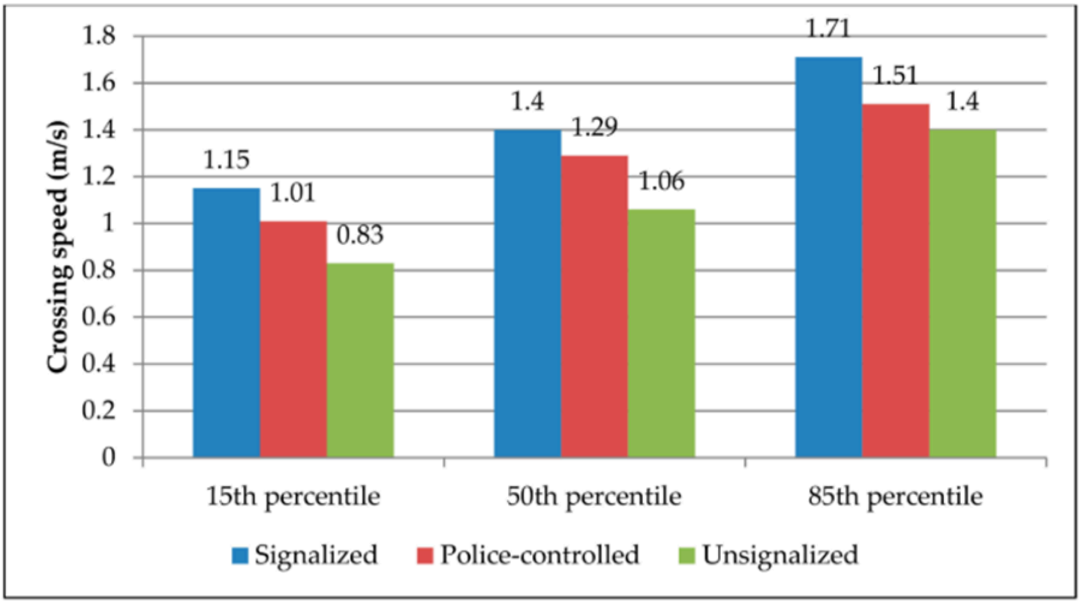

Figure 1. Pedestrian crossing speed by intersection control type.

FIG 2.4 Pedestrian crossing speed by intersection control type

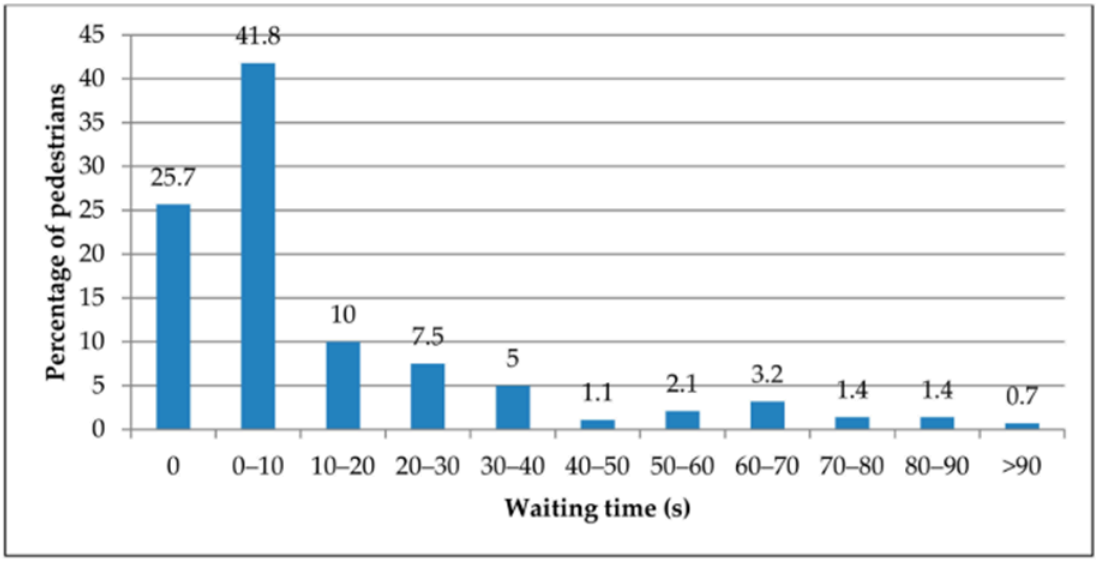

Figure 2. Waiting time of pedestrian at intersections.

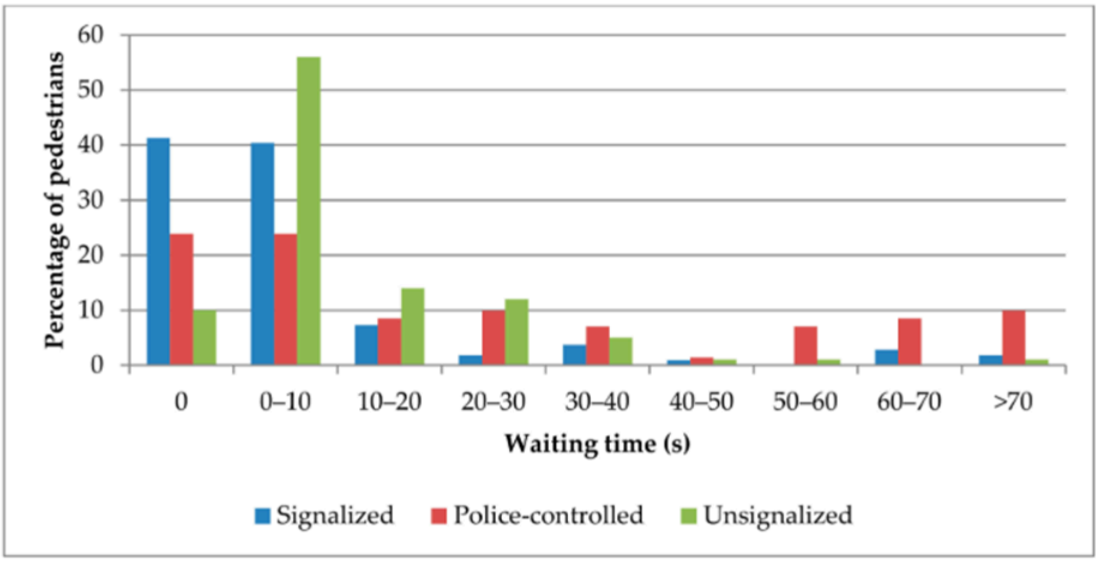

Figure 3. Waiting time of pedestrian by intersection control type.

FIG 2.5(a) Waiting time of pedestrian at intersections.

FIG 2.5(b) Waiting time of pedestrian by intersection control type.

Lynn Scholl, Mohamed Elagaty, Bismarck Ledezma-Navarro, Edgar Zamora and Luis Miranda-Moreno(2019) introduces a proactive surrogate safety methodology aimed at identifying pedestrian injury-risk factors and assessing low-cost temporary countermeasures at intersections in Latin America. Using computer vision and deep-learning techniques, road-user trajectories and conflicts were analyzed for thousands of vehicle-pedestrian interactions. Regression models were then employed to model risk indicators, revealing significant factors such as motorcycle speed and multilane roundabouts as high-risk locations for pedestrians. In a before-after analysis, low-cost treatments at four-way intersections proved effective in reducing speeds and risk, while their impact on roundabouts was less conclusive. The methodology offers a proactive approach to road safety, allowing for the evaluation of temporary measures before permanent solutions are implemented. While promising, the study acknowledges limitations, including the need for larger sample sizes and validation using crash data. Further research is warranted to refine surrogate safety measures and assess their effectiveness across diverse urban contexts.

Mahdi Moshki, Abdoljavad Khajavi, Leila Doshmangir, Saeid PourDoulati(2019) delves into the belief system of pedestrians regarding red light violations. It identifies friends/peers as the most influential group in approving and behaving, while family members are significant in disapproving and not behaving. Educational interventions targeting these groups could effectively modify unsafe crossing behavior. Despite positive attitudes towards red light violations driven by time-saving and urgency, highlighting the risks and negative consequences could deter such behavior. Further quantitative research is needed to validate these findings and explore the predictive power of the Theory of Planned Behavior constructs on pedestrian crossing behavior. Additionally, assessing the effectiveness of TPB-based interventions in improving pedestrian behavior is crucial for road safety enhancement.

Haeryung Lee and Seung-Nam Kim(2019) investigated the impact of PPS (Pavement Pedestrian Space) paving designs on safety and safety perceptions through video analysis and survey research. While traffic speeds were generally slower where PPS strategies were applied, there was an increase in vehicle speeds where pedestrian and vehicular zones were not clearly distinguished. This poses risks to pedestrians, especially when level surfaces are used for pedestrian zones. The findings underscore the importance of adhering to PPS design principles to avoid adverse outcomes. They provide valuable insights for government officials and residents, emphasizing the effectiveness of PPS paving designs in promoting safety. Additionally, the study highlights the need for related policies to ensure appropriate PPS implementation, particularly regarding speed control and pedestrian rights. However, the study acknowledges limitations such as the lack of individual vehicle data and the challenge of controlling for natural changes over time. Further research is suggested to address conflicting results and enhance future PPS plans.

Reza Riahi Samani(2023) reviews pedestrian road safety research, focusing on public transit areas. It covers the correlation between pedestrian collisions and public transit presence, statistical collision count models, hotspot identification methods, and the impact of road geometry and built environment. Challenges in collision count modeling include over-dispersion, unobserved heterogeneity, low sample mean, small sample size, and endogenous variables. Statistical models like Negative Binomial (NB), Poisson-lognormal (PLN), and finite mixture models address these challenges, accounting for factors like overdispersion and unobserved heterogeneity. Multilevel and random-effects models enhance analysis by considering varying coefficients and multiple risk sources. Overall, the chapter aims to fill gaps in the literature by advancing understanding of pedestrian safety in public transit areas through comprehensive data analysis and model development.

Table 2-1 Summary of Collision Frequency Models

Model	Main Characteristics	Initial Example of Research
Standard Poisson Distribution	• Start point for Poisson family Collision Frequency Models • Restricted to equal mean and variance • Incapable of dealing with over dispersion	(Olkin, Gleser, and Derman 1980)
Negative Binomial	• Variance to mean ratio larger than one • Capable of dealing with overdispersal data	(Paul P Jovanis 1986)
Zero Inflated Negative Binomial	• Dual state data generating process • Deal with excess count of zeroes through a separate distribution • Assuming perfectly safe and unsafe entities (theoretically questionable)	(V. Shankar, Milton, and Mannering 1997)
Poisson Lognormal (PLN)	• Poisson Parameter follows a lognormal distribution • Flexible for observations located at the tail end of the distribution	(Miaou, Bligh, and Lord 2005)
Negative Binomial-Lindley	• Multi-distribution statistical model • Analyzing data characterized by a large number of zeroes • Maintaining similar characteristics as the traditional negative binomial	(Lord and Geedipally 2011)
Random Effect	• Argue a not purely random error • Adding one or more random intercept terms to deal with spatial-temporal unobserved heterogeneity • Capturing within observations variance	(V. N. Shankar et al. 1998)
Random Parameter	• Extension of randomness from intercept only to all model's coefficients • Improve capturing unobserved heterogeneity	(Anastasopoulos and Mannering 2009)
Multiple Sources of Risk	• Multi sources of risk such as engineering, unobserved spatial, and driver behavioural • Source-specific crash count modelling	(Afghari et al. 2018)

TABLE 2.2 SUMMARY OF COLLISION FREQUENCY MODELS

The process of network screening identifies hazardous points in transportation safety management, crucial for directing resources towards reducing crashes. Methods include observed crash methods like Crash Rate and Severity Index, and predicted crash methods using Safety Performance Functions (SPFs) to estimate expected crash frequency. Bayesian methods address bias, while GIS-based analyses leverage Geographic Information System (GIS) tools for hotspot identification. Traffic calming strategies, like speed reduction measures and road medians, are essential for pedestrian safety. The literature gap underscores the need for comprehensive analysis of public transit's impact on pedestrian safety, addressing factors beyond bus stops and transit frequency. This study aims to fill this gap by considering additional transit characteristics and built-environment factors, using a substantial dataset to provide insights for enhancing pedestrian safety at public transit access points (PTAPs).

Md Shakhawat Hossen(2021) researched on Dynamic Road Traffic Sign (DRTRS) systems draws on existing Tire Rumble Strip (TRS) studies due to their functional similarities. Literature review on TRS dimensions, sound and vibration effects, driving behavior changes, and limitations informed the design and objectives of DRTRS. TRS dimensions from various US states and international practices guided the selection of suitable dimensions for DRTRS rumble units. Studies on TRS revealed insights into in-vehicle and roadside sound and vibration generation, aiding in understanding DRTRS's cognitive inputs to drivers. TRS effectiveness in reducing vehicle speeds, particularly approaching intersections, informed the research goal of quantifying speed reductions due to DRTRS. However, TRS limitations, such as driver lane-changing behaviors and diminishing speed reduction effects over time, underscored the need for dynamic countermeasures like DRTRS. The literature review facilitated the formulation of research goals, objectives, and evaluation parameters for DRTRS based on TRS research findings, ensuring a comprehensive understanding and effective implementation of the new system.

Deep Patel(2020): Pedestrian crashes present a significant safety concern globally, with various factors influencing injury severity. Studies have identified key contributors to severity, including pedestrian characteristics such as age and alcohol influence, driver characteristics like age and alcohol consumption, vehicle characteristics such as vehicle type and movement direction, environmental factors like weather and lighting conditions, and roadway attributes like speed limit and type. Understanding these factors is crucial for developing effective pedestrian safety measures. For instance, older pedestrians and those under the influence of alcohol are at higher risk of severe injuries, while adverse weather conditions and poor lighting increase the likelihood of severe pedestrian injuries. Engineering solutions, educational campaigns targeting pedestrian and driver behavior, and programs focusing on improving road attributes contribute to enhancing pedestrian safety. Overall, a comprehensive approach considering various factors is necessary to mitigate pedestrian crash severity effectively.

Studies identifying significant factors contributing to pedestrian injury severity

Studies	Year	Pedestrian Characteristics	Driver Characteristics	Vehicle Characteristics	Temporal and Environmental Characteristics	Roadway Characteristics
Zajac and Ivan	2003	X	X	-	-	-
Lee and Abdel-Aty	2005	X	-	-	X	-
Siddiqui et al.	2006	X	X	-	X	-
Eluru et al.	2008	X	-	-	X	X
Kim et al.	2008	X	X	X	X	-
Kim et al.	2010	X	X	X	-	-
Maybury et al.	2010	X	-	-	-	-
Kwigizile et al.	2011	-	-	-	X	-
Moudon et al.	2011	X	X	X	-	-
Tarko and Azam	2011	X	-	-	-	X
Zahabi et al.	2011	-	X	X	-	-
Dai	2012	X	-	-	X	-
Abdul Aziz et al.	2013	-	-	-	X	-
Jang et al.	2013	X	X	X	X	-
Mohamed et al.	2013	-	-	X	X	X
Tefft	2013	X	-	-	-	X
Islam and Jones	2014	-	-	-	-	X
Yasmin et al.	2014	-	-	-	X	-
Das and sun	2015	-	-	-	X	X
Haleem et al.	2015	X	-	X	X	X
Khattak and Tung	2015	-	-	-	X	-
Pour-Rouholamin and Zhou	2016	X	X	X	X	-
Guo et al.	2017	X	X	-	-	X
Salon and McLntyre	2018	-	X	-	-	-
Uddin and Ahmed	2018	X	X	X	-	X
Chen and Fan	2019	X	-	X	X	X
Liu et al.	2019	X	X	X	-	-
Mokhtarimousavi	2019	-	X	X	X	-
Sun et al.	2019	X	-	X	X	-

(Note: "X" denotes the significant factors identified by each study with respect to their objective and raw data set)

TABLE 2.3 STUDIES IDENTIFYING SIGNIFICANT FACTORS CONTRIBUTING TO PREDESTRIAN INJURY SEVERITY

A. Martin (2006) researched on pedestrian attitude and behavior has employed various methods, including video observation and self-report surveys, revealing several factors contributing to road traffic collisions. Pedestrian behavior can increase collision risk by choosing unsafe crossing places, non-compliance at designated crossings, crossing speed, and failure to attend to traffic. Choice of crossing place significantly impacts safety, with drivers more likely to yield at formal crossings. However, crossing away from designated areas poses higher risks. Peer pressure, especially among children, influences disobedience at pedestrian signals. Non-compliance at designated crossings, such as crossing against a red signal, is prevalent, with pedestrians prioritizing convenience over safety. Traffic volume and waiting times influence pedestrian behavior at signalized crossings, with longer waits increasing the likelihood of non-compliance. Demographic variables like age and gender also affect pedestrian behavior, with older pedestrians and females more likely to comply with signals. Failure to attend to traffic is a major cause of collisions, especially among children and elderly pedestrians. Alcohol consumption among pedestrians exacerbates collision risk, with a significant percentage of casualties associated with alcohol consumption, highlighting the need for interventions to address this issue.

CHAPTER III: STUDY GAPS

3.1. STUDY GAPS in Past Literatures

3.1.1. INVESTIGATING PEDESTRIANS' CROSSING BEHAVIOR DURING CAR DECELERATION USING WIRELESS HEAD MOUNTED DISPLAY: AN APPLICATION TOWARDS THE EVALUATION OF eHMI OF AUTOMATED VEHICLES

1. Lack of Studies on Pedestrian Behavior During Vehicle Deceleration: Existing research on pedestrian behavior in the context of automated vehicles (AVs) has primarily focused on interactions when vehicles come to a complete stop. However, there is a gap in understanding how pedestrians perceive and respond to vehicle deceleration during their crossing maneuver, especially in virtual reality (VR) settings.
2. Limited Investigation of External Human-Machine Interfaces (eHMI) Impact on Pedestrian Behavior: While previous studies have explored the role of eHMI in AV-pedestrian interactions, there is a dearth of research examining the effect of eHMI on pedestrians' actual crossing behavior, particularly in relation to vehicle deceleration scenarios.
3. Need for Objective Evaluation Measures: Current research often relies on subjective measures, such as surveys and interviews, to assess pedestrian perceptions of eHMI. However, there is a need for objective evaluation measures to quantitatively analyze the safety, efficiency, and learnability of different eHMI designs in influencing pedestrian crossing decisions.
4. Limited Application of VR in Studying Pedestrian Behavior: While VR technology offers a controlled environment for studying pedestrian behavior, its application in investigating pedestrian interactions with AVs, particularly during vehicle deceleration, remains underexplored. There is a gap in utilizing VR to simulate realistic pedestrian-vehicle interactions and evaluate the effectiveness of eHMI designs.
5. Insufficient Understanding of Pedestrian Judgment of Approaching Vehicle Speed: Despite the importance of pedestrians accurately judging approaching vehicle speed for safe crossing, there is limited research on how pedestrians perceive and respond to varying vehicle speeds during their crossing maneuver, especially in the absence of guaranteed vehicle yield.
6. Lack of Comprehensive Framework for eHMI Evaluation: Current studies often lack a comprehensive framework for evaluating eHMI effectiveness, encompassing safety, efficiency, and learnability aspects. There is a need for a structured approach to assess the impact of eHMI on pedestrian behavior across different scenarios and conditions.
7. Limited Generalizability of Findings: Many existing studies on pedestrian behavior in AV environments have focused on specific scenarios or have small sample sizes,

limiting the generalizability of findings. There is a gap in conducting large-scale studies with diverse participant demographics and real-world scenarios to validate research outcomes.

3.1.2. THE IMPACT OF PEDESTRIAN CROSSING FLAGS ON DRIVER YIELDING BEHAVIOR IN LAS VEGAS, NV

1. Limited Generalizability: The study acknowledges the limitation of only observing driver behavior at two mid-block crosswalks in Las Vegas, NV. There is a need to replicate the study in other geographical areas to determine the effectiveness of pedestrian crossing flags (PCFs) across different locations and traffic conditions.
2. Gender Differences: The study only involved female pedestrians, indicating a gap in understanding potential gender differences in driver yielding behavior. Future research should examine whether there are variations in driver response based on the gender of the pedestrian.
3. Long-Term Effects: The cross-sectional nature of the study prevents the assessment of how driver behavior may change over time with continued exposure to PCFs. Research is needed to investigate the potential fade-out effect and whether driver yielding behavior remains consistent over an extended period.
4. Legislative Clarity: The study highlights the ambiguity in Nevada state law regarding driver yielding to pedestrians, particularly at mid-block crosswalks. Further research could explore the impact of legislative clarity or ambiguity on driver behavior and pedestrian safety.
5. Technological Solutions: While PCFs are a low-cost intervention, there is a need to explore and evaluate other technological solutions, such as automatic emergency braking (AEB) systems, and their effectiveness in enhancing pedestrian safety, especially in areas with high traffic volume or speed.
6. Systems Approach to Road Safety: The study emphasizes the importance of adopting a systems approach to road safety, integrating various interventions targeting different components simultaneously. Future research could investigate the synergistic effects of combining engineering modifications, legislative changes, educational campaigns, and technological advancements on pedestrian safety outcomes.

3.1.3. PEDESTRIAN CROSSING BEHAVIOUR BETWEEN NORMAL TRAFFIC CONDITIONS

1. Lack of comprehensive study on pedestrian crossing behavior at unsignalized intersections/mid-block crossings.
2. Limited analysis of factors influencing pedestrian crossing choices (jaywalking, using grade separations, etc.) beyond just traffic conditions.

3. Need for more in-depth examination of pedestrian crossing patterns for different user groups (elderly, children, disabled, etc.).
4. Absence of analysis on the impact of roadway geometry, land use, and built environment factors on pedestrian crossing behavior.
5. Lack of evaluation of pedestrian education/awareness campaigns and their effectiveness in improving crossing behavior.
6. No exploration of emerging technologies (sensors, video analytics, etc.) for enhanced data collection on pedestrian movements.
7. Limited modeling or simulation of pedestrian crossing scenarios to test potential countermeasures before implementation.
8. Insufficient consideration of pedestrian delay and level of service metrics in evaluating crossing facilities.
9. Gaps in understanding pedestrian risk perception and acceptance levels for different crossing situations.
10. Need for more robust methodologies to quantify safety impacts of pedestrian crossing treatments and countermeasures.

3.1.4. COUNTERMEASURES FOR PEDESTRIAN-INVOLVED ACCIDENTS ON INTERSTATE HIGHWAYS

1. West Memphis has the second highest number of pedestrian-involved accidents on interstates in Arkansas from 2011-2017.
2. The majority of these accidents involve intentional pedestrians using the interstate illegally as a means of transportation, often crossing at night when visibility is low.
3. A critical area with a high concentration of these accidents near the Ingram Boulevard overpass is identified as the focus area.
4. Data analysis looks at factors like time of day, lighting conditions, age/race of pedestrians involved, etc.
5. A survey was conducted to gauge public perception and transportation preferences related to crossing the interstate.
6. Texarkana, which has a similar interstate layout, is compared as a "matched city" and has far fewer such pedestrian accidents, suggesting site-specific factors beyond just demographics.
7. Potential countermeasures evaluated include barriers/fencing, improved lighting, signage, sidewalk/overpass improvements, public transportation, education campaigns, and increased enforcement.
8. Crash reduction factors and cost-to-reduction ratios are calculated to compare and rank the potential countermeasures.

The main gap seems to be a lack of definitive crash reduction data and cost estimates specific to pedestrian-involved interstate accidents to conclusively recommend the optimal countermeasure(s) for implementation in West Memphis. More research targeting this unique issue is suggested as a next step.

3.1.5. EVALUATION OF PEDESTRIAN LEVEL OF SERVICE AND USERS' SATISFACTION ON SELECTED PEDESTRIAN SIDEWALKS IN DOWNTOWN WALNUT CREEK

1. Incorporating more qualitative factors into pedestrian level of service (PLOS) analysis beyond just sidewalk width and pedestrian flow rate.
2. Developing methods to quantify and include elements like aesthetics, street furniture, landscaping, etc. in PLOS calculations.
3. Exploring ways to integrate pedestrian perceptions of safety and comfort more directly into PLOS models.
4. Investigating the role of site-specific factors (e.g. adjacent land uses, traffic characteristics) on pedestrian experiences beyond the sidewalk itself.
5. Examining how PLOS evaluation methods could be updated to better account for different pedestrian user groups (elderly, disabled, children, etc.).
6. Assessing the transferability and consistency of qualitative pedestrian survey data across diverse urban contexts.
7. Comparing pedestrian level of service results from different calculation methodologies across a wider range of sidewalk facilities.
8. Integrating geographic information systems (GIS) more extensively to model pedestrian level of service at a network scale.
9. Further research on developing composite walkability indices that combine qualitative and quantitative pedestrian environment factors.
10. Exploring how advancements in data collection (video, sensors, etc.) could enhance pedestrian level of service evaluation methods.

3.1.6. PEDESTRIAN SAFETY: A NEW METHOD TO ASSESS PEDESTRIAN KINEMATICS

1. No accurate and convenient method existed previously to assess the influence of a vehicle's front-end design on the safety of vulnerable road users (pedestrians and cyclists).
2. Current type-approval tests using impactors do not fully represent the complete kinematics of pedestrian-vehicle collisions, which is very significant for the injuries sustained by pedestrians.
3. There was no criterion available before to determine the geometric properties of pedestrian motion after a collision with a motor vehicle.
4. Existing methods did not adequately assess the risks posed to pedestrians by SUVs and other vehicles with high bumper/bonnet leading edge heights compared to passenger cars.

5. Pedestrian injury assessment was previously focused only on biomechanical criteria from impactor tests, lacking consideration of the post-impact kinematics of the pedestrian's body.

3.1.7. ANALYSIS OF PEDESTRIAN CROSSING SPEED AND WAITING TIME AT INTERSECTIONS IN DHAKA

1. Lack of locally derived design parameters: The paper highlights the lack of locally derived standards for pedestrian crossing speed and waiting time in Bangladesh. Foreign guidelines from countries like the USA or UK may not be applicable due to differences in pedestrian behavior across countries/regions.
2. Limited understanding of factors affecting pedestrian behavior: While the paper examines various factors affecting pedestrian crossing speed and waiting time at intersections, there could be additional factors not considered in this study that influence pedestrian behavior and safety.
3. Lack of data on vulnerable pedestrian groups: The study does not specifically focus on pedestrian behavior and safety needs of vulnerable groups such as children, elderly, or disabled individuals, who may have different crossing speeds and tolerances for waiting times.
4. Limited scope to intersections: The study is limited to pedestrian behavior at intersections only. However, pedestrian safety issues may also exist at mid-block locations or other roadway segments that are not covered in this research.
5. Lack of evaluation of infrastructure design elements: The study does not evaluate the impact of various infrastructure design elements (e.g., crossing facilities, signage, lighting, etc.) on pedestrian behavior and safety at intersections or other locations.
6. Need for more comprehensive data collection: While the study collected data from three intersections, a more extensive data collection effort across different areas of the city and over different time periods could provide more robust insights into pedestrian behavior patterns.

3.1.8. A SURROGATE VIDEO-BASED SAFETY METHODOLOGY FOR DIAGNOSIS AND EVALUATION OF LOW-COST PEDESTRIAN SAFETY COUNTERMEASURES: THE CASE OF COCHABAMBA, BOLIVIA

1. Limited work examining vehicle-pedestrian interactions and conflicts, and the underlying factors that cause collisions in the context of developing countries.
2. Lack of research investigating pedestrian safety in the Latin American context, partly due to the lack of reliable crash data in this region.

3. Very few studies have documented the feasibility of using surrogate safety measures and video analytics approaches for pedestrian safety analysis in low-income country contexts.
4. Limited research on evaluating the effectiveness of low-cost, temporary pedestrian safety countermeasures using before-after studies, especially in resource-constrained settings.
5. Need for methodological approaches to identify risk factors and evaluate countermeasures when crash data is incomplete or missing in developing countries.
6. Lack of studies on the distinct traffic patterns, risk factors, and safety issues faced by pedestrians in the context of rapid urbanization and lack of adequate infrastructure in developing countries.

3.1.9. RED LIGHT VIOLATION AND PEDESTRIANS' MODAL SALIENT BELIEFS ABOUT UNSAFE ROAD CROSSING BEHAVIOR: A QUALITATIVE STUDY

1. Gap in qualitative formative research to deeply understand underlying beliefs and factors influencing pedestrians' traffic signal violation behavior across different cultural contexts.
2. Lack of context-specific elicitation of modal salient beliefs (advantages, disadvantages, referents, circumstances) regarding pedestrian red light violations in the cultural setting of Iran.
3. Need for a systematic qualitative study to identify salient beliefs driving pedestrian red light violations in Iran, in order to inform culturally-relevant TPB questionnaire development and intervention design.
4. Absence of any prior qualitative elicitation studies examining pedestrian beliefs specifically related to red light violation behavior based on the Theory of Planned Behavior framework.

3.1.10. SHARED SPACE AND PEDESTRIAN SAFETY: EMPIRICAL EVIDENCE FROM PEDESTRIAN PRIORITY STREET PROJECTS IN SEOUL, KOREA GAPS

1. Limited empirical evidence on the effectiveness of the Pedestrian Priority Street (PPS) projects and the design principles in improving pedestrian safety, particularly in the context of Seoul, Korea.
2. Lack of understanding of how different paving design types and visual elements (e.g., colors, patterns, transverse lines) influence vehicle speeds and driver behavior in narrow streets shared by pedestrians and vehicles.
3. Gap between objective safety measures (e.g., vehicle speeds) and pedestrians' subjective perceptions of safety in shared street environments.
4. Need for more research on the optimal design strategies to balance pedestrian safety and mobility while also ensuring driver compliance in shared spaces.

5. Limited evaluation of the long-term effects and sustained impacts of shared space interventions like the PPS on pedestrian safety and driver behavior.
6. Lack of research on potential policy interventions and legal frameworks needed to support and reinforce the principles of pedestrian priority and shared space in urban areas.

3.1.11. A CORRIDOR-LEVEL PEDESTRIAN CRASH RISK ASSESSMENT FRAMEWORK USING AUTONOMOUS VEHICLE SENSOR DATA

1. Limited reliance on crash-based statistical models: Existing studies predominantly utilise crash-based statistical models for pedestrian safety analysis, primarily focusing on mid-blocks and signalised intersections. However, these models rely heavily on police-reported data, which may suffer from under-reporting and lack detailed behavioural information.
2. Need for alternative assessment frameworks: To overcome the limitations of police-reported data, there is a growing interest in utilising traffic conflict-based pedestrian safety assessment frameworks, such as extreme value theory models. These frameworks offer alternative perspectives and valuable insights beyond traditional crash-based analysis.
3. Lack of comprehensive utilisation of video data: While various methods, especially utilising video data, have been employed to collect information on traffic conflicts, there is still room for more comprehensive utilisation of this data, particularly at intersections. Extracting meaningful information from video data can provide insights into road user trajectories and behavioural patterns.
4. Untapped potential of autonomous vehicle data: Despite recent advancements in vehicle technologies, such as autonomous vehicles, there remains a lack of comprehensive exploration and utilisation of autonomous vehicle data for corridor-level pedestrian safety analysis. Few applications of autonomous vehicle data exist in the literature, highlighting a significant research gap in this area.

3.1.12. DESIGN OF VEHICLE FRONTAL PROTECTION SYSTEMS CAPABLE OF MEETING FUTURE PEDESTRIAN SAFETY

1. Comprehensive understanding of pedestrian safety requirements and test methods for Australian manufacturers, including Toyota Australia
2. FEA evaluation processes of pedestrian safety assessment methods on Australian VFPS products
3. Innovations of the new design of VFPS that can meet the imminent and stringent pedestrian safety requirements
4. Design parametric studies of VFPS regarding how to design pedestrian-friendly VFPS

3.1.13. PEDESTRIAN SAFETY PREDICTION METHODOLOGY

1. Lack of Quantification for Pedestrian Signal Effects: The paper does not provide quantification for the effect of pedestrian signals on safety. Further research is needed to determine the impact of pedestrian signals on pedestrian safety at signalised intersections.
2. Uncertainty Regarding Signal Timing and Right Turn-on-Red Effects: The literature suggests that the effects of signal timing and right turn-on-red operations on pedestrian safety are small or inconclusive. Further investigation is required to clarify these effects and their implications for pedestrian safety.
3. Need for Extension to Unsignalized Intersections and Roadway Segments: The pedestrian safety prediction methodology presented in the paper focuses solely on signalised intersections. There is a gap in research regarding pedestrian safety at unsignalized intersections and roadway segments. Further study is needed to develop models or databases to address these areas.
4. Lack of Pedestrian Volume Data: Extending the pedestrian safety prediction methodology to unsignalized intersections and roadway segments requires extensive databases containing pedestrian volume data. However, the availability of such data may be limited. Research is needed to develop models that can estimate pedestrian volumes from land-use and demographic data.

3.1.14. PEDESTRIAN SAFETY RELATIVE TO TRAFFIC SPEED MANAGEMENT

1. Effectiveness of Traffic-Speed Management Efforts: There is a lack of understanding regarding the effectiveness of speed-reduction countermeasures for pedestrian safety, both individually and in combination. Research often lacks sufficient time to measure pedestrian crashes rigorously, necessitating field studies to assess the impacts of speed management efforts over a longer period or via multiple-site case control studies.
2. Contextual Effectiveness of Countermeasures: Certain countermeasures may work better in specific geographic or land use contexts than others for improving pedestrian safety. Information on the effectiveness of speed management efforts in various combinations and contexts is essential for cities aiming to enhance pedestrian safety.
3. Long-term and Geographic Impacts: More information is needed about the long-term impacts and geographic extent of reduced vehicle speeds resulting from countermeasures, including potential spillover effects on other areas.
4. Perceived Safety Impacts: Research on perceived safety relative to various treatments is lacking. Understanding pedestrians' perceptions of safety when crossing streets with specific treatments can inform decision-making.
5. Evaluation of Comprehensive Programs: The effectiveness of comprehensive programs, such as Vision Zero, remains understudied, including the impacts of various engineering treatments and education and outreach efforts.

6. Solutions for Arterials: There is a need for solutions to manage traffic speed on higher-volume, higher-speed roadways like arterials, which experience the most injurious crashes.
7. Role of Driving Culture: Research on facilitating behaviour and culture change related to speed and auto dependence is lacking, despite the recognition of speeding as a problem.
8. Speed Limit-Setting Process: There is a lack of clarity on the process for setting speed limits within each state, including key decision makers and decision points.
9. Framework for Intra-Agency Collaboration: A framework is needed to foster collaboration between city and state agencies, legislative authorities, and federal agencies to achieve safety goals effectively.

3.1.15. PEDESTRIAN DETECTION AND IDENTIFICATION

1. Real-time Processing Demand: Applications like surveillance and monitoring require real-time pedestrian detection and identification, but rich descriptions and complex frameworks pose challenges for industrial applications, where simpler algorithms may suffice.
2. Reliability of Classification Algorithms: Statistical modeling and logic-based classification algorithms often fail to mimic the human vision system accurately, leading to limitations in identification and detection, as evidenced by false alarms in popular frameworks like HOG SVM.
3. Hierarchical Protocol for Complex Problems: Existing frameworks face limitations in solving complex identification and detection problems. A proposed hierarchical protocol with flexible layers aims to overcome these limitations by allowing the addition of algorithms as needed.
4. Pedestrian Tracking Challenges: Pedestrian tracking presents challenges akin to a chicken-egg problem, where continuous detection relies on equalised tracking. False alarms persisting in later frames necessitate the adoption of simple appearance-based algorithms for identification.
5. Performance Improvement Strategies: To enhance the performance of existing frameworks like HOG SVM, novel approaches such as using head-shoulder structures or approximated symmetrical features as evidence of pedestrian presence are proposed, along with mosaic images to separate multiple pedestrians in one box.
6. Future Work Needed: While the proposed protocol and algorithms show promise, further research is required to address their limitations and refine their effectiveness in pedestrian detection and identification tasks.

3.1.16 A STUDY OF PEDESTRIAN SAFETY BEHAVIOR USING ACTIVITY SAMPLING:

1. The study only examined a small number of intersections, limiting the generalizability of its findings. A larger sample size would have provided more robust results.
2. The analysis relied on a small number of pedestrian accidents, which didn't allow for conclusive statistical analysis. A more comprehensive examination over multiple years and at numerous sites could have provided clearer insights.
3. The study lacked control groups or comparison sites, which are essential for determining the true impact of pedestrian signals. Including control groups would have allowed for a more rigorous evaluation of the signals' effectiveness.
4. There's no mention of a thorough screening process for accidents unrelated to pedestrian signals. Omitting ACCIDENTS caused by factors like vehicle failure or drunk driving could have provided a clearer picture of the signals' impact on safety.
5. The study could have benefited from a more robust experimental design, such as randomized control sites or trend analysis, to better isolate the effects of pedestrian signals.
6. Despite the study's attempt to analyze pedestrian accident data, the findings don't provide conclusive evidence either supporting or refuting the effectiveness of pedestrian signals in reducing accidents.

3.1.17. BEHAVIORAL EVALUATION OF PEDESTRIAN SIGNALS. TRAFFIC ENGINEERING

1. The study focuses solely on pedestrian compliance and successful crossings but does not include data on pedestrian accidents. Without considering accident data, it's challenging to ascertain the direct impact of pedestrian signals on safety.
2. The study seems to provide a snapshot comparison between intersections with and without pedestrian signals. A longitudinal analysis over time could provide insights into any changes in pedestrian safety due to the introduction of pedestrian signals.
3. While hazard indices were calculated, the review doesn't elaborate on their specific components or how they were derived. A more detailed explanation of these indices would provide a clearer understanding of the hazards associated with pedestrian crossings.
4. There's no mention of potential confounding factors that could influence pedestrian compliance and safety, such as traffic volume, pedestrian density, or environmental factors. Accounting for these variables could enhance the validity of the findings.
5. The study may lack generalizability if it only focuses on a specific geographic area or type of intersection. Including a broader range of intersections in diverse settings would improve the applicability of the findings.
6.The review provides a summary of Mortimer's findings but lacks detailed contextual information about the methodology employed, data collection procedures, and any

limitations encountered during the study. A more comprehensive understanding of these aspects would aid in evaluating the study's validity and reliability.

3.1.18 PEDESTRIAN VEHICLE CONFLICT AND OPERATION OF PEDESTRIAN LIGHT-CONTROLLED (PELICAN) CROSSINGS. PROC.

1. Lack of Accident Data Analysis: The study does not analyze any accident data related to pelican crossings, which limits its ability to assess the safety implications of these crossings. Accident data analysis would provide valuable insights into the actual safety performance of pelican crossings.
2. Absence of Operational and Compliance Data: The study does not include any analysis of operational or compliance data associated with pelican crossings. Understanding factors such as pedestrian and driver compliance rates, traffic flow patterns, and operational efficiency would enhance the assessment of pelican crossing effectiveness.
3. Limited Scope of Study: The study mainly focuses on opinion surveys among pedestrians regarding their understanding and effectiveness of pelican crossings. While public perception is important, it is just one aspect of assessing the overall effectiveness of traffic control devices. The study could benefit from a more comprehensive analysis that includes multiple metrics beyond public opinion.
4. Insufficient Information on Methodology: The review does not provide detailed information about the methodology employed in conducting the opinion surveys. Without clarity on the survey methodology, it's difficult to assess the reliability and validity of the study findings.
5. No Discussion of Specific Design or Operational Recommendations: While the study recommends operational and design improvements for pelican crossings based on its findings, it lacks specific details about these recommendations. Providing concrete suggestions for improvement would enhance the practical utility of the study.
6. Limited Generalizability: The study's findings are based on surveys conducted in specific locations in England, which may limit the generalizability of the results to other contexts or regions. Including a more diverse range of locations would improve the applicability of the study findings.

3.1.19. THE COMPARATIVE SAFETY OF PEDESTRIAN CROSSINGS

1. While the study analyzes injury accident data, pedestrian counts, and vehicle flows for lengths of road on and near pedestrian crossings, it does not consider other factors that could influence pedestrian safety, such as environmental conditions, time of day, or pedestrian behavior. A more comprehensive analysis that includes these factors could provide a more nuanced understanding of pedestrian safety at different types of crossings.

2. The study seems to provide a snapshot comparison of pedestrian accident rates at zebra and pelican crossings. A longitudinal analysis over time could reveal any trends or changes in pedestrian safety associated with the use of these crossings.
3. The study focuses on crossings located in England and may not be directly applicable to other regions with different traffic patterns, infrastructure, or pedestrian behavior. Including data from a more diverse range of locations would improve the generalizability of the findings.
4. The review does not mention whether the study accounts for potential confounding variables that could influence pedestrian accident rates, such as traffic volume, road design, or driver behavior. Failing to control for these variables could affect the validity of the study's conclusions.
5. The review does not provide detailed information about the methodology used in the study, such as data collection procedures, statistical analysis methods, or criteria for selecting candidate crossings. Without this information, it's challenging to assess the rigor and reliability of the study.
6. While the review mentions the findings regarding the effectiveness of pelican and zebra crossings in reducing pedestrian accidents, it does not discuss the broader implications of these findings for traffic safety policies, infrastructure design, or pedestrian education programs.

Addressing these gaps would strengthen the review and provide a more comprehensive evaluation of the effectiveness of different types of pedestrian crossings in reducing pedestrian accidents.

3.1.20. PELICAN CROSSINGS, MYTH OR MIRACLE

1. Limited Data Analysis: While Williams discusses the findings and experiences of different researchers regarding the safety, operation, and behavior of pelican crossings, there is a lack of detailed analysis of the underlying data from these studies. Without a thorough examination of the data, it's challenging to draw definitive conclusions about the safety benefits of pelican crossings.
2. Absence of Comparative Analysis: While the discussion compares pelican crossings with their predecessor, the zebra crossing, there is a lack of detailed comparative analysis regarding the safety performance of these two types of crossings. A more comprehensive comparison could provide insights into the relative effectiveness of each type in reducing pedestrian accidents.
3. Limited Consideration of Confounding Factors: The review mentions that positive safety benefits of pelican crossings may be masked by the presence of other factors, such as additional countermeasures installed at the sites. However, there is limited discussion on how these confounding factors were addressed or controlled for in the studies reviewed. Without accounting for confounding variables, it's difficult to accurately assess the impact of pelican crossings on pedestrian safety.

4. Insufficient Discussion of Methodological Limitations: There is little discussion of the methodological limitations of the studies reviewed, such as sample size, study design, data collection methods, and potential biases. A more thorough examination of these limitations would provide a clearer understanding of the reliability and validity of the findings.
5. Limited Discussion of Policy Implications: While Williams suggests that the studies do not provide conclusive evidence of the positive safety benefits of pelican crossings, there is limited discussion of the implications of these findings for traffic safety policies and infrastructure design. A more robust discussion of the policy implications would enhance the practical relevance of the review.

3.1.21. PEDESTRIAN SIGNAL PHASING

1. Limited Data Analysis: The review notes that the association between safety and compliance is primarily based on judgmental factors rather than specific data analysis. Without a detailed analysis of pedestrian accident data or other relevant safety metrics, it's difficult to determine the precise safety benefits of different signal phasing techniques.
2. Absence of Comparative Analysis: While the study analyzes three types of signal phasing (early release, late release, and scramble timing), there is a lack of comparative analysis to assess the relative effectiveness of these techniques in reducing pedestrian accidents. A comparative analysis could provide insights into which signal phasing technique is most effective for enhancing pedestrian safety.
3. Limited Scope of Study: The study focuses on compliance studies conducted in Sioux City, Iowa, but does not consider a broader range of locations or environmental conditions. Including data from diverse geographic areas and traffic environments would improve the generalizability of the findings.
4. Insufficient Discussion of Violation Rates: While the review mentions higher violation rates at scramble-timed intersections, there is limited discussion on the implications of these violation rates for pedestrian safety. A more thorough examination of the reasons behind the violations and their potential impact on safety would enhance the understanding of the findings.
5. Lack of Methodological Detail: The review does not provide detailed information about the methodology used in the compliance studies, such as data collection procedures, sample size, or statistical analysis methods. Without this information, it's challenging to assess the rigor and reliability of the study findings.
6. Limited Discussion of Practical Implications: While the study provides information about pedestrian behavior and compliance relative to different signal-timing schemes, there is limited discussion of the practical implications for traffic engineering and pedestrian safety policies. A more robust discussion of the practical implications would enhance the usefulness of the study findings for decision-makers.

3.1.22. EVALUATING THE EFFECTIVENESS OF THE PEDESTRIAN SAFETY INTERVENTION PROGRAM: BEHAVIORAL AND OBSERVATIONAL APPROACH

1. Demographic Representation Improvement:
- Ensure demographic representation in survey responses aligns closely with the area's demographics.
- Use additional qualification questions to achieve better matching.
- Aim for a larger sample size to support subgroup analysis effectively.

2. Enhanced Survey Questions:
- Include questions to ascertain respondents' primary mode of transportation (e.g., walking or driving).
- Determine the respondent's perspective (driver or pedestrian) when answering survey questions.
- Utilize this perspective information for deeper analysis, such as understanding behaviors at specific intersections or locations.

3. Advanced Image Processing Techniques:
- Implement modern image-processing techniques leveraging deep learning and machine learning algorithms.
- Collect extended video data spanning 48-72 hours for comprehensive analysis of pedestrian and driver activities at study locations.

4. Surrogate Safety Measures (SSM) Evaluation:
- Assess surrogate safety measures as indicators of potential crashes and incidents.
- Utilize SSMs to provide practitioners and professionals with a clearer understanding of safety issues, aiding in informed decision-making and interventions.

3.1.23. EXPLORING PEDESTRIAN ROAD SAFETY IN PUBLIC TRANSIT LOCATIONS

1. Exploration of Passenger Count and Vehicle Location Datasets:
- Future research could utilize datasets from public transit agencies, including passenger count and vehicle location data, to enhance safety analysis at public transit access points (PTAPs).
- Investigate how these datasets could provide insights into pedestrian collision risk and safety measures at PTAPs.

2. **Detailed Analysis of Road Geometry:**
- Consider additional parameters such as lane width and number of lanes alongside road width to further analyze the impact of road geometry on pedestrian safety at PTAPs.
- Explore how variations in lane width influence pedestrian road safety and identify configurations that contribute to safer PTAP environments.

3. **Evaluation of Pedestrian Walk Interval Specifications:**
   - Study the effect of pedestrian walk interval specifications, including walk interval and clearance duration, on pedestrian safety at PTAPs near intersections.
   - Analyze how different walk interval settings impact pedestrian behavior and collision risk at PTAPs.
4. **Specification of Traffic Control Devices:**
   - Investigate the specifications and effectiveness of stop signs near PTAPs, distinguishing between those for pedestrian crossings and those on side streets.
   - Assess how different traffic control devices affect pedestrian safety at PTAPs and identify optimal configurations for improved safety.
5. **Analysis of Road Median Types:**
   - Explore the role of different types of road medians in enhancing pedestrian safety at PTAPs, considering variations in configurations and their impact on pedestrian behavior.
   - Evaluate how road medians channelize pedestrian traffic and provide refuge during road crossings to improve safety.
6. **Integration of Traffic Operation and Network Performance:**
   - Conduct integrated research studies considering both road safety geometry, built-environment measurements, and traffic operation to provide comprehensive safety analyses at PTAPs.
   - Assess how factors affecting traffic operation and network performance influence pedestrian safety and identify strategies for improved road safety management.
7. **Comparison of Collision Count Models and Hotspot Identification Methods:**
   - Evaluate and compare the performance of various collision count models and hotspot identification methods to enhance pedestrian road safety analysis at PTAPs.
   - Assess the suitability of different models and methods for identifying collision hotspots and informing safety interventions.
8. **Temporal Analysis of Collision Counts:**
   - Consider shorter time periods for aggregated collision counts to capture temporal changes in the built environment and traffic patterns.
   - Analyze how collision risk varies based on temporal factors such as time of day, day of the week, and season, and recommend appropriate countermeasures.
9. **Consideration of Crash Types:**
   - Take into account different types of pedestrian-vehicle collisions, such as midblock dart/dash, intersection turning/through vehicle, and bus-related collisions, to tailor safety interventions accordingly.
   - Provide crash-type-specific inferences to address collision counts and enhance safety measures at PTAPs.

10. Temporal Variation in Collision Counts:

- Analyze the temporal variation in collision counts to understand how collision risk fluctuates based on time and date, including rush hours, weekdays vs. weekends, and seasonal patterns.
- Recommend countermeasures tailored to specific temporal variations to improve road safety management at PTAPs.

3.1.24. FACTORS AFFECTING PEDESTRIAN SAFETY

1.Measures at signalised junctions Pedestrian collisions at signal-controlled junctions account for a surprisingly high proportion of the total. Suitable measures to adopt are signal strategies that shorten waiting times for pedestrians, the provision of pedestrian phases, and all-red periods. This may be achieved as in the list of possible enhancements to pedestrian crossings by using shorter cycle times or increasing the window of opportunity for the pedestrian phase. Clearly these proposals will tend to increase delay to vehicles and they will only be possible in suitable locations.

2. Measures suitable for use in residential areas An area wide consideration of residential areas, to determine the route hierarchy and hence which streets should have traffic calming measures and 20mph speed limits and where home zones or play zones could best be implemented. On the latter, pedestrian crossings should be informal or zebra crossings depending on the flow. Simple measures such as road narrowings e.g. build-outs to allow pedestrians to cross safely, particularly if there are parked cars.

3.Measures suitable for use in shopping areas Shopping streets are good candidates for pedestrianisation or semi-pedestrianisation. Where this is not possible, suitable crossings should be introduced at frequent intervals. These could be enhanced e.g. by the use of raised crossings or wide crossings with a central refuge. The use of pedestrian priority signals could also be considered.

4. Measures suitable for use outside schools As far as possible, schools should be located in 20mph zones. Other possibilities are the use of intelligent road studs or vehicle-activated signals that work on 30mph most of the time but 20mph at school times, or pedestrian priority signals. The introduction of play zones may be appropriate.

5. Measures suitable for use in historic areas with high pedestrian and vehicle usage In historic areas, it is important to maintain the aesthetic appearance. For example, the use of coloured surfacing should be avoided and high quality materials adopted.

Where there are large numbers of tourists, reminders on the road surface reminding foreign tourists in particular to look left/right, and wide crossings are appropriate. Timings should minimise delay to pedestrians as far as possible without increasing congestion. All red periods are easy to understand and decrease pedestrian delay.

6.Measures suitable for use on mixed priority routes Reducing the amount of parking (e.g. by red routes) will allow drivers a clear view of pedestrians (although they may also encourage speeding), but generally zebra or Puffin crossings will be required. These should have short cycle times to minimise pedestrian delay. The use of countdown timers should also be considered. Speed cameras may be needed on the busier routes.

3.1.25. IMPROVING PEDESTRIAN SAFETY WITH THE IMPLEMENTATION OF THE DEMAND-RESPONSIVE TRANSVERSE RUMBLE STRIP AS A NEW TRAFFIC SAFETY COUNTERMEASURE

1. Upgradation of the Constructed Prototype The first prototype of DRTRS suffered a few minor issues, such as not being completely level with the roadway surface during its inactive state and displacement of the rumble unit itself which generated unwanted sound and vibration. In addition, when vehicles ran over active DRTRS, the rumble units made subtle rattling noise. The above-mentioned uneven rumble unit and rattling noise due to the displacement issues can be fixed in future updates.

2. Appropriate Synchronization of System Equipment Currently, the cameras (TrafiSense™ and TrafiRadar™) are not synced with the communication unit of the DRTRS system. Therefore, for data collection purposes, the activation and deactivation mechanisms of the DRTRS system were operated manually. The communication between the cameras and DRTRS were designed with radio communication, which will be a potential added upgrade of the next DRTRS system prototype. The upgrade will include communication among the cameras, DRTRS, and the pedestrian push button. This communication will facilitate the system to operate DRTRS (activate/ deactivate), as per the below associated events (to mention a few):
• Presence of inattentive pedestrians in the crosswalk (signal from TrafiSense™ to DRTRS)
• Presence of attentive pedestrians in the crosswalk (signal from pedestrian push button to
DRTRS)
• Over-speeding vehicles (signal from TrafiRadar™ to DRTRS)
• Wrong-way driven vehicles (signal from TrafiRadar™ to DRTRS)

3.Deployment on the Regular Roadway to have Drivers' Naturalistic Feedback

- The experiments with the DRTRS system were conducted within the UNLV jurisdiction area. The sound and vibration experiments were performed under the controlled environment with informed drivers. In addition, most of the stakeholders of the experiments were from a selective demography such as university professors, staffs, and students.
- The deployment of DRTRS on a regular roadway with regular ongoing traffic will yield more naturalistic drivers' feedback. The results from the

experiments on the regular roadway would cover the diverse demographic population. A future study would have the scope to expand the experiment from a university road to neighborhood roads, intersections, arterial roads, or even highways.

CHAPTER IV: CONCLUSIONS

4.1. Conclusions:

In conclusion, this study sheds light on the critical importance of pedestrian safety, particularly in urban environments where mixed traffic and inadequate infrastructure pose significant risks. Through a thorough review of existing literature, we have identified key factors contributing to pedestrian accidents, emphasizing the need for targeted interventions to address these challenges. Our findings underscore the importance of adopting a multi-faceted approach that incorporates infrastructure modifications, traffic control measures, and public education campaigns to improve pedestrian safety outcomes.

Moreover, this report highlights the potential of emerging technologies, such as smart traffic systems and pedestrian detection sensors, to play a transformative role in enhancing pedestrian safety. By leveraging real-time data and providing timely feedback to both pedestrians and drivers, these technologies have the potential to mitigate the risk of accidents and create safer urban environments for all road users.

Moving forward, there is a clear need for further research to bridge the identified gaps in pedestrian safety studies. Future studies should explore innovative methodologies, such as the temporal proximity surrogate safety approach, to measure pedestrian safety more effectively. Additionally, continued advancements in technology and the integration of data-driven solutions will be essential for developing comprehensive strategies to address pedestrian safety challenges in urban areas. Through ongoing research and collaboration, we can work towards creating safer streets and reducing pedestrian accidents worldwide.

4.2. Scope for future research:

The study has unveiled several critical gaps in existing literature regarding pedestrian safety, highlighting the need for further research to address these deficiencies comprehensively. Future investigations should focus on implementing innovative methodologies, such as advanced data extraction techniques and sophisticated data analysis approaches, to delve deeper into the identified gaps and enhance our understanding of pedestrian safety dynamics. Specifically, there is a need for research that delves into the effectiveness of various pedestrian safety interventions, including infrastructure modifications, traffic control measures, and public education campaigns. By conducting rigorous data extraction and analysis, future studies can provide valuable insights into the impact of these interventions on pedestrian safety outcomes, helping policymakers and urban planners make informed decisions.

Furthermore, exploring the role of emerging technologies, such as smart traffic systems and pedestrian detection sensors, warrants further investigation. By leveraging data-driven approaches, researchers can assess the efficacy of these technologies in enhancing pedestrian safety and reducing the risk of accidents in urban environments.

Overall, future research endeavors should aim to bridge the identified gaps in pedestrian safety literature through comprehensive data extraction, rigorous analysis, and innovative methodologies. By advancing our understanding of pedestrian safety dynamics, we can develop more effective strategies to create safer streets and mitigate pedestrian accidents.

CHAPTER V: RECOMMENDATIONS

5.1. Recommendations for pedestrian's safety:

5.1.1. Implement pedestrian awareness campaigns to discourage phone usage while walking.

5.1.2. Install signs reminding pedestrians to stay off their devices while crossing.

5.1.3. Educate pedestrians about the risks of walking in groups.

5.1.4. Encourage pedestrians to travel individually and avoid overloading themselves with goods.

5.1.5. Encourage pedestrians to make eye contact with drivers before crossing the road.

5.1.6. Enforce traffic signal compliance through increased police presence.

5.1.7. Install cameras at intersections to monitor and deter signal violations.

5.1.8. Install physical barriers or fences to prevent pedestrians from crossing at unauthorized locations.

5.1.9. Increase pedestrian education on the importance of using designated crosswalks.

5.1.10. Enhance driver awareness through public education campaigns.

5.1.11. Improve road design by incorporating pedestrian-friendly infrastructure.

5.1.12. Implement speed reduction measures in areas with high pedestrian-vehicle conflict.

5.1.13. Install reflective materials or signage to make pedestrians more visible to drivers.

5.1.14. Improve crosswalk visibility through signage and pavement markings.

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