Identification of Black Spots for Pedestrian Accident in Yangon

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Abstract: This research focuses on the identification of pedestrian accident black spots in Yangon, where there has been a critical rise in the occurrences of pedestrian accidents from 2017 to 2023. Using Geographic Information System analysis, 2,029 pedestrian accidents were mapped to identify high-risk locations. Five major black spots have been ranked according to the Severity Index values that denote the severity of accidents occurring in these locations. Factors contributing to the severity of the accident include poor lighting, lack of marked crosswalks, and heavy flow. The Severity Index will help identify the risk in each location for the implementation of safety treatments. Some of the proposed countermeasures will be improving street lighting, providing marked pedestrian crossings, and introducing enhanced traffic management methods. The findings point out the urgency for targeted interventions to improve pedestrian safety and reduce the severity of accidents within Yangon's urban landscape.

Keywords: Black spots, Pedestrian accidents, Yangon, Geographic Information System, Severity Index

1. INTRODUCTION

Pedestrian accidents have grown to be a major worldwide issue, with significant financial, physical, and psychological costs to communities and families. Yangon is not only the former capital city but also a commercial hub. And then, the public transportation system in Myanmar is mainly concentrated in Yangon. As the city expands, interactions between pedestrians and other various forms of transportation such as cars, buses, bikes become more complex. There were 2029 pedestrian accidents from 2017 to 2023 in Yangon according to Yangon Traffic Police Department. It is essential to provide the counter measures for the accident-prone locations, black spots to reduce the losses due to the pedestrian accident. Therefore, identification of black spots is crucial to find out the locations where countermeasures are needed priorly.

The ability of GIS to associate attribute data with spatial data enables the prioritizing of road accident occurrences and visually represents the results for enhanced planning and

decision-making. Using GIS, black spot location can be identified and factors causing the accidents can also be figure out. Therefore, reasonable countermeasures can then be provided to improve safety in each black spot location according to its caused factors. In this study, GIS analysis is performed using ArcGIS 10.1 software.

This study is structured into five main sections. Section one: Introduction provides an overview of the research background, objectives, and significance of identifying pedestrian black spots. Related Works section reviews existing literature on pedestrian safety, accident analysis, and black spot identification methodologies. The Methodology section outlines the research framework, describes the study area, and details the processes of data collection, preparation, importing, and mapping. The Results and Discussion section presents the identification of pedestrian black spots and proposes countermeasures for each identified location. Finally, the Conclusions and Recommendations section summarizes the key findings and suggests policy and engineering interventions for improving pedestrian safety.

2. RELATED WORKS

Pedestrian safety has been extensively studied worldwide, with numerous research efforts dedicated to identifying contributing factors and pinpointing black spots in urban environments. A review of the existing literature provides crucial insights into the methodologies and frameworks employed to address this critical issue in transportation safety.

Geographic Information System (GIS) tools are widely used to analyze traffic crash characteristics (Cheng et al., 2018; Steenberghen et al., 2004). For instance, Steenberghen et al. (2004) utilized GIS combined with point pattern analysis to identify black spot locations in the Belgian city of Mechelen. Simple techniques for locating high-risk areas often involve determining sites where the crash count or crash rate per unit exposure surpasses a predefined threshold (Taylor et al., 2000).

Other approaches rely on critical crash rate comparisons to identify hazardous locations with crash records significantly above the system-wide average, as described by Austroads (1988). Statistical methodologies, such as the empirical Bayes method, offer an advanced alternative by creating a model based on reference populations and comparing the expected crash counts to observed data (Elvik, 2008; Li & Zhang, 2008). Additionally, ranking unsafe locations by crash severity is common practice. Geurts et al. (2004) proposed a weighting system of 1, 3, and 5 for minor, serious, and fatal injuries, respectively. Similarly, RTA (1994) introduced a severity index calculated using weights of 3.0 for fatal crashes, 1.8 for serious injuries, 1.3 for other injuries, and 1.0 for property damage.

Recent advancements in spatial crash data analysis have introduced methods like Kernel Density Estimation (KDE) for identifying high-risk zones. KDE is widely applied in hot spot analysis and involves generating a continuous density surface by aggregating crash events within a defined search bandwidth (Pulugurtha et al., 2007). For instance, studies focusing on high pedestrian crash zones frequently utilize planar KDE techniques. In the context of this research, black spots are identified using KDE, weighted by severity indices of 5 for fatal crashes, 3 for severe injuries, and 1 for minor injuries, to provide an area-wide analysis of high-risk locations.

3. METHODOLOGY

3.1 Framework of Methodology

Figure 1 presents the methodological framework employed to achieve the study's objectives: black spots and their caused factors investigation. The analysis relies on secondary data sourced from the Yangon Traffic Police Department.

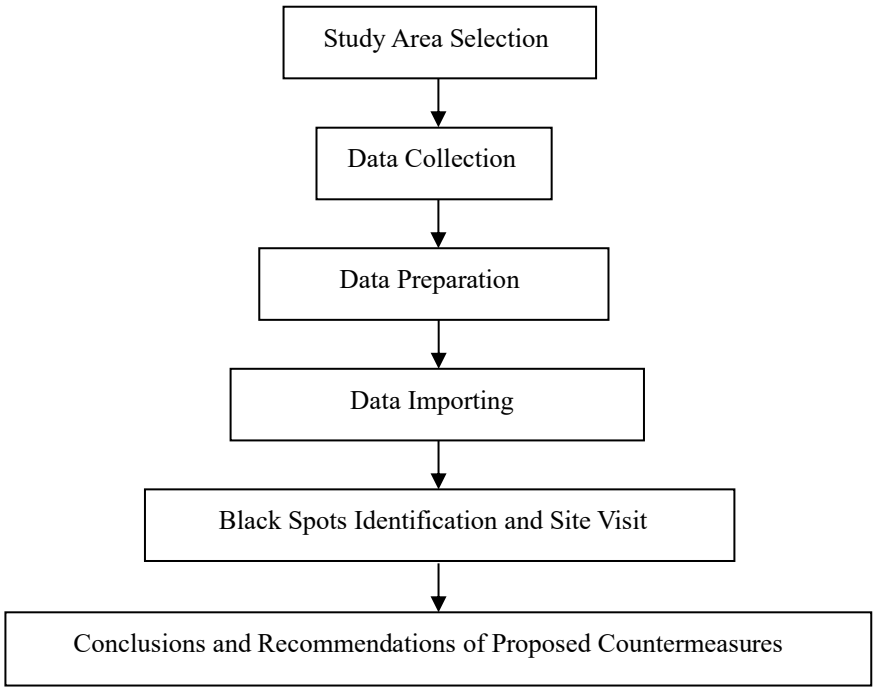

Figure 1. Flow Chart of Methodology Framework

The initial step in the research involves systematically collecting data on pedestrian accidents in Yangon between 2017 and 2023. This dataset provided by the Yangon Traffic Police Department will form the basis of the analysis.

Before incorporating the raw data into the analytical framework, it will undergo a comprehensive pre-processing phase. This process includes cleaning the data to eliminate any missing or erroneous entries, as well as transforming relevant factors to meet the study's specific requirements.

After the preparation process, the data will be imported to the Microsoft Excel, and ArcGIS software in order to carry out identification of blackspots based on the accident severity levels and their caused factors.

3.1.1 Study Area

Yangon, the largest city in Myanmar, is the commercial and transport hub of the country. The city has a population of 5.20 million people and covers an area of 598.750 km2, with 33 townships under the Yangon City Development Committee (YCDC) jurisdiction. These 33 townships, encompassing the central business district, inner city, outer city, old suburbs, and new suburbs, have been selected as the study area for this research. Yangon, which was previously the capital, continues to play an important role as the transport intersection connecting the various regions and international markets within Myanmar.

Yangon, as the largest economic center in Myanmar, has experienced significant infrastructure development and rising vehicle ownership in recent years, leading to worsening

traffic congestion and an increased potential for traffic-related accidents, particularly involving pedestrians. And then, there is a need to analyze the black spots in pedestrian accidents in Yangon in order to reduce the number of accidents and its severity level. Therefore, the urban area of Yangon was selected as a case study. The location of the study area is shown in Figure 2.

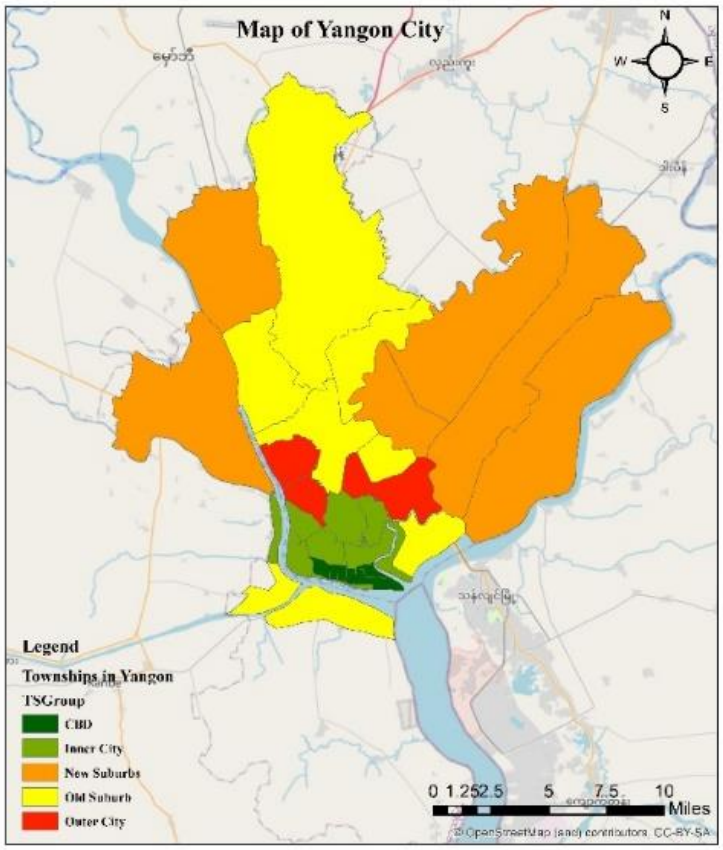

Figure 2. Location of the study area

3.1.2 Data Collection

The data for this study was collected from the Yangon Traffic Police Department, covering a 7-year period from January 1, 2017, to December 31, 2023. As accidents are unexpected events, only secondary data is available from the related authority. The dataset includes information on pedestrian accidents that occurred within the 33 townships under the Yangon City Development Committee's jurisdiction.

3.1.3 Data Preparation

The data collected include date, time, townships, region (CBD or non-CBD), gender and age of the driver and victim, type of vehicle involved, location of the accident, manner of occurrence, collision type, direction of travel for the driver and victim, the cause of the accident, and the severity level of the accidents. The data from Yangon Traffic Police Department are recorded in paragraph and they are needed to be prepared to be useful in the analysis. The severity level was determined based on the provided legal codes, where Law No. 337 represents slight injury, Law No. 338 represents serious injury, Law No. 304(A) represents fatality, Law No. 202 represents hit-and-run incidents, and Law No. 279 represents property damage only.

3.1.3 Data Importing and Mapping

Pedestrian accident locations for the years 2017 to 2023, totaling 2029 incidents are mapped on ArcGIS. These locations have been placed on ArcGIS as individual points on a map, each with a unique identifier, ID. The severity indices of each accident are also imported as an attribute.

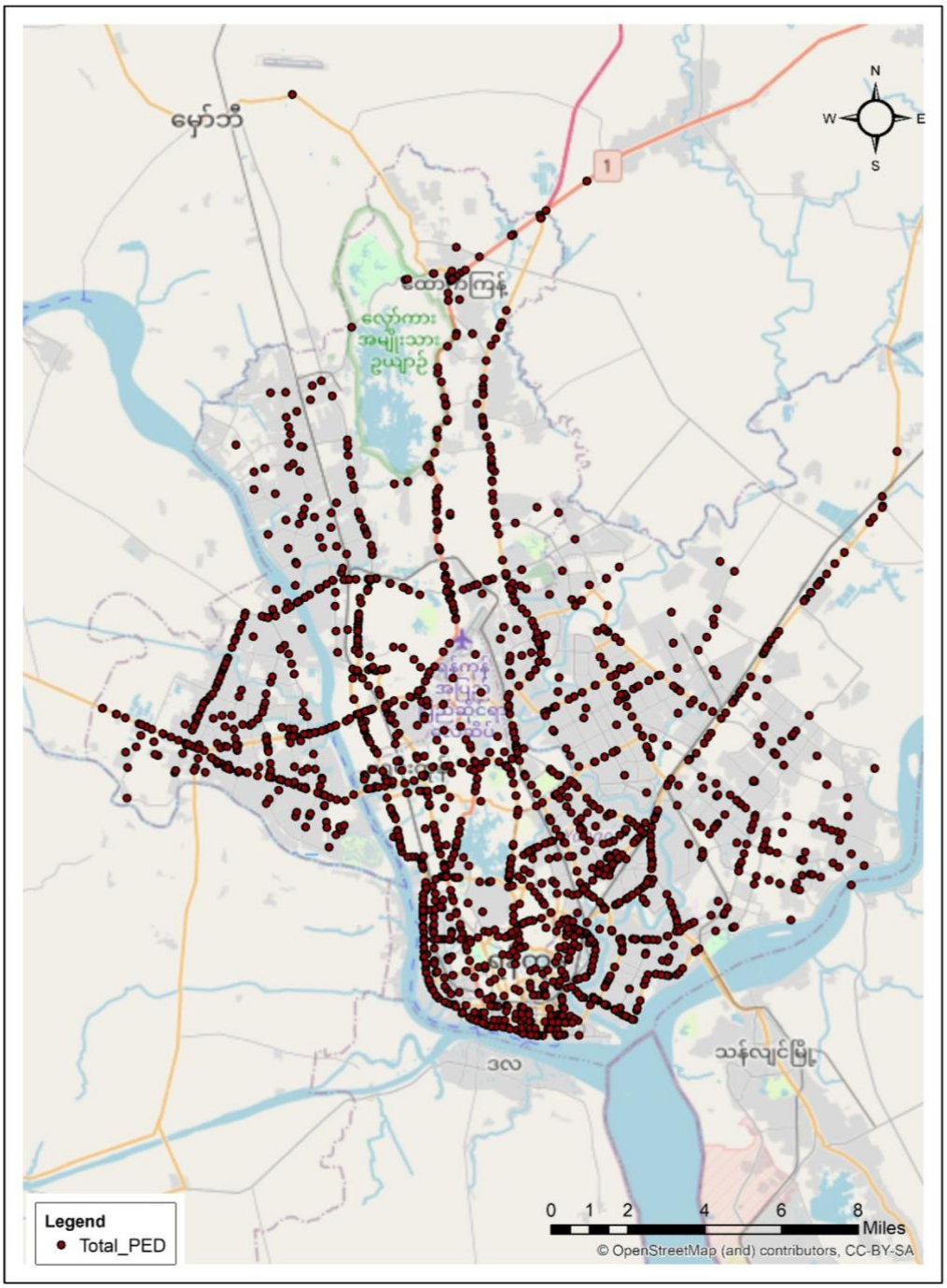

Figure 3. Location of pedestrian accidents

The spatial distribution of pedestrian accident locations provides key insights into traffic safety. The accident locations in this study were placed on the map according to the secondary source's data from the Yangon Traffic Police Department. Figure 3. shows pedestrian

accident locations in the study area where each point representing an accident. And then, further spatial analysis is conducted to determine priority zones for safety improvements.

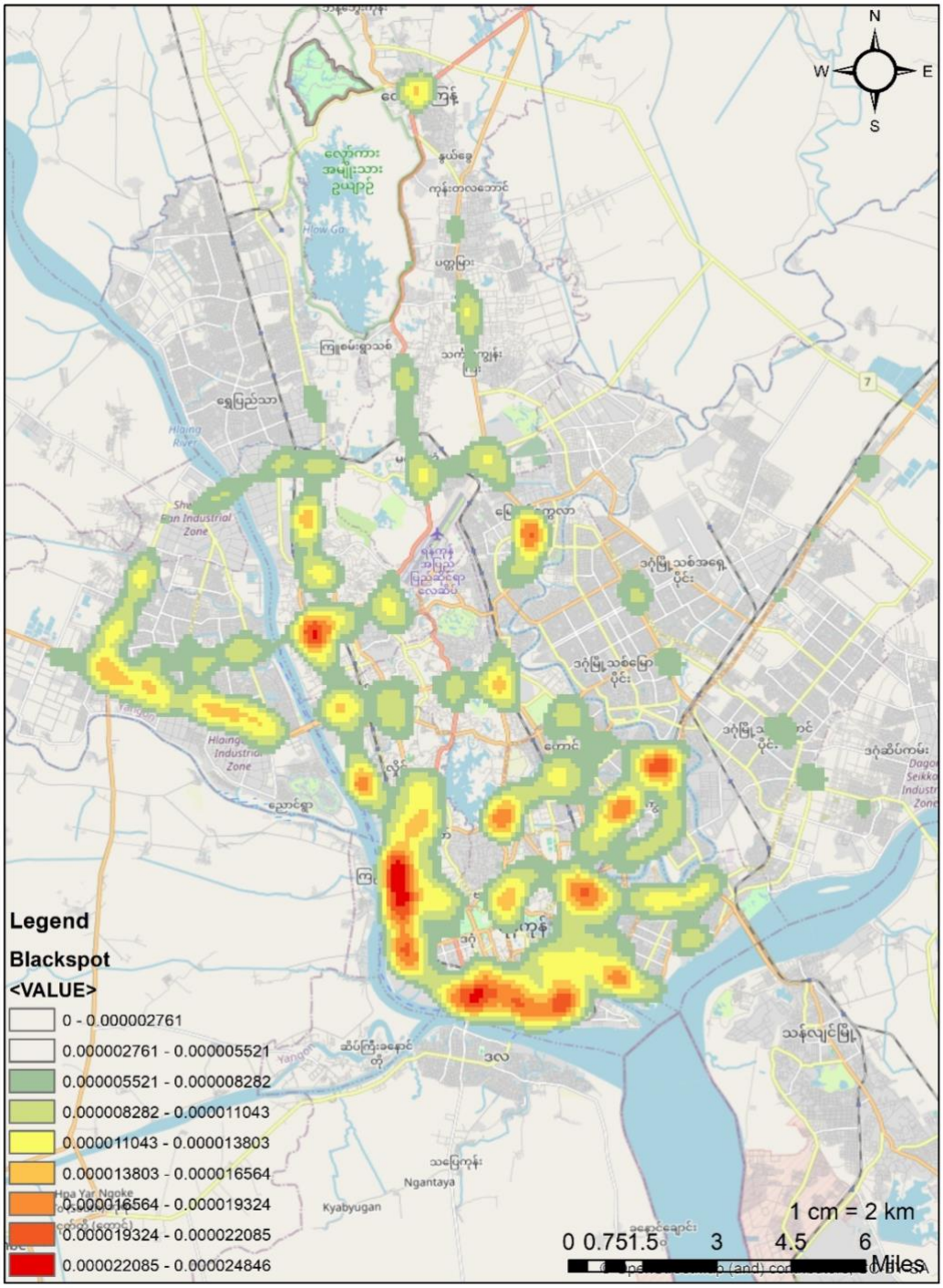

Figure 4. Heat map of pedestrian accidents

The Kernel Density Estimation (KDE) method is used to identify accident hotspots by considering severity index of each location. Figure 4. presents a KDE-generated hotspot map, providing an insight for severity index of the accidents' locations. The severity index ensures areas with higher fatality or injury rates receive greater emphasis. The red-colored areas indicate the highest-risk locations. KDE helps urban planners develop targeted safety measures to minimize pedestrian accidents and improve road safety.

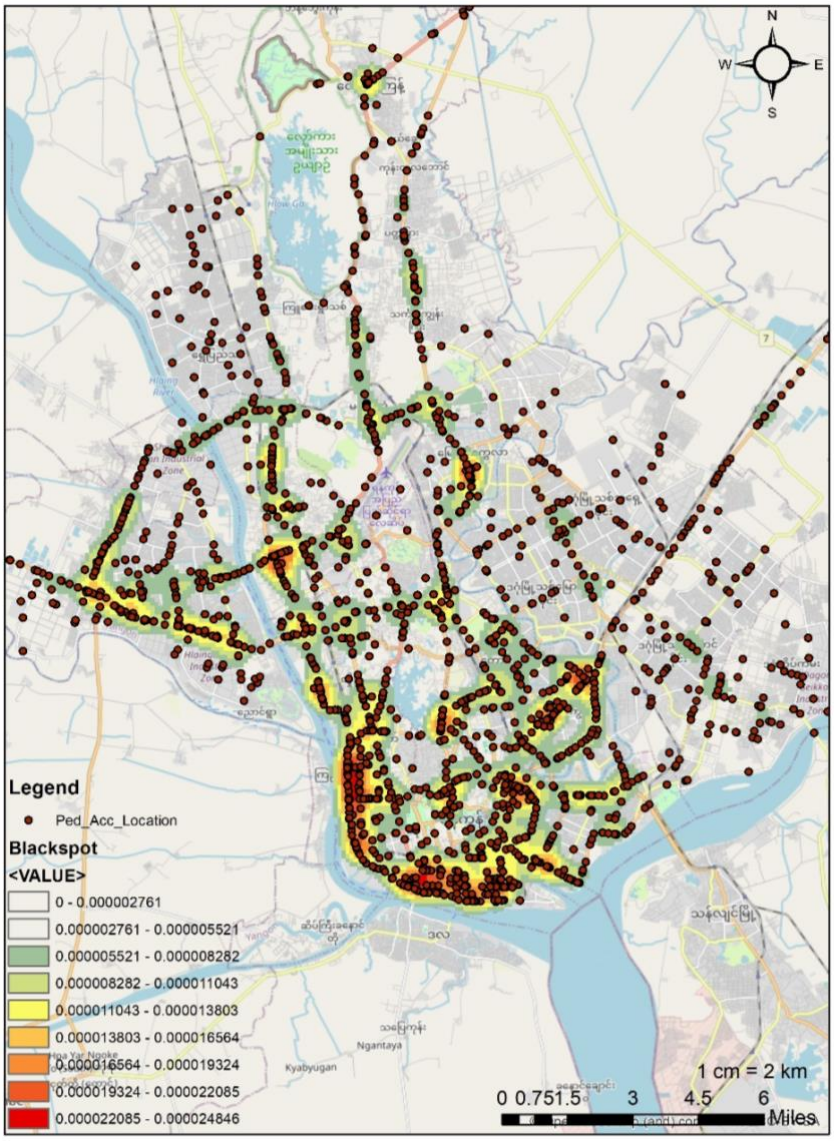

Figure 5. Combined map of pedestrian accidents location with kernel density estimation

The combined map overlays accident locations with KDE-based severity index hotspots for a comprehensive risk assessment. Figure 5 shows this mixed representation, illustrating accident occurrences and broader high-risk zones. Black dots indicate each accident location, while the color gradient highlights severity distribution of that area.

The accident-hotspot overlay map helps identify blackspot locations through calculation of total severity index of the area. The locations, which has the greater severity index than the critical severity index for the study area, are identified as blackspots. Moreover, factors causing the pedestrian accidents of that blackspots can be determined form the data attribute of each point.

4. RESULTS AND DISCUSSIONS

4.1 Identification of Black Spots

To identify and prioritize the most critical locations for safety improvements, black spots are ranked according to their Severity Index values. In this research, the top five black

spots which have the highest severity index are selected for proposed countermeasures. Table 1 shows the top five black spots for pedestrian accidents in Yangon.

Table 1. Black Spot Locations with Severity Index

Rank	SI	Location
1	55	On Thu Damar Road, Around Kan Thar Yar Park, North Okkalapa
2	52	On Kabar Aye Pagoda Road, around Myanmar Plaza, Bahan
3	52	On Ba Yint Naung Road, between Hlaing Station Street and Mya Kan Thar Street, Hlaing
4	48	On Kannar Road, between Thar Du street and Pan Pin Gyi street, Kyi Myin Daing
5	46	On Kannar Road, between Sin Min street and Ahlone Tower, Ahlone

All accident locations (black spots) are ranked according to their Severity Index values. Higher Severity Index values indicate more severe accidents. Locations with higher Severity Index values are ranked higher because they represent areas with more severe accidents or greater number of accident occurrence.

4.2 Proposed Countermeasures for Black Spots

The top five locations with the highest Severity Index values are identified as the most critical black spots. These top five black spots are selected based on their Severity Index, ensuring that the locations with the most severe accidents are prioritized. And then, on ground surveying (Site Visit) is conducted to provide reasonable countermeasures to each black spot.

4.2.1 Black Spot Location (Rank 1)

This blackspot, rank 1, is on Thu Damar Road, around Kan Thar Yar Park, North Okkalapa Township. In this location There is 1 accident with slightly injured individuals, 8 accidents with seriously injured individuals, and 6 fatal accidents. The Severity Index of 55 reflects the weighted severity of accidents at this location, with fatalities and serious injuries contributing significantly to the high SI.

This location is the highest-ranked black spot based on the Severity Index, indicating it is the most critical area for intervention due to the high severity of accidents. Figure 3 shows the black spot location (rank 1).

Figure 6. Black Spot Location (Rank 1)

Thu Damar Road is arterial road is designed to handle high volumes of traffic and facilitate long-distance travel. They connect different parts of a city or region and are crucial for efficient traffic flow. The road accommodates various types of vehicles, including cars, trucks, buses, and possibly bicycles. Mixed traffic can lead to complex interactions and increased accident risk.

The road supports bidirectional travel with separate lanes for each direction. There are three lanes in each direction, which helps manage high traffic volumes but can also contribute to higher speeds and potential conflict.

There are no designated pedestrian crossing signs, making it difficult for pedestrians to safely cross the road. There are no marked pedestrian crossings on the road, further increasing the risk for pedestrian. The intersection where the black spot is located is controlled, likely by traffic signals or signs, which manages vehicle flow but does not address pedestrian needs. There is no dedicated pedestrian phase at the traffic signals, which means pedestrians do not have a specific time to cross safely.

The area around the black spot has a high population density, increasing the number of pedestrians and vehicles and contributing to higher accident rates. 66.7% of accidents occur at night, suggesting that poor visibility or lighting conditions may be a significant factor and 33.3% of accidents occur during the day, indicating that issues are present both during daylight and nighttime.

There are 6.7% of accidents result in slight injuries, 53.3% of accidents result in serious injuries and 40% of accidents result in fatalities, highlighting the high severity of incidents at this location. 51.4% of accidents are attributed to inadequate lighting, which contributes significantly to visibility issues at night. 28.6% of accidents occur because pedestrians do not use designated crossing points, which may be due to their absence or accessibility issues. 20% of accidents are caused by crowded conditions, both for pedestrians and vehicles, leading to increased risk and potential conflicts.

The combination of high traffic volume, mixed usage, lack of pedestrian facilities, poor lighting, and crowded conditions contributes to a high accident rate and severity at this location.

To enhance safety, it is recommended to install pedestrian crossing signs and markings, improve lighting conditions, especially at night, consider adding pedestrian phases at traffic signals and address crowd management to reduce congestion and improve safety.

4.2.2 Black Spot Location (Rank 2)

This black spot is located on Kabar Aye Pagoda Road, specifically around the Myanmar Plaza area in Bahan. This area is a significant location likely to have a high volume of both vehicle and pedestrian traffic.

The black spot has a total of 2 slightly injured accidents, 10 seriously injured accidents, and 4 fatal accidents. This distribution reflects a significant severity of accidents, with the majority being serious injuries.

The calculated Severity Index of 52 indicates a high level of accident severity at this location. The higher the Severity Index, the more severe the accidents tend to be at that location.

The Severity Index of 52, along with the high number of serious and fatal accidents, indicates that this location is a major concern for road safety. The high number of serious injuries and fatalities suggests that urgent attention is needed to address the factors contributing to these severe accidents. Figure 4 shows the black spot location (rank 2).

Kabar Aye Pagoda Road is major road and designed to handle high traffic volumes and provide important connections within a city or region. They are crucial for facilitating long-distance and high-speed travel. This mixed usage can lead to interactions that may increase the risk of accidents.

This road allows vehicles to travel in both directions, which supports bidirectional movement but requires careful management to prevent accidents. The road has three lanes in each direction, providing substantial capacity for handling high traffic volumes. However, the wide lanes can also contribute to higher speeds and potential conflicts.

Figure 7. Black Spot Location (Rank 2)

The pedestrian crossing signs are present, indicating designated points for pedestrians to cross the road safely. This helps in guiding pedestrians and improving their safety. The road features well-marked pedestrian crossings, which provide clear guidance for pedestrians and enhance safety at crossing points.

In the time of accident, 81.3% of accidents occur at night, suggesting that poor lighting conditions are a significant factor in these incidents. 18.7% of accidents occur during the day, indicating that while nighttime accidents are more prevalent, daytime accidents still contribute to the overall risk. Figure 5.5 shows Kabar Aye Pagoda Road, around the Myanmar Plaza area in Bahan Township.

In the case of severity level, 12.5% of accidents result in slight injuries and 62.5% of accidents result in serious injuries, reflecting a high severity of accidents at this location. 25% of accidents result in fatalities, indicating a significant risk of severe outcomes. In the reason of accidents; 75% of accidents are attributed to poor lighting conditions, which affects visibility and increases the likelihood of accidents, particularly at night, 18.8% of accidents occur because pedestrians do not use the designated crossing points. This could be due to the crossings being

inconvenient or not well-utilized and 6.2% of accidents are caused by high-speed driving, contributing to the severity and likelihood of accidents.

Despite the presence of pedestrian crossing signs and good markings, the high proportion of accidents at night and the significant impact of poor lighting suggest that additional measures are needed. The high severity of accidents, with a substantial percentage resulting in serious injuries and fatalities, highlights the urgency for improvements.

To enhance safety at this black spot, consider implementing to enhance street lighting to address visibility issues, especially at night, ensure that pedestrian crossings are well-maintained and consider adding additional crossing points if needed and implement speed control measures or traffic calming features to reduce the likelihood of high-speed collisions.

4.2.3 Black Spot Location (Rank 3)

This black spot is situated on Ba Yint Naung Road, specifically between Hlaing Station Street and Mya Kan Thar Street in the Hlaing area. This location is crucial for understanding the distribution and concentration of accidents in this part of the city.

At this location, there were no accidents resulting in slight injuries. However, there were 9 serious injuries and 5 fatalities. This indicates that while minor injuries are absent, serious and fatal accidents are prominent.

The Severity Index of 52 indicates a significant level of accident severity at this location. The absence of slight injuries and the presence of serious injuries and fatalities contribute to the high Severity Index. Figure 5 shows the black spot location (rank 3).

Figure 8. Black Spot Location (Rank 3)

Ba Yint Naung Road is arterial road and accommodates a variety of vehicle type. This mixed traffic usage can create complex interactions and increase the risk of accidents.

The road has lanes for traffic in both directions, allowing bidirectional travel. This configuration requires careful management to prevent accidents.

The road has three lanes in each direction, providing substantial capacity for handling high traffic volumes but also contributing to higher speeds and potential conflicts.

There are no designated signs indicating pedestrian crossing points, which may make it difficult for pedestrians to find safe places to cross the road. The road has pedestrian crossing markings, but they are faded and less visible, reducing their effectiveness in guiding pedestrians safely. The intersection is controlled by traffic signals or signs, which help manage vehicle flow but may not adequately address pedestrian needs. There is no dedicated pedestrian phase at the traffic signals, meaning pedestrians do not have a specific time to cross safely, contributing to increased risk.

In the occurrence time**,** 71.4% of accidents occur at night, indicating that poor lighting and visibility are significant factors. 28.6% of accidents occur during the day, suggesting that

although nighttime accidents are more common, daytime accidents still contribute to the overall risk.

In the case severity levels, 0% of accidents result in slight injuries. This indicates that when accidents occur, they are either serious or fatal. 64.3% of accidents result in serious injuries, reflecting a high level of severity. 35.7% of accidents result in fatalities, indicating a significant risk of severe outcomes.

The reason of accidents, 71.4% of accidents are attributed to poor lighting conditions, which affects visibility, especially at night, and increases the risk of accidents. 28.6% of accidents occur because pedestrians do not use the designated crossing points, possibly due to the absence of clear signage or the inconvenience of existing crossings. The combination of poor lighting, faded pedestrian markings, and the absence of clear pedestrian crossing signs and phases contributes to a high risk of serious and fatal accidents. The high percentage of accidents at night exacerbates these risks due to reduced visibility.

To improve safety at this black spot, consider the improving of street lighting to increase visibility during night-time and reduce accidents related to poor lighting, refresh and clearly mark pedestrian crossings to make them more visible and effective and to add clear signage indicating pedestrian crossing points to guide pedestrians and enhance safety. And then implement dedicated pedestrian phases at traffic signals to provide safe crossing opportunities.

4.2.4 Black Spot Location (Rank 4)

Figure 6 shows the location of the black spot ranking 4. The black spot is on Kannar Road, situated between Thar Du Street and Pan Pin Gyi Street in the Kyi Myin Daing area. This specific segment of the road is identified as having a high accident severity.

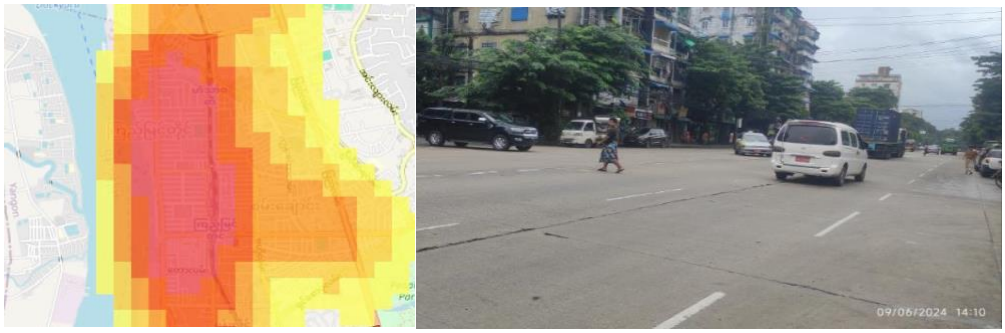

Figure 9. Black Spot Location (Rank 4)

There is 1 incident with minor injuries, indicating that while there are some less severe accidents, they are less frequent. 9 incidents resulted in serious injuries, reflecting a high level of severity in accidents occurring at this location. 4 incidents resulted in fatalities, showing that the location is particularly hazardous and has a high risk of severe outcomes. With a Severity Index of 48, this location is identified as having a significant level of accident severity. The Severity Index reflects the combined impact of slight, serious, and fatal injuries, with serious and fatal accidents contributing the most to the high index. Figure 6 shows the black spot location (rank 4).

Kannar Road is arterial road and supports a variety of vehicles, including cars, trucks, buses, and possibly bicycles. Mixed traffic can lead to complex interactions and increase the risk of accidents. The road has lanes for traffic traveling in both directions. The road features three lanes in each direction, which provides ample capacity for handling high traffic volumes but can also lead to higher speeds and potential conflicts. There are no signs indicating where pedestrians should cross, which can lead to unsafe crossing practices and increase the risk of

accidents involving pedestrians. There are no designated pedestrian crossing markings on the road. The absence of clear pedestrian crossing points makes it difficult for pedestrians to cross safely.

In Occurrence Time; 64.3% of accidents occur at night, indicating that poor lighting and visibility are significant factors in these incidents. 35.7% of accidents occur during the day, suggesting that while nighttime accidents are more common, daytime accidents still contribute to the overall risk.

In the severity levels; 7.1% of accidents result in slight injuries. This indicates that while some accidents are less severe, the majority are serious. 64.3 % of accidents result in serious injuries, reflecting a high level of severity and a significant risk of severe outcomes. 28.6% of accidents result in fatalities, highlighting a substantial risk of deadly accidents at this location.

In causes of accidents; 64.3% of accidents are attributed to poor lighting conditions, which affects visibility and increases the likelihood of accidents, particularly at night.14.2% of accidents occur because pedestrians do not use designated crossing points, which could be due to their absence or inconvenience. 7.38% of accidents are caused by crowded conditions, both for pedestrians and vehicles, leading to increased risk and potential conflicts. 14.12% of accidents are due to high-speed driving, which contributes to the severity and likelihood of accidents.

For improving safety at this black spot; to enhance street lighting to address visibility issues, particularly at night, to add pedestrian crossing signs and markings to guide pedestrians and improve safety at crossing points and to introduce traffic signals or other control measures at the uncontrolled intersection to better manage vehicle and pedestrian movement and educate the public about road safety and proper crossing practices to reduce accidents involving pedestrians.

4.2.5 Black Spot Location (Rank 5)

The black spot is on Kannar Road, specifically between Sin Min Street and Ahlone Tower in the Ahlone area. This segment of the road has been identified as having a high accident severity. There are no incidents involving slight injuries at this location. This suggests that the accidents occurring here are either serious or fatal. The high number of serious injuries (12 incidents) indicates that accidents at this location are frequently severe. With 2 fatalities, this location also poses a significant risk of deadly accidents. The Severity Index of 46 reflects the combined impact of serious and fatal injuries. The absence of slight injuries, combined with the number of serious injuries and fatalities, contributes to this high Severity Index. Figure 7 shows the black spot location (rank 5).

Kannar Road, between Sin Min Street and Ahlone Tower, Ahlone Township is arterial road and accommodates various types of vehicles, including cars, trucks, buses, and possibly bicycles. The road has lanes for traffic moving in both directions and the road features three lanes in each direction, providing substantial capacity for handling high traffic volumes but also increasing the potential for conflicts and high-speed interactions.There is the intersection at this location is managed by traffic signals or other control measures, which helps regulate the flow of vehicles and reduce potential conflicts. This controlled environment can help manage traffic but may not fully address pedestrian safety issues. The location is in proximity to a market, which typically means increased pedestrian activity and potentially higher traffic volumes. Markets often attract large crowds, which can exacerbate traffic-related issues. The road has well-marked pedestrian crossings, which should ideally provide safe crossing points for

pedestrians. However, despite these markings, the effectiveness of pedestrian safety may be impacted by other factors such as traffic flow and crossing usage.

The occurrence time is 78.6% of accidents occur at night, indicating that poor lighting and reduced visibility are major factors contributing to accidents during this time. And 21.4% of accidents occur during the day, suggesting that while nighttime accidents are more prevalent, daytime accidents also contribute to the overall risk.

The severity levels are 0% of accidents result in slight injuries, indicating that accidents at this location are either serious or fatal. 85.7% of accidents result in serious injuries, reflecting a high level of severity and significant risk at this location. 14.3% of accidents result in fatalities, suggesting a substantial risk of deadly accidents despite the reason of accidents are 78.6% of accidents are attributed to poor lighting conditions, which significantly affects visibility, especially at night.

Figure 10. Black Spot Location (Rank 5)

7.1% of accidents occur because pedestrians do not use designated crossing points, which may be influenced by factors such as crossing location and convenience. 14.3% of accidents are caused by crowded conditions, which can increase the likelihood of accidents due to high traffic volume and pedestrian density. Despite having good pedestrian crossing markings, the fact that some pedestrians do not use these crossings suggests a potential issue with either the placement or convenience of these crossings. This can lead to accidents as pedestrians cross at unsafe locations.

To address these issues, consider the improve lighting; enhance street lighting to increase visibility at night and reduce the risk of accidents related to poor lighting, evaluate pedestrian crossings; review the placement and accessibility of pedestrian crossings to ensure they are convenient and encourage their use. And then to make traffic management; implement measures to manage the high traffic volumes and pedestrian activity, especially near the market area. This might include traffic flow adjustments or additional control measures.

5. CONCLUSIONS AND RECOMMDENDATIONS

Improving pedestrian safety at high-risk areas, often referred to as "black spots," necessitates a comprehensive approach involving several safety enhancements. One of the most crucial factors is providing sufficient lighting. Well-lit roads and sidewalks help ensure better visibility for both drivers and pedestrians, especially during nighttime, dawn, or dusk, reducing the risk of collisions. Furthermore, installing dedicated pedestrian crossings, along with visible signage and designated sidewalks, plays a vital role in directing pedestrian movement and alerting drivers to pedestrian zones.

Another critical intervention is the use of pedestrian-activated flashing beacons and

pedestrian refuge islands, particularly in high-traffic or multi-lane roads. These features increase driver awareness and provide pedestrians with a safer, more controlled environment when crossing the road. Similarly, constructing overpasses or underpasses can effectively separate pedestrians from traffic, virtually eliminating the potential for vehicle-pedestrian conflicts in certain areas.

Additionally, crosswalk enhancements such as adding high-visibility paint, raised crosswalks, textured surfaces, and even signalized crossings can significantly improve safety. These enhancements make pedestrian pathways more noticeable to drivers, particularly in areas with high vehicle speeds. Regular maintenance of these infrastructure improvements, along with public awareness campaigns, can further strengthen the effectiveness of these countermeasures in reducing pedestrian accidents and improving overall road safety.

By systematically addressing these black spots with targeted interventions, cities can better protect vulnerable road users and create safer urban environments.

To further enhance pedestrian safety at black spots, several additional measures can be implemented to ensure safer interactions between pedestrians and vehicles. First, introducing advanced traffic signal systems, such as pedestrian phases with countdown timers, provides pedestrians with clear information on how much time they have to cross safely. Leading pedestrian intervals (LPIs), where pedestrians are given a head start before vehicles are allowed to move, can reduce conflicts, especially at busy intersections. Pedestrian-only phases, often featuring scramble crossings that allow pedestrians to cross in all directions simultaneously, offer a high level of safety by fully separating pedestrian and vehicle movement.

Controlling vehicle speed in areas with high pedestrian traffic is another critical countermeasure. Installing speed limit signs, particularly in black spot zones, helps regulate traffic and makes drivers more aware of the need to slow down. Additionally, in-pavement flashing lights at crosswalks can warn drivers of pedestrians actively crossing, enhancing driver awareness and reducing the chance of accidents. These visual cues, especially at night or in poor weather conditions, can dramatically improve safety.

Improving sight distance is equally important for preventing accidents. The removal of on-street parking near intersections and pedestrian crossings can greatly enhance visibility for both drivers and pedestrians. Obstacles like parked cars or street furniture can obstruct a driver's view, making it harder to see pedestrians stepping into the road. By clearing these obstructions, drivers can see pedestrians earlier, and pedestrians can better judge oncoming traffic before crossing.

Finally, enforcement and education are key to sustaining the effectiveness of these physical improvements. Regular enforcement of traffic laws, including speed limits and pedestrian right-of-way rules, ensures that drivers remain cautious and responsible. Law enforcement can also deter dangerous behaviors, such as speeding or ignoring crosswalk signals, through fines and penalties. In tandem with enforcement, public education campaigns play a vital role in raising awareness about pedestrian safety. Educating both drivers and pedestrians on the importance of following traffic laws, using crosswalks, and being alert at intersections can lead to safer habits and prevent accidents.

Combining infrastructure improvements with robust enforcement and educational efforts creates a comprehensive approach to addressing black spots. These measures work

together to reduce pedestrian accidents, protect vulnerable road users, and promote a safer urban environment for all.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the Yangon Traffic Police Department for providing the invaluable accident data used in this study. The authors also acknowledge the support of the professors, associate professors and lecturers from Department of Civil Engineering at Yangon Technological University in facilitating this research.

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