Barriers to Pedestrian-Related Road Crash Analysis in Identifying Engineering Countermeasures

TWKIM Dias[1#]

[1#]*Department of Civil Engineering, Faculty of Engineering, Kotelawala Defence University, Ratmalana, Sri Lanka*
[#] *ishanidias@kdu.ac.lk*

Abstract— *Nonmotorized transportation is one of the trending transportation modes in a world where sustainable transportation is considered vitally important. They, being the most vulnerable road users in the road, people are not so much motivated to walk, mostly as short trips rather than for recreational walking. On average, 686 pedestrians are killed on roads in Sri Lanka per year. It is important if engineering countermeasures can be taken either to reduce the number of pedestrian crashes or to reduce the crash severity of the same. In order to do so, there needs to be sound evidence pointing at significant parameters in pedestrian crashes that can be addressed by engineering countermeasures. However, the Sri Lankan crash reporting system maintained by Sri Lanka Police has limited entries to carry out such a detailed study. Hence this paper has assessed the current crash reporting system and matched it with globally accepted minimum crash reporting criteria as well as frequently used pedestrian crash analyses around the world. The findings were limited to engineering parameters such as road geometry, the presence of road work zones, etc. Many details are not directly available, and a researcher is forced to collect data from secondary sources to map with the crash site. As a result, this paper has identified different data sources that can be used in pedestrian crash analysis other than the data directly from the Police database, and also identified missing but important data entries such as road alignment.*

Keywords— ***Pedestrian crashes, Engineering countermeasures, Crash reporting***

I. INTRODUCTION

Non-motorized transportation is the major branch in achieving a sustainable transportation system. Walking is hence believed to be a trending mode of transportation, attracting government and non-government funds around the world. However, walkability and pedestrian road safety play a big role hand in hand when achieving this goal. According to the World Health Organization (WHO), more than half of all road traffic deaths in the world are among vulnerable road users: pedestrians, cyclists, and motorcyclists (World Health Organization, 2022). WHO adds further that the road infrastructure must be designed es with adequate facilities for pedestrians, cyclists, and motorcyclists. Examples of such facilities for pedestrians can be listed as sidewalks, safe crossing points, and traffic calming measures. The statistics from the National Council for Road Safety Sri Lanka say 686 pedestrians per year were killed in road crashes on average for the past three years (2019-2021). Considering all, it is clear that a government shall invest in improved infrastructure to encourage safe walking either for short trips or for recreational walking.

According to the World Bank's Global Road Safety Facility, 80% of road crash deaths are missing from official low-income country statistics (Global Road Safety Facility (GRSF), 2023). This hinders the high-quality crash data analysis and modeling to identify the road safety risk factors and therein negatively affects improving the road safety in the country.

The current method of crash data collection is using a crash report card which is named as "Road Accident Report 297B". It was noticed that many types of pedestrian-related crash analyses cannot be done in Sri Lanka either because of the lack of available data or simply because there is no mechanism to record much information in the current system. Hence, the main objective of this research was to identify whether any improvements are required for the current crash recording system to capture more information on pedestrian-related crashes. Furthermore, the convenience of the Police officer who enters this information, the time taken to obtain and record these data, and the practicality are also considered. This research paves the path to identify engineering solutions to prevent pedestrian crashes and also to reduce the crash severity. In order to do so, modeling crash data for pedestrian-related crashes is vitally important. This study will hence assess the crash reporting system and the crash data available for a researcher in Sri Lanka compared to other countries.

Human errors when transferring pen-and-paper entries to the crash database in the computer are not considered here as they are not within the scope of this study.

II. LITERATURE REVIEW

A. *Local literature on pedestrian-related crashes*

There was only a handful of research done on pedestrian-related motor vehicle crashes in Sri Lanka. This may be mainly due to the unavailability of publically available crash data.

Pedestrian behavior risk was assessed near school zones in Colombo. The vulnerability of a pedestrian (school children) for not using sidewalks near the school was 15% on average and the vulnerability for not using pedestrian crossings was less than 10% for all school gates considered in both morning and afternoon periods (Dias and Wickramarachchi, 2021). This study has not done an in-depth crash analysis using local data. Another study was done in Sri Lanka where 17.4% of the targeted population have met with road crashes and 29% of them were involved as pedestrians (Fernando and Arnold, 2018).

A case study on pedestrian-involved crashes was carried out in Kandy in 2019. It has collected crash data from Kandy Police Station and some of their findings were: "Motorcycles and three-wheelers are responsible for most of the pedestrian-involved accidents' and Pedestrian-related accidents are more prominent during weekends (Edirisinghe, 2019). These findings cannot be directly used in identifying or proposing engineering countermeasures.

A study done in Malabe has carried out face-to-face interviews to identify potential issues of implementation, design, construction, and operation of some crossings in the selected area. They had not done any crash data analysis. They identified issues such as poor visibility at crossings at night, long crossing distances, absence of speed restriction, lack of road markings and signs, low protection for vulnerable users, and poor pavement conditions near crossings (Mallawaarachchi and Amarasingha, 2017). Most of these issues can be rectified by engineering countermeasures. However, there needs to be a sufficient number of crashes coupled with these parameters to evaluate which aspect is more significant than the other at increasing crash frequency or crash severity.

Another study from Sri Lanka on injuries in vulnerable road user fatalities, their study was based on police information, eyewitness records as well a final interpretation of the post-mortem report (Edirisinghe et al., 2014). Their findings did not aid in identifying engineering countermeasures, but their collection of data could lead to useful findings if it was matched with Police data.

B. Pedestrian-related crash analyses around the world

In their review of risk factors on pedestrian safety and the built environment, Stoker et. al (2015) emphasized that planners need to design or modify the built environment to minimize the risk for pedestrians (Stoker et al., 2015).

Pulgurtha & Sambhara (2011) have categorized the predictor variables in their crash analysis as, demographic characteristics, socio-economic characteristics, land use characteristics, road network characteristics, and the number of transit stops. They have specifically analyzed intersection-related pedestrian crashes. This was done in Charlotte, North Carolina and the demographic and socio-economic characteristics such as population, household units, total employment within walking distance, and land use were extracted from GIS considering the relevant Transport Analysis Zone (TAZ). It was important to identify that people generally walk or bike to access transit (bus) stops, creating a significant pedestrian volume. Hence, the number of transit stops related to the intersection has been considered. The buffer for one intersection has been considered as 30.5 m (100 ft). In addition to those, the following road-related information was extracted from GIS: the number of lanes, speed limit, presence of median, and, pedestrian and vehicular volume (obtained from the relevant Department of Transport). It is evident that these data need not be collected and recorded in a crash report card each time a crash occurs at a particular location. Instead, these data need to be available for post-crash analysis. Also for this study in North Carolina, they were able to obtain traffic counts and aerial photographs from the responsible agencies. The only information they gathered from crash data was the crash count per intersection. Their statistical analysis indicated that an increase in population, the number of transit stops, the number of legs in an intersection, and the pedestrian volume will lead to an increase in the number of pedestrian crashes. However, this must not be confused with commercial activity, where an increase in commercial activity has reduced pedestrian crashes (Pulugurtha and Sambhara, 2011).

National Academies of Sciences, Engineering, and Medicine (2008), has discussed the effects of a comprehensive list of intersection characteristics in the National Cooperative Highway Research Program (NCHRP) Report 17-26 which is a USA-based report. Some of them were pedestrian volume, traffic volume, crossing width, presence of refuge island, raised crosswalks and intersections, crosswalk marking, crosswalk illumination, location of the bus stop, signage, signal timing, and one-way traffic. Regarding roadway segments, they have reported the impact of sidewalks, midblock raised crosswalks, illuminated signs, pedestrian overpasses and underpasses, medians and pedestrian refuges, and traffic calming measures. Table 1 shows a summary available in the NCHRP report related to their intersection-related crash study. Multiple resources for these data were identified: highway agency data, field or video logs, aerial photographs, field measurements, or deductions. This study is helpful for a researcher to identify potential data sources. Other than these road-related factors, they have also considered land use and demographic factors such as the presence of a bus stop within 300 m, the presence of schools/ parks/ alcohol sales, etc.

A pedestrian crash model developed in Montreal has collected its crash data from ambulance services in the city. They have stated that the ambulance service data have less underreporting and miss-location problems compared to police report data. Their study has attempted to model how the built environment affects pedestrian activity and collision frequency (Miranda-Moreno et al., 2011).

Table 1. Parameters considered in NCHRP Report 17-26

Data element
INTERSECTION-LEVEL DATA
Number of intersection legs
Intersection/skew angle
Presence of lighting
INTERSECTION-LEG-LEVEL DATA
Number of through lanes
Number of left-turn lanes
Number of right-turn lanes
Right-turn treatment
The presence of marked pedestrian crosswalks
Presence of median
Presence of curb parking
Presence of sidewalks (left and right)
Presence and type of pedestrian signal
Type of left-turn phasing
Curb return radius
One-way vs. two-way traffic operation
Posted speed limit
Presence and type of turn restrictions
VOLUME DATA
Average daily traffic volume by leg
Vehicle turning movement counts by leg
Pedestrian crossing volume by leg

Source: (National Academies of Sciences, 2008)

The Vehicle Black Box (VBB) is an in-vehicle data recording device that was approved as legally valid evidence in Korea (Koo et al., 2013).

A study in Korea has analyzed the accuracy of the crash data collected from existing road crash data recording methods, which has been recorded by police officers with the crash data obtained from the VBB system. Those Police data have been gathered based on accident parties' statements or eyewitness accounts. Data collectible from the VBB in this study were the time of the crash, GPS-based vehicle location, GPS-based vehicle speed, weather information, roadway condition, roadside facilities through images, vehicle's control status, type and maneuver of the 'other vehicle', or any object in front. Their finding revealed that there was an average spatial deviation of 85 and 188 of 206 crashes were included within 150 m spatial deviation (Chung and Chang, 2015). They have also discussed the significance of such errors when the analyses are done via highly sophisticated statistical and mathematical models.

III. METHODOLOGY

A. *Evaluating global guidelines on road crash reporting systems*

Multiple international bodies have established guidelines to build, modify, or maintain a national crash reporting system. Also, there are safety manuals that discuss about minimum requirements for routine collection of crash data and their importance in crash data analyses. As the first step of achieving the objectives, those manuals and guidelines were studied first to identify the gaps in the 297B form of the Sri Lanka Police.

B. *Evaluating the current practice*

The current system of crash data collection was assessed. A sample of crash statistics was observed to identify the effectiveness, accuracy, and availability of information on pedestrian-related crashes.

C. *Assessing the pedestrian-related crash analyses to identify useful crash parameters*

Recent pedestrian crash analyses were studied to identify the parameters they have used in their models or any other analysis. Then the sources for each of those parameters were identified. This will help in identifying the inventories that should be maintained by road agencies and other stakeholders.

III. RESULTS AND DISCUSSION

A. *Global guidelines on road crash reporting systems*

According to the WHO, Road Safety Manual on Data Systems, elements to be included in a crash reporting system should satisfy three criteria: "Data elements and values must be useful for road crash analysis", "Data elements and values should be comprehensive and concise", and "Data which are very difficult to collect should not be included" (WHO et al., 2010). Examples of national frameworks facilitating uniforme`s3 data collection are Australia's "Minimum Common Dataset for Reporting of Crashes on Australian Roads" and the USA's "Model Minimum Uniform Crash Criteria (MMUCC). The common dataset recommended by WHO (2010) was based on the Common Accident Dataset (CADaS).

The Road Safety Manual of PIARC lists typically collected crash variables as follows:

- Crash location (including geographic coordinates)
- time of day, day of week, month of year, year
- Road user information on those who were involved (including road user type, age, gender, and injury sustained)
- Details regarding the road (whether at an intersection, speed limit, curvature, traffic control, or markings)
- Details on the environment (light conditions, weather, road surface wet or dry
- information regarding what happened in the crash (vehicle movement types, objects struck (including off-road), and contributory factors such as speed, alcohol use or driver distraction);
- Vehicle factors (type of vehicles involved).

Elements related to pedestrian crashes encouraged by MMUCC (NHTSA, 2017) are included in Table 2 with a comparison of the parameters already available in the 297B form of Sri Lanka.

B. Assessment of the current crash reporting system in Sri Lanka

The entry number A20 can help identify whether a vehicle collision was with a pedestrian. "A25" is to collect data on the "Type of location when a pedestrian(s) is/are involved" and the entries say, "on pedestrian crossing/ pedestrian crossing within 50 m, pedestrian crossing beyond 50 m, pedestrian overpass or underpass tunnel within 50 m, hit outside sidewalk, hit on the sidewalk, hit on the road without a sidewalk, other". Entry A24 denotes whether the crash occurred on/ near an intersection. Entry E15 lists pedestrian pre-crash factors contributing to the crash: unexpected pedestrian movement, disobeying designated crossing, influenced by alcohol/ drugs, and poor visibility (clothing). Further, E21 notes whether the pedestrian was at fault. As for the demographic details of the pedestrian, only the gender (E7/ C4) and age (C5) are recorded. Compared to pedestrian-related crash data analysis found in literature, Sri Lanka does not facilitate many important entries. Even though some entries were available in the 297B card, they have not been filled over the years and the entry has been kept blank for the majority of crashes. Moreover, for many entries "Other" or "Not Known" were frequently selected.

Table 2. Elements related to pedestrian crashes encouraged by MMUCC compared with Sri Lankan 297B form

Variable from MMUCC		***Availability in 297B***
V17. Traffic Control Device Type		
Sign	Pedestrian Crossing Sign	X
Marking	Pedestrian Crossing	X
P4. Person Type		
Non-Motorist	Pedestrian	√
	Other Pedestrian (wheelchair, person in a building, skater, personal conveyance, etc.)	X
NM2 (Non-Motorist Action/Circumstance Before Crash		
Action/ Circumstance	Crossing Roadway	X
	In Roadway – Other	X
	Waiting to Cross the Roadway	X
	Walking Along Roadway Against Traffic (In or Adjacent to Travel Lane)	X
	Walking Along Roadway with Traffic (In or Adjacent to Travel Lane)	X
	Walking on Sidewalk	√
	Working in Trafficway (Incident Response)	√
NM3: Non-Motorist Contributing Action(s)/ Circumstance(s)		
	Dart/ dash	X
	Disabled Vehicle-Related (Working on, Pushing, Leaving/Approaching)	X
	Entering/Exiting Parked/Standing Vehicle	X
	Failure to Obey Traffic Signs, Signals, or Officer	X
	Failure to Yield Right-Of-Way	X
	In Roadway Improperly (Standing, Lying, Working, Playing)	X
	Not Visible (Dark Clothing etc.)	X
	Wrong-Way Walking	X
NM4. Non-motorist Location at Time of Crash		
Roadway Facility	Intersection – Marked Crosswalk	X
	Intersection – Unmarked Crosswalk	X
	Intersection – Other	X
	Median/Crossing Island	X
	Midblock – Marked Crosswalk	X
	Shoulder/Roadside	X
Other Facility	Driveway Access	X
	Non-Trafficway Area	X
	Shared-Use Path or Trail	X
	Sidewalk	√
NM5. Non-Motorist Safety Equipment		
	Reflective Wear (backpack, triangles, etc.)	X
NM6. Initial Contact Point on Non-Motorist		
	Front/ Right/ Rear/ Left	X

Considering comprehensive crash analyses carried out over the world, it is clear that most of them have gone beyond what was just available in the Police crash database of the respective country. Site visits to the crash location were one means of collecting road-related parameters. Crash coordinates in the 297B are recorded in a coordinate system unique to Sri Lanka, considering 5000,5000 on the Piduruthalagala peak. When these coordinates are plotted on Google Maps using a conversion equation, the majority of the point locations are misplaced.

They are frequently located off the road, in the sea, beyond road corridors, etc. With such vague data, locating these crash locations for site visits has become a difficulty. Other entries to record the location are road number, nearest lower Km post, distance to lower km post, node number, and link numbers. None of these entries are completely filled in most of the crash records.WHO (2010) has proposed the Linea Referencing System (LRS), where a chainage can be used for each road to describe the location. Well-updated road maps for each Police Division should be developed to facilitate this.

In comparison to the minimum data elements proposed by WHO (2010), missing elements in the Sri Lanka Police database are, ‘road obstacles’, ‘road curve’, ‘road segment grade’, and ‘pedestrian maneuver’. It is mentioned that these road-related elements can be obtained through linkage to other databases depending on their quality, and availability of road inventory. As proposed as additional variables, road-related entries such as “number of lanes’, and ‘markings’, and person-related entries such as ‘distracted by device’ and ‘trip purpose’ could aid more detailed analyses for pedestrian-related crash analyses.

C.Findings from literature

As IRTAD puts it, “There is no crash injury database that will provide enough information to give a complete picture of road traffic injuries”. They recommend that police data should remain the primary source of road crash statistics. However, it should be completed by health sector data (IRTAD, 2011).

The Road Safet Manual from the World Road Association under the Permanent International Association of Road Congress (PIARC), has discussed establishing and maintaining crash data systems. Among the “useful” road inventories listed in this Road Safety Manual, road alignments (horizontal and vertical), shoulder details (width, paved, unpaved), and pedestrian crossing type are the missing entries in 297B nor available with responsible road agencies.

Considering GIS data from TAZs for each intersection or road segment to factor it into a crash model can lead to new findings. However, it may not be helpful when analyzing only the signalized intersections in Sri Lanka. Because signalized intersections are available in the urban areas that have similar land use.

A study on the causative factors and trends in Florida pedestrian crashes has referred to the Fatal Traffic Crash Report (FTCR) which is maintained by law enforcement officers. Also, they have used the Traffic Homicide Investigation Report (THI) which is maintained by specially trained crash investigating officers. Other than the common parameters they had used pedestrian pre-crash contributing factors such as decision, perception, mental-emotional, mobility, and physical defect. Among road-related parameters, they had used construction, curvature, lighting, maintenance, and distance to the nearest traffic signal, other than the most common ones (Spainhour et al., 2006).

Das and Sun (2015) have assessed the multiple correspondences of factors associated with vehicle-pedestrian crashes. They have carried out a multiple corresponding analysis (MCA) and have detected significant contributing factors and degrees of association between the factors. Findings such as fatal pedestrian crashes were correlated to two-lane roadways with no lighting at night. As road-related parameters, they used parameters such as alignment: straight-level, curve-level, on-grade, dip-hump, and hillcrest (Das and Sun, 2015). 297B does include a ‘straight road segment’ vs. intersection criteria, but it does not include road alignment at all.

A study in the European Union has discussed the contributory factors to pedestrian impacts. None of those 11 factors they considered can be found in Sri Lankan crash databases. An attempt can be made to gather them in hospital data only if there is a format for them to include those entries: ‘failed to look’, ‘inattention’, carelessness, reckless or thoughtless, cross from behind a parked car, ignored lights at a signalized crossing, surroundings obscured by stationary or parked car, failure to judge other by persons path or speed, impairment through alcohol, in a hurry, wearing dark or inconspicuous clothing, and lack of judgment of own path (Levulytė et al., 2017).

A pedestrian crash analysis with the Latent Class Clustering (LCC) model was carried out by a study followed by Multinomial Logit (MNL) to identify the main factors in pedestrian crash severity. They had considered pedestrian actions such as crossing, entering the road, walking on the road, or other inappropriate behavior (Sun et al., 2019). Their findings revealed hidden patterns such as “crossing, entering road roadway under influence of alcohol or drugs significantly increase the likelihood of a fatal crash.”

A study from Dak also considered road geometry, and the presence of dividers other than the typical parameters and found that dividers on the roadway were found to have a significant and negative relationship with the crash severity (Zafri et al., 2020). This could be because pedestrians can use the median as a refuge area when crossing the road.

III. CONCLUSION AND RECOMMENDATIONS

This study was carried out to deliver a review paper compiling crash reporting systems in the world. To narrow down the scope, the paper only focused on vehicle-pedestrian crashes. While there can be over 20 parameters used in crash analysis, this study focused on parameters that can lead to identifying engineering countermeasures to reduce the number of pedestrian crashes or to reduce the crash severity of the same. A comprehensive literature review was carried out identifying global road safety manuals and guidelines that recommend minimum required crash data types to be maintained by a country. That is basically because a crash reporting card should be concise, complete, and easy to fill. At the same time, popular crash analyses in the world cannot be carried out using Sri Lankan crash data due to a lack of important parameters such as road curvature at the location of the crash. Considering all, this study has revealed that some data can be made available in a different database, only to link with crash records. Eg. Road inventory data. Simple entries like, 'curved-level' or 'straight-level', mid-block or intersection crossing could be added to the accident report card. Table 2 shows more parameters that can be added. However, the available parameters in Sri Lanka Police database can still be used for a simple crash data analysis. This paper paves the path for relevant stakeholders and road agencies to identify these different categories of crash data. Also, researchers can follow multiple data analyses if the stated data sources are used in order to identify engineering countermeasures.

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AUTHOR BIOGRAPHY

TWKIM Dias is a senior lecturer at the Department of Civil Engineering, Faculty of Engineering, KDU. Her research areas include road safety, vulnerable road user safety, walkability, cycling, transport planning, and non-motorized transportation planning. Her teaching areas are Transportation Engineering, Highway Engineering, and Traffic Engineering.