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**RESEARCH PROJECT FINAL REPORT
ON
EVALUATION OF THE NEW PEDESTRIAN CROSSING IN TRINIDAD
By**

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ABBREVIATIONS, ACRONYMS, AND INITIALISMS

EMR – Eastern Main Road
FHWA – Federal Highway Administration
LED - Light Emitting Diode
MoW&T – Ministry of Works & Transport
MTC-- Metropolitan Transportation Commission
MUTCD – Manual on Uniform Traffic Control Devices
NMT – Non Motorized Transport
NZ - New Zealand
PBR – Priority Bus Route
RC – Roman Catholic
SPSS -- Statistical Package for Social Sciences
SUV – Sport Utility Vehicle
TCD – Traffic Control Device
T&T – Trinidad & Tobago
UK – United Kingdom

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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Ministry of Works & Transport of the government of Trinidad & Tobago. This report does not constitute a standard, specification, or regulation.

Executive Summary

Walking mode is widely used in everyday activities. Recently it has received more attention from transportation professionals because of its advantages over motorized transport modes especially for short trips. However, pedestrians are the most vulnerable road users for various reasons, more so in developing countries including Trinidad & Tobago. Most vehicle-pedestrian crashes in Trinidad are reported to involve a pedestrian crossing the roadway.

A widely used conventional zebra crossing consisting of transverse white pavement markings across the roadway suffers low drivers' yielding rates to pedestrians. Engineers have been searching for innovative engineering treatments to supplement zebra markings to increase driver's yielding behaviour. In this endeavour the government of Trinidad & Tobago has introduced an improved zebra crossing in 2004, which will eventually replace conventional zebra crossing.

Flashing lights on painted posts, zigzag lines on the pavement, advance sign, and pedestrian-friendly guidelines when using the crossing are the major improvements on this crossing compared with conventional zebra crossing. The new crossing has a unique image; visible from sufficient distance under all roadway, traffic, and weather conditions. These features are vital in increasing yielding behaviour from an average driver.

The study involved evaluation of the new crossing, specifically the effect of the crossing on motorists; and public opinion about the crossing. The study did evaluate the effect of the crossing on pedestrian crossing behaviour. It was done through a survey administered to drivers, interviewing pedestrians, field observation of drivers' behaviour at crossings during daylight hours.

Flashing light operation was associated with increased drivers' yielding behaviour observed in the field. However, self-reported drivers' yielding rates were much higher than observed rates—self-reporting bias. Driver's risk perception of potential collision with a pedestrian prompted driver's yielding than activation of flashing lights. Pedestrians were not satisfied with drivers' yielding behaviour probably because of initial higher expectations. Drivers support the new crossing to increase pedestrian safety. Most drivers do not understand the meaning and hence the purpose of zigzag lines at the new crossing, leading to frequent disrespect of zigzag lines prohibitions (parking, overtaking, and stopping) at the crossing.

Engineering features of the priority crossing offers a viable solution for deficiencies of conventional zebra crossing, specifically of all-weather visibility. It promises in improving pedestrian safety in Trinidad & Tobago, and is likely to benefit developing countries where driving culture marginalizes pedestrians and road maintenance practices are not adequate. However, based on experience from other countries there exist opportunities of improving the crossing. Engineering, Education, Enforcement, and Research elements are recommended for further improvement of the crossing.

CHAPTER ONE: INTRODUCTION

1.1 Background

More emphasis is being placed on Non-Motorised Transport (NMT) modes (walking and cycling) for short trips. NMT modes are more healthy and environmental friendly than motorised modes. NMT support safer streets, cleaner environment, and increased activity on the part of the traveller, which may help to fight some common health problems such as diabetes, etc. Walking mode is used by almost every trip maker, be walking to parking lots, to public transport stands/stations, or even as the only mode for the entire trip.

Besides advantages offered by the walking mode, still it is considered a risky undertaking. Road safety statistics indicate pedestrians as the most vulnerable road user group. The problem is of higher magnitude in developing countries, including Trinidad & Tobago (T&T). High frequency of pedestrian-related crashes is a result of higher pedestrians' exposure to vehicular traffic, mostly when crossing roadways; and inability of pedestrians' bodies to absorb impact energy during crashes. In recognition to the pedestrian safety problem in T & T, the Ministry of Works & Transport (MoW&T) in 2004 initiated installation of new pedestrian zebra crossing type which will eventually replace conventional zebra crossing.

Zebra crossings are places where pedestrians can cross the road legally on the same level/grade as vehicular traffic. They are marked by black & white strips across the pavement with or without supplemental engineering design elements or/and traffic control devices. They could be either at intersections or at mid-block sections.

1.2 Problem Statement

For the purpose of this study we define a conventional zebra crossing to consist of only alternate transverse white pavement markings across the roadway

without any engineering design modification or supplemental traffic control device(s) (TCD). Significant proportion of drivers who don't yield the right-of-way to pedestrians at conventional zebra crossings has been found to be a major setback for these crossings. As low as five percent drivers' yield rate have been observed at zebra crossings at mid-block location (Várhelyi, 1998). In another study by the same author, 73% of drivers either kept or increased their speed when approaching a zebra crossing in the presence of a pedestrian (Várhelyi, 1996). Both parties involved in a pedestrian related crash possess opposing views and attitudes toward pedestrian safety. While motorists blame pedestrian for risky behaviours, pedestrians blame motorists for marginalizing pedestrians. Redmon (2003) asserts that these attitudes change depending on whether one is a driver or a pedestrian.

Unsatisfactory yielding behaviour by drivers to pedestrians at conventional zebra crossings has prompted most road agencies to search for innovative engineering treatments to supplement zebra markings (Dun, 1989; Public Works, 2003). Some of these treatments have been successful than others in increasing drivers' yielding rates (Public Works, 2003). Effectiveness of road safety projects and public opinion about these projects plays a significant role in sustaining such project for long term. We couldn't find any literature addressing the application and effectiveness of the new zebra crossing adopted in T&T. In light of the above, there is a need for evaluation of this new crossing.

1.3 Study Objectives

The main objective of the study was to evaluate the new pedestrian crossing, recently introduced in T&T, specifically its:

- i) Effectiveness on increasing drivers' yielding behaviour to pedestrians, and
- ii) Public opinion on the new crossing.

1.4 Study Methodology

The study involved literature review; triangulation method about drivers' yielding behaviour (public opinion, self-reported & observed), and public opinion on the effectiveness of the new crossing. Also field visits to the new crossings was made to get familiar with the crossing application and use.

1.5 Scope of the Study

This study is limited to evaluation of the new zebra crossing in Trinidad. The crossings are located at mid-block sections. The study didn't include effect of crossing on pedestrians' behaviour. Driver's behaviour at the crossing was observed only during daylight hours. The terms "crosswalk" and "crossing" are used interchangeably in this report.

1.6 Report Organization

The report is made up of five chapters. Chapter one deals with introduction such as background information, problem statement that lead to the formulation of the project, brief discussion on study methodology, and scope of the study. Chapter two scoops the literature to solicit information relevant to mid-block zebra pedestrian crossings. Chapter three presents study methodology and data collection, while chapter four presents data analysis and discussion of the results. Chapter five caps the report with conclusions drawn from the study and suggestions to improve pedestrian safety at these crossings in T&T.

CHAPTER TWO: LITERATURE REVIEW

Available literature was searched on the subject of pedestrian safety at mid-block zebra crossings.

2.1 Pedestrian Safety in Trinidad

Similar to most developing countries, pedestrians and cyclists in T&T are the most vulnerable road users. It is reported that between 1965 and 2000 pedestrians have constituted between 42 and 50 percent of all road fatalities and 33-41 percent of all road injuries in T&T. While pedestrians have traditionally accounted for the majority of injuries and road fatalities since 1960, decline of cyclists injured and killed have been observed. (St. Bernard and Mathews, 2003).

“Pedestrian crossing the roadway” is the frequently reported scenario in crashes involving pedestrians in Trinidad. Pedestrian infrastructures are inadequate, under-utilised and misused, while most pedestrians are considered high-risk takers. Local driving culture which is understood to marginalize pedestrians has a major influence on pedestrian safety. Pedestrian safety in Trinidad is hereby summarised by addressing crash data, young pedestrians, pedestrian infrastructure, road users’ attitude and behaviour, and the government’s role on pedestrian safety.

2.1.1 Crash Data

Official data on crashes involving pedestrians are collected and maintained by the Traffic Branch of the Police Department in the Ministry of National Security. Most roadway attributes at the crash site, specifically, the geographical locations are too general for detailed research purposes. Although in most reported pedestrian crashes, “pedestrian crossing the roadway” is the frequent reported scenario, some members of the public may not always agree to this reason. Limitations of crash data make it difficult to ascertain the pre-crash conditions and crash locations in relation to marked crosswalks.

2.1.2 Young Pedestrians

Although adults make up the largest percentage of pedestrian crashes, young children's safety, as pedestrians, is of particular concern in view of their vulnerability in traffic situations and the special value societies places on children. For the years 1989–2002 in Finland it was found that at sites with no marked pedestrian crossings, children were more often injured, compared to the other age groups. Similar trend was observed at mid-block, marked crossings on multilane sections due to overtaking vehicles (Leden et al., 2006). Young pedestrian vulnerability stems from a number of factors including their smaller stature, small and overestimated cognitive skills, their unpredictable actions, lack of experience as road users, and their inability to drive making them heavily dependent on NMT modes including walking.

Their unpredictable actions are the result of the fact that they may be old enough to be mobile but too small to be easily visible from the driver's position. They have difficulty of seeing and evaluating the entire traffic situation correctly because of their short height. They have difficulty in correctly perceiving the direction, sound and speed of vehicles. They are also easily distracted. Redmon (2003) reported that one of drivers' concerns is the possibility of children running in front of them. A study of children crossing road at intersection found that less than half of the children looked in the direction of oncoming traffic before crossing, while a full visual search (looking in all directions before and while crossing) was carried out by fewer than 5 percent (MacGregor et al., 1999). Connelly et al., (1998) found that children between ages of 5 to 12 years use the same distance gap threshold in road crossing decisions irrespective of speed of the oncoming vehicle.

Adults tend to overestimate children's pedestrian skills. The extent of overestimation of children's road use skills by parents increased with decreasing

child's age. However, estimation of child's vocabulary skills by the same parents was not influenced by child's age (Paediatrics for Parents, 1991). Children's ability overestimation was also observed by Harré (2003) in the study of drivers' speeds in the presence of child, in which New Zealand drivers were found to make inadequate speed adjustments in the presence of children. Similar results were obtained in United Kingdom (UK) where the presence of children by the roadside had no effect on drivers' speeds or lateral positions of their vehicles (Thompson et al., 1985).

Many children believe that the safest way to cross the street is to run, that it is safe to cross against the red light, and that adults will always be kind to them by stopping instantly if they are in danger (MacGregor et al., 1999). The same study found that a number of gaps exist between the instructions parents give, and their expectations of children's capabilities, and what children actually do when crossing roadways.

Studies on school transport conducted to public schools in St. George East County in north-central Trinidad revealed an increased percentage of school children who walk to school between 1980 and 2003 (Mutabazi and Akberali, 2008; Underwood and Rasul, 1984). Proportion of younger children (from primary schools) walking to school is higher than that of corresponding older children (from secondary schools) (Mutabazi and Akberali, 2008). This implies that more young school children, as pedestrian, are exposed to vehicular traffic than older school children, despite the fact that older children are more likely to make safe crossing decision than younger children (Connelly et al, 1998).

Crossing roadways while going to, or coming from school is not limited to only children who walk to school as the main mode of transport. Those who use public transport are also required to walk and/or cross roads to get into school compounds, the extent of such activities depend on the relative location of the

school compound and public transport vehicles stops. Students being picked and dropped by parents/guardians using private transport, sometimes may also be required to cross roadways to get into school compounds due to inadequate parking facilities at most schools in the country. Recognizing the need for school children safety, MoW&T prioritized school areas when installing new zebra crossings.

2.1.3 Pedestrian Infrastructures

Pedestrian infrastructures are inadequate, under-utilised and misused. Pedestrian grade-separated crossings (pedestrian bridges) are few because are expensive to construct. Use of pedestrian bridges without escalators in developing countries such as T&T is not always encouraging (Räsänen et al., 2007). As such most pedestrians are seen crossing vehicular traffic streams on busy roadways. Sidewalks on most parts of urban and suburban streets are either non-existent or are insufficiently planned and maintained. It is common to find a sidewalk crossing the roadway and yet the crossing is not painted (unmarked crossing) or the sidewalk being terminated abruptly along its route.

2.1.4 Road Users' Attitudes and Behaviours

Pedestrians are normally considered high-risk takers. A study of a level crossing over the railway track used by both vehicles and pedestrians in Finland found that pedestrians and cyclists had higher frequency of violation than motor vehicles (Knutton, 2004). Pedestrians' unsafe behaviour in Trinidad includes crossing roadways at non-authorized locations. Authorized crossings are considered to include pedestrian over-/under-passes, and marked crossings. Other unsafe behaviours include violating traffic signals, walking on roads (jay walking), etc. This has prompted some members of the public and government officials to suggest that pedestrians should be accountable for their behaviours when using roadways.

Local driving culture has a major influence on pedestrian safety. Drivers' behaviours that affect pedestrian safety in Trinidad include non-yielding to pedestrians crossing roads; parking vehicles on footpaths and sidewalks; encroaching pedestrian areas without due consideration to pedestrian when drivers are trying to avoid rough pavement surfaces such as potholes; and hit-and-run attitude, especially when pedestrians are involved in crashes. In some cases running away drivers involved in such crashes may claim that they thought they hit objects other than pedestrians. Hit-and-run behaviour can present difficulties in processing compensation from insurance companies to crash victims and their families.

Misuse of pedestrian facilities by sidewalk vendors, intersection petty traders, and commercial enterprises can degrade pedestrian safety. While sidewalk vendors conduct their activities on pedestrian sidewalks, business community considers sidewalks to be part of their parking lots. These behaviours in conjunction with physical poor condition of sidewalks' surfaces result into pedestrians walking in middle of roads creating safety problems. Intersection petty traders apart from exposing themselves to traffic crashes they are source of drivers' distraction resulting into crashes.

2.1.5 Government Role

To some extent road users' unsafe behaviours reflects the unbalance between what a transportation system offers (supply) and the demand placed upon it. For example, parking vehicles on sidewalks in part could reflect inadequate parking spaces and/or weakness in parking regulations & control. Mitigation of most road safety problems requires both an increased capacity to road infrastructures and regulations on how road users should behave on roadway environment. In Trinidad regulation outpace capacity improvement probably because the former requires minimum resources to set them up. However, some

of regulations that are in place may not be effective because of some inherited weaknesses.

Enforcement of traffic regulations related to “pedestrian crossings” are either missing or inadequate. Statutory regulations supporting right-of-way for pedestrian at zebra crossing is too general to be enforced in an effective manner. The law requires motorists to yield to pedestrians, not specifically stopping. The only proof that the motorist did not yield would be when the pedestrian is hit. It is only recently when introducing the new zebra crossings that drivers have been directed to stop for pedestrians. The fact that the directive is considered a mere guideline and is not part of the law, its enforcement is questionable. Some enforcement agencies use stopping condition or speed limit, as a criterion for drivers’ violation at a crosswalk. These measurable criteria make enforcement feasible and easier. Enforcement of regulations pertaining zebra crossing in Trinidad cannot be effected efficiently until speeding and stopping criteria are part of the pedestrian crossing laws.

Apart from providing roadway infrastructure and setting up associated regulations, the government have the role of setting up supportive programs. One such program is school safety for children who are more at risk of road crashes, as discussed in section 2.1.2 above. School speed zoning, road safety education for the young road users, traffic calming in school zones, safe pedestrian routes to school, and crossing guards would have equipped school children with appropriate tools and means for walking and cycling safely to/and from schools.

Lack of public policy may jeopardize pedestrian safety. A motorist complaining against having a crossing guard to stop traffic to help pedestrian cross the highway asserted that the Minister was against such exercise because it blocks traffic on that highway (Express^a, 2004). Yet in another instance, the local

newspaper carried out a story of a traffic light signal installed by the government outside Dede High School to assist pedestrian cross the busy road. However, the traffic light signal could not put into use for two years because no one was ready to pay initial cost for electricity (Express^b, 2005). These issues may in part reflect a policy problem.

2.2 The New Zebra Crossing

This section describes the new zebra crossing based on information obtained from literature survey and authors' experience. The new zebra crossing consists of a conventional zebra crossing supplemented with zigzag lines, yellow flashing lights sometimes called flashing beacons or simply flashers, and an improved advance warning sign.

2.2.1 Historical Background

Literature indicates that the new zebra crossing in T&T was officially documented in 1993 (Government of Trinidad & Tobago^a, 1993). Figure 2.1 shows the early documented crossing on which pedestrians are prohibited from crossing the carriageway except within the limits of the crossing's give-way lines. It is made up of: 1) traditional black and white stripes (zebra stripes) parallel to the curb – i.e., the conventional zebra crossing, 2) longitudinal zigzag lines parallel to the roadway on both approaches, and 3) flashing yellow globes mounted on top of a white-and-black striped poles placed on the side of the roadway at the crosswalk locations. The globes flash continuously at a rate of one-per-second. In UK this globe is known as orange belisha beacon named after Leslie Hore-Belisha, the Minister of Transport who introduced them in 1934. In New Zealand yellow belisha beacons flashes only at night (Dunn, 1989), and they could be substituted by fluorescent beacon discs (Land Transport NZ, 2006). The crossing has some similarities to the crossing used in the United Kingdom (UK), New Zealand (NZ), and in the former British crown colonies of Singapore, South

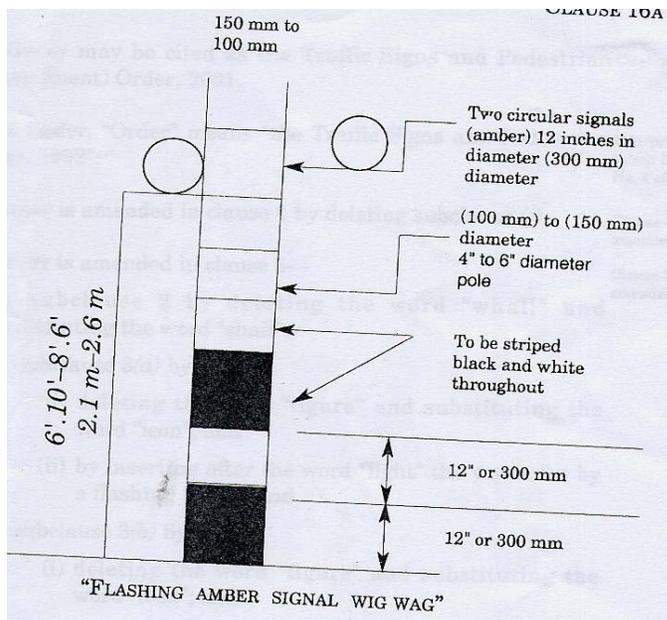


Figure 2.2: Flashing lights on black & white posts (Government of Trinidad & Tobago, 2001^b)



Figure 2.3: Advance sign at new zebra crossings

The Ministry of Works and Transport gave guidelines for the use of the crossing, summarized as follows: - (Guardian, 2004)

- 1) The pedestrian has the right-of-way on pedestrian-priority zebra crossing, and therefore the driver must stop to permit the pedestrian to cross the roadway;
- 2) A maximum speed of 25 Km/h when approaching the pedestrian-priority zebra crossing;
- 3) Although pedestrians have right-of-way on “pedestrian-priority zebra crossings” still they should exercise care and caution when using them.

Some members of the public understood these guidelines to be the first to accord a pedestrian the right-of-way when crossing the roadway at zebra crossings in the country (Defour, 2004). Prior to these guidelines pedestrian were accorded right -of -way only at pedestrian crossings controlled by light signal or by the police, according to article 23 of the Highway Code (Ministry of Works, 1972). Right-of-way guideline has an element of regulation and is intended to ensure there is no doubt where and when a vehicle should stop at a pedestrian-priority

zebra crossing. Speed limit guideline puts the driver in an environment that he/she can stop easily. However, we found that these two measures are only documented in newspapers -- this leads to a question on their statutory power. The third measure is intended to protect pedestrians from being over-confident at these crossings, a phenomenon that may lead to unsafe crossing behaviour on the part of pedestrians.

2.2.2 Zebra Markings

Transverse pavement (zebra) markings are intended to define the area where a pedestrian can cross the road legally, in a way; pedestrians are channelled and guided into the proper path. They help the driver to see the crossing well in advance. The combination of these two features is expected to improve the safety of pedestrians using the crossing. However, study results are mixed and inconclusive pertaining to the safety effect of marking crossings at uncontrolled locations. Campbell et al. (2004) after reviewing pedestrian safety research concluded that marked crosswalks at uncontrolled intersections on two-lane roads are not necessarily safer than unmarked ones unless they are accompanied with some additional engineering improvements. Koepsell et al. (2002) concluded that crosswalk markings appear associated with increased risk of pedestrian-motor vehicle collision to older pedestrians at sites where traffic is controlled. Zegeer et al. (2004) asserts that these studies were inconclusive because of inherited limitations in methodological approach, sample size limitation, and limitation on accounting contributing factors.

Wide application of zebra markings at pedestrian crossings worldwide indicates the extent road agencies' belief on their effectiveness. Ekman and Hyden (1999) argue that despite the well-known fact that most of the accidents where pedestrians have been hit by a car in urban areas occur either at a zebra crossing

or at a signalized intersection; this has not changed the opinion by many people about the zebra crossing being a safer place to cross the roadway.

Zebra markings are only useful if they are visible at a distance far enough to allow the driver to take safer action. Some agencies use zebra markings visibility, among the criteria for deciding the zebra crossing location (Vermont Agency of Transportation, 2004). Zebra markings visibility depends on roadway geometric design; marking material reflectorization property, weather, and road maintenance level & practice.

Roadway Geometric Design

Three geometric design elements that affect the visibility of zebra markings are horizontal alignment, vertical alignment, and overall width of zebra markings (i.e. the length of crossing in driver's line of sight). Unfavourable horizontal and/or vertical alignment may result into non-visibility of the crossing from driver's position at a sufficient distance. Figure 2.4 & 2.5 demonstrate sight distance restriction due to adverse horizontal and vertical alignment respectively. Location decisions of pedestrian crossings to solve roadway alignment problem may at times conflict with other location criteria such as spatial relationship between pedestrian crossing and pedestrian traffic generators.

Even with perfect horizontal and vertical alignments, yet the driver may be unable to see the markings at sufficient distance due to smaller width of zebra markings. The required width depends on driver's eye height, vehicle approaching speed, and driver's minimum angle of resolution. New Zealand using a model shown in Figure 2.6 with driver's eye height (h) of one meter, driver's minimum angle of resolution (α) of two minutes, and appropriate stopping sight distances, for each design speed, they developed desirable zebra bar lengths (l). For example at speeds of 60 & 70 Km/h desirable length l should

be 5.6 & 9.10 metres respectively (Dunn, 1989). Values recommended by Litman et al. (2002) are 3.0 & 4.0 metres respectively. Model used by Litman et al. could not be found in the literature.



Figure 2.4: Crossing obscured by adverse horizontal alignment (sharp horizontal curve)



Figure 2.5: Crossing obscured by adverse vertical alignment (sharp vertical curve)

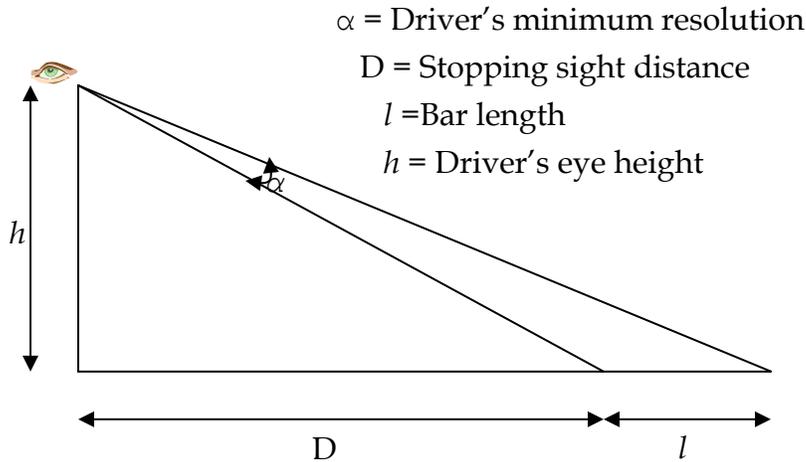


Figure 2.6: Zebra marking bar length (Dunn, 1989)

Wider markings may reduce pavement skid resistance, making it slippery when wet for motorists. Minimum width of markings by both Dunn and Litman requires wider painted area at higher speeds when skid more resistance is needed. Recognizing this problem, New Zealand recommends a cut-off value of five metres, and encourages the use of mono-plastic/spray plastics rather than paint (Dunn, 1989). T&T guidelines on the minimum overall width of zebra markings are not known if they exist.

Marking Material Retroreflectorization

Zebra markings usually fade away with time, traffic, environmental condition, and other factors (Smadi et al., 2008) making them difficult to see at sufficient distance. The quality and type of the road marking material have a significant influence on marking's durability and retroreflectivity. Lee et al. (1999) asserted that solvent borne paint, which is mostly used by MoW&T has a lowest durability period of less than one year compared with other road marking materials such as thermosets, thermoplastics and tapes which can last up to three, five, and eight years respectively. When to re-mark zebra markings is an issue of road agency maintenance level and practice. Most agencies schedules re-marking of pavement markings based on experience.

Inclement weather such as fog, haze, heavy rain, etc. limits how far a driver can see. At night time on unlit crossing, the source of light is the vehicle's beam light. By then visibility of zebra markings depends on the amount of beam light reflected back by the marking's, which in turn depends on strength of the original beam light and retroreflective characteristics of the pavement marking material. Amount of light reflected back to the driver depends on the angle made up by driver's line of sight and vehicle's beam light -- observation angle (Smith, 2008). Drivers' eyes are further from the headlamps in larger vehicles, resulting in a greater observation angle and hence lesser amount of reflected light back to the driver. While conscious design and precise fabrication of the prismatic structures used in modern sheeting can solve this problem for signs, it is not the same for road paints.

2.2.3 Advance Sign

Some local agencies would normally supplement zebra markings with signing(s) and/or pavement markings in the advance zone to enhance crossing visibility. Litman et al. (2002) recommends that zebra markings should be supplemented by signs as the means to identify the place of the zebra crossing. The advance sign for the pedestrian-priority zebra crossing (Figure 2.3) intends to alert the driver on the approaching of zebra crossing. Additional words on the sign serve to differentiate pedestrian priority zebra crossing from a conventional zebra crossing. However, a sign, posted at height above the region of vehicle beam lighting, may become difficult to be read at a sufficient distance during nighttimes (Rys et al. 2001). In busy urban roads, meaning of advance sign or marking could get lost in the clutter and hence of little importance.

2.2.4 Flashing Lights on Black & White Posts

Yellow flashing lights also known as yellow flashers or beacons are mounted on posts painted with alternate black & white reflective bands. Flashing lights

supplement pavement markings and advance sign in identifying the position of the crossing. Yellow flashing lights have also been used:-

- In school zones;
- In median island noses to provide motorist guidance of obstacles;
- On construction barricades where there are lane reductions, detours, or other unexpected changes in traffic conditions;
- At sharp horizontal curves to influence drivers' speed;
- At rail-highway grade crossings to indicate the presence of the train; and
- At Kaola pedestrian crossing in South Australia.

Twin yellow flashing lights at Kaola crossing generally operate during times when most schoolchildren are travelling to and from school; in the mornings and afternoons of school days only.

Installation above the ground and stronger visual cue, yellow flashing lights possess advantages over signs & pavement markings in attracting drivers' attention making the crossing visible at sufficient distance in cases of:-

- Awkward horizontal or/and vertical alignment;
- Shorter zebra marking lengths;
- Inclement weather & night time;
- When pavement markings are obscured by traffic, or have faded away;
- During the time after resurfacing and before re-marking is done (Figure 2.7);
- Also where maintenance level or maintenance practise of traffic control devices is inadequate leaving signs and markings in a worn state most of the time.



Figure 2.7: Crossing before re-marking

Flashing Light Features

Effectiveness of flashing lights depends on its size, quantity, colour, flashing rate, type of light, height position, mode of operation, and configuration. The crossing uses four (two on each post at either side of the crossing) amber incandescent circular signals 300 mm in diameter, continuously flashing at the rate of 60 cycles per minute, positioned between 2.1 to 2.6 m from the ground. The two units on a post flash alternatively in a wigwag fashion similar to rail-highway grade crossing. Two flashing lights, at each side, both face the same on-coming traffic, adds an advantage to the crossing in case one of them is malfunctioning.

The size of 300 mm in diameter used at this crossing was found to increase conspicuity compared to the 200 mm at a rail-highway grade crossing (Ruden and Coleman, 1979). In the same study, placement position of flashers at 2.7 m from the ground level was better than 5.1 m in terms of conspicuity. The upper limit height of 2.6 m used in Trinidad is close to 2.7 m tested by Ruden and

Coleman. However, the effect of placement height lower than 2.7 m could not be found in literature. Faster flash rate than that used at this crossing has been found to increase conspicuity while strobe was better than incandescent in Ruden and Coleman (1979) study. Faster flashing Light Emitting Diode (LED) beacons increased drivers' yielding behaviour in Florida (Shurbutt et al., 2008).

A study that compared several treatments to improve motorist yielding to pedestrians at un-signalized intersections indicated that red signal or red beacon devices produced higher yielding behaviour than in-roadway signs, yellow overhead flashing beacons, pedestrian crossing flags, and in-roadway warning lights (Turner et al., 2006). In the laboratory study of flashing lights at railway grade crossing, red flashing lights were found better in attracting subjects (Ruden and Coleman, 1979). The City of Los Angeles uses mid-block pedestrian signals that display a flashing red signal when activated (Fitzpatrick et al., 2006).

It appears that pedestrian actuated flashers prompt drivers to yield for pedestrian more than continuous flashing mode used in Trinidad. Increased driver yielding to pedestrians at crosswalk with actuated flashers in Chattanooga, Tennessee, was attributed to flashers actuation (Van Winkle and Neal, 2000). Fitzpatrick et al. (2006) reported several studies that have shown that intermittent flashing beacons provide a more effective response from motorists than continuously flashing beacons. Sparks and Cynecki (1990) found that continuous flashers offer no benefit for intermittent pedestrian crossings in an urban environment and conceded that actuated warning flashers may be beneficial in a high-speed rural environment with unusual geometrics, high pedestrian crossings, and unfamiliar drivers. Some agencies prefer activated flashing over continuously flashing beacons, for the fear that the later may eventually lose its effectiveness because it becomes like a background to a driver who has driven through the section for a long time.

Posts Stripped in Black & White

It is a common practice in Trinidad to paint sign posts with black & white strips. In the study of low-cost traffic control systems for passive rail-highway grade crossings, Russell and Kent (1993) found that reflectorization of a crossbuck sign along with its post had a high visual impact on driver behaviour at rail-highway grade crossing. Similarly Yeh and Multer (2007) argue that the fully reflectorized posts allow drivers to see where the roadway meets the railroad tracks.

Reflective black & white strips on the posts would reflect back the beam light from the vehicle at night, thereby enable the driver to locate the position of the crossing in case flashing lights are not working due to malfunctioning or power cut. This way the position of a crossing is easily identified during all weather conditions.

2.2.5 Zigzag Lines

Zigzag lines are marked on both lane edges and sometimes along the roadway centre line. Zigzag lines at a zebra crossing are also used at zebra crossings in UK, South Africa, New Zealand, and some agencies in Australia. The practice in Australia is to mark only along the centre line on both approaches.

Purpose of zigzag lines in T&T, UK and South Africa is to restrict parking, overtaking, and stopping of vehicles within the crossing. In South Africa they also restrict changing lanes, and pedestrians prohibited from crossing within the zigzag zone (Ribbens, 1996). In Australia however, zigzag lines are used as an advance warning to the pedestrian crossing. Restricting parking, overtaking and stopping in the vicinity of a crossing can increase the visibility of a pedestrian entering the crossing. This can reduce the potential of an accidents resulting from hidden pedestrians by parked/stopped or overtaking cars (multiple threat). Advance yielding by shifting a stop line upstream the pedestrian crossing was one of the mitigation measures showed pedestrian safety improvement at

pedestrian crossings (Van Houten et al., 2001; Van Houten et al., 2002) that. In Finland, children pedestrians were more vulnerable to crashes with overtaking vehicles at mid-block, multilane, marked crossings (Leden et al., 2006). In New Zealand, Canada and Europe parking or stopping too close to the crossing was found to be the most significant safety problem (Dunn, 1989). Another negative effect of parked/stopping vehicle at the crossing would be the obscure of flashing light(s) by big trucks, tall enough to obstruct the visibility of flashing light(s). A typical example which zigzag lines intend to avoid is shown in Figure 2.8 where a pedestrian is crossing in front of stopped mini-bus may be difficult to see from a vehicle that would try to overtake the min-bus.

In Trinidad zigzag lines extend to a maximum distance of about sixteen metres on either approach of the crossing. Standards allows as low as four metres in case the crossing is too close to the intersection. In South Africa they extend a distance of 30 metres on either approach (Ribbens, 1996). In Los Angeles a length of no-stopping zone at pedestrian crosswalk is based on the safe stopping distance (Jones and Tomcheck, 2000). It appears the no-parking zone at priority pedestrian crossing in T&T, defined by the length of zigzag lines, is too short compared with other agencies.



Figure 2.8: Pedestrian trapped between opposite traffic on the crossing

2.2.6 Safety Performance

Road user's expectation plays a key role in road safety. Drivers expect pedestrians at crosswalks that are located at intersections more than at crosswalks located at mid-block locations. Likewise, pedestrians expect drivers to yield to pedestrians on crossings at intersections more than those at mid-block locations. In a survey conducted by Ullman et al. (2004) concluded that unpredictability of a driver as to whether he/she will yield to a pedestrian at a pedestrian crossing was the main concern to pedestrians.

Another factor that influences pedestrian safety at at-grade pedestrian crossings is the level of traffic control. For the purpose of this report, the term "traffic-controlled" refers to pedestrian crossing where vehicular traffic is regulated by "STOP sign" or traffic signals. At such locations, driver's yielding behaviour is improved by TCD's command rather than drivers' discretion. This phenomenon is likely to make the crossings at traffic-controlled locations safer than those at uncontrolled locations (Dunn, 1989). Chu et al. (2002) developed a model of how

pedestrians cross roads. From the model it was found that people are more likely to cross at a traffic-controlled intersection. Also, people are more likely to cross at any location with a marked crosswalk than at those without. The presence of a marked crosswalk is more influential at an intersection than at a mid-block location. Most of the priority zebra crossings in Trinidad are at uncontrolled mid-block locations on two-lane roads.

2.3 State-of-the Practice on Mid-block Pedestrian Crossings

Mid-block pedestrian crossings are classified into three categories: 1) conventional zebra crossing, 2) improved zebra crossing, and 3) Traffic controlled pedestrian crossings. Conventional mid-block zebra crossings consists only zebra markings. Improved zebra crossing is a conventional zebra crossing supplemented by one or more passive traffic control devices or engineering design features. Traffic controlled pedestrian crossing normally do not contain zebra markings, instead they have traffic signals to control vehicular traffic as well as pedestrian signals; and they may contain also some improvement features used at improved zebra crossing.

2.3.1 Improved Mid-block Zebra Crossings

Improved zebra crossings consist of conventional zebra crossing supplemented by one or more engineering elements in the form of traffic control devices or roadway design elements. They are intended to:-

- Improve visibility of crossing & pedestrian from drivers' positions,
- Remind drivers & pedestrians,
- Reduce vehicle speeds,
- Reduce vehicle-pedestrian conflicts & pedestrian exposure,
- Provide pedestrian detection system.

Crossing & Pedestrian Visibility

Crossing visibility improvement features may include:-

- 1) Passive or active signs placed either in the advance zone or at the crossing (at the sides or overhead) informing driver the location of the crossing. Some overhead signs are internally illuminated to increase conspicuity, while others may project incandescent light downward onto the crosswalk which helps motorists see pedestrians in the crossing at night. Nitzburg and Knoblauch (2001) concluded that the high-visibility crosswalk treatments had a positive effect on pedestrian and driver behaviour on the relatively narrow low-speed crossings.
- 2) Advance signs and pavement markings in the form of zigzag lines—an Australia practice, diamond shape—New Zealand practice, or words on pavement, etc.
- 3) Flashing lights or belisha beacons flashing continuously or activated by pedestrians. They use different flash rates, sequences, with/without strobe effect. Flashing lights sometimes placed in overhead position or in-pavement.
- 4) Conspicuous reflectors such as fluorescent disc on a post in New Zealand and sign posts stripped black & white in Trinidad.
- 5) Orange yellow flags carried by pedestrians crossing the road increases pedestrian visibility and conspicuity; and increased intensity of roadway lighting.
- 6) Crossing paved with coloured material different from roadway pavement colour.

Drivers and Pedestrian Reminders

Crossing signs placed in the roadway reminding road users of their obligations. Example is a sign placed along the centre line of the roadway reading “**State Law: Yield to Pedestrians in Crosswalk**” was cited to be helpful to drivers in Washington, DC. (Redmon, 2003); A similar sign reading “**STOP FOR **” was associated with drivers’ yielding rate as high as signal controlled crossings (Fitzpatrick, et al., 2007); “**Look Right**” and “**Look Left**” messages on signs and

as pavement markings are used in UK to remind pedestrians of the direction to look for vehicles before stepping on a crossing (Tan and Zegeer, 1995); Placards demonstrating the meaning of pedestrian signal are used in North America (Redmon, 2003); Advance signing instructing drivers to yield to pedestrian when flashing lights are activated were found to increase driver yielding behaviour at intersections (Van Houten et al., 1998).

Reduce Vehicle Speeds

Reduced vehicle speeds at pedestrian crossings is accomplished by placing the crossing between two speed cushions such as humps, placing the crossing on top of a speed table—raised crosswalk, providing rumble strips upstream the crossing, narrowing the roadway at the crossing by curb extension or middle refuge islands, and providing warning flashing lights in the advance zone. However, pedestrians in Sweden had a problem of predicting whether the driver will stop for them at sites using speed cushions (Leden et al., 2006).

Minimize Vehicle-Pedestrian Conflicts and Pedestrian Exposure

At a pedestrian crossing, pedestrians are separated from vehicles in time or space. Time separation involves traffic signal control with pedestrian phase. Vertical spatial separation is accomplished by pedestrian bridge while horizontal spatial separation is accomplished by shifting the vehicular stop line further upstream of the crossing. Pedestrian barriers between footpaths and roadway are used to prohibit pedestrians crossing the roadway at any location except at the designated place such as a crosswalk. Provision of a refuge island at the middle of the multilane road crosswalk reduces pedestrian exposure by shortening the distance a pedestrian is required to cross at a time and help the pedestrian in evaluating gaps between traffic streams. Median refuge islands when used with Danish offsets, requiring pedestrians to walk facing oncoming traffic, provides them a better view of oncoming traffic and allows drivers to clearly see pedestrians. They also diminish vehicles overtaking at the crossing.

Pedestrian Detection

Activated in-pavement lighting and animated signal have been used to alert the driver of the presence of a pedestrian at the crossing. Pedestrian detection is accomplished by push button or automatically by sensors. Retting et al. (2003) suggested that crossings with pedestrian signals are more effective when accompanied with pedestrian activation systems.

2.3.2 Traffic Controlled Mid-block Pedestrian Crossings

There are two types of traffic controlled crossings at mid-block locations. First, vehicular and pedestrian traffic are controlled by traffic lights. Pedestrian signal is activated by pedestrian push button or passive detection. In this category vehicle control signal, the display sequence is similar to that at signalized intersection, i.e., red to green to yellow. Three variations of this type include Pelican (Pedestrian Light Controlled), Toucan (Two Can Cross), and Puffin (Pedestrian User-Friendly Intelligent). Countdown signal informing pedestrians the remaining time for the walk signal is a recent concept more applicable at signalised intersections.

Second, vehicular signal uses two red and one yellow signals. It has five display indication patterns as opposed to three at standard signalised intersection (FHWA, 1988). Fitzpatrick et al. (2006) summarised the signal display sequences variations among installations practices. Half signals in the city of Seattle dwell in steady green and then cycle to steady yellow and then steady red when activated by a pedestrian. The HAWK (high-intensity activated crosswalk) signals in Tucson are dark until activated by a pedestrian; then they cycle through flashing yellow, steady yellow, steady red, and then flashing red. Half signals in the Vancouver dwell in flashing green and, on activation, steady green, steady yellow, and then steady red. The mid-block pedestrian signal in Los Angeles shows a green arrow, cycles to a steady yellow, and then cycles to steady red during the walk interval. During the flashing Don't Walk interval,

drivers see a flashing red indication and, after stopping, may proceed if the crosswalk is not occupied.

CHAPTER THREE: METHODOLOGY

Evaluation of the new zebra crossing was done through triangulation method by interviewing drivers, interviewing pedestrians, and observing drivers' yielding behaviour in the field.

3.1 Observed Drivers' Yielding Behaviours

Drivers' yielding behaviours at pedestrian crossings were observed in the field. Factors that were thought to influence driver's yielding behaviour were accounted for. They include flashing light operation status, vehicle size, vehicle use, and incipient pedestrian-vehicle conflict. Conflicts were measured by observing approaching drivers' action when the pedestrian was on the crosswalk.

3.1.1 Experimental Design

To assess the effect of flashing lights on drivers' yielding behaviours, a cross-section design with a control group and a treatment group was employed. The control group has "priority-pedestrian crossing" under installation. These crossings would have reached at a stage whereby all elements including flashing lights hardware have been installed but not yet activated. The treatment group consisted of similar crossings where flashing lights are activated and are working. Selection of crossings in the control group was largely determined by the schedule of contractors installing these new crossings with an objective of covering wider geographical area as possible. Within the neighbourhood of each crossing in the control group, at least one crossing was selected to make up the treatment group. All crossings were located on 2-lane, 2-way roads except one crossing on a 2-lane, one-way street in urban environment. Subjects were drivers at these crossings who encounter a single pedestrian already stepped on the crossing area. Only platoon leaders whom braking behaviour is not likely to be

influenced by other than a pedestrian in the crossing, were observed. It is noted that a single vehicle is considered to be a platoon of one vehicle.

3.1.2 Data Collection

Data was collected in 2005 and 2006 during daylight hours. Two observation sessions, one for each approach, were made at each crossing in both control and experimental groups. The observer located few meters upstream of the crossing, far enough not to distract drivers approaching the crossing, but close enough to observe driver's breaking behaviour as they approach the crossing. In order to expedite data collection, a researcher would selected a free flowing vehicle or a platoon leader approaching and then begin crossing the roadway. The crossing was done taking into consideration safety of the crossing person. This procedure was also used by Van Winkle and Neal (2000) who also associated it with test consistency.

In response to the presence of the pedestrian in the crossing and an approaching vehicle, the second researcher observed the following: 1) driver's action (stop, slow, nothing), 2) vehicle size and registration type, 3) pedestrian's walking direction (into or away from vehicle's trajectory path). Brake light indication was used as a criterion to differentiate between slowing and doing nothing.

Vehicles were classified into three size groups: small, medium, and large. Small vehicles include passenger cars and sport utility vehicles (SUVs) while medium vehicles included pick-ups, vans, and small trucks up to approximately three tons. Large vehicles include trucks above three tons and buses. Vehicle deceleration rate depends on the vehicle size, with small vehicles having higher rates than bigger vehicles.

Driver's decision to yield for the pedestrian who is on the crossing is likely to be influenced by the potential of vehicle-pedestrian conflict. DeVeause et al. (1999)

found that drivers comply more with stop sign at pedestrian crosswalks when pedestrians are present. If the pedestrian walking direction is likely to cause vehicle-pedestrian conflict, the position of the pedestrian was recorded as critical region and non-critical region otherwise. Figure 3.1 demonstrates the two pedestrian regions at the crossing.

A vehicle in Trinidad is registered either for private use; carrying passengers for hire/fare; renting; or transporting goods. Their respective registration number plates start with letters P (Private), H (Hire), R (Rent), or T (Transport) respectively. Drivers of hire vehicles have been considered to disobey traffic regulations more than other groups.

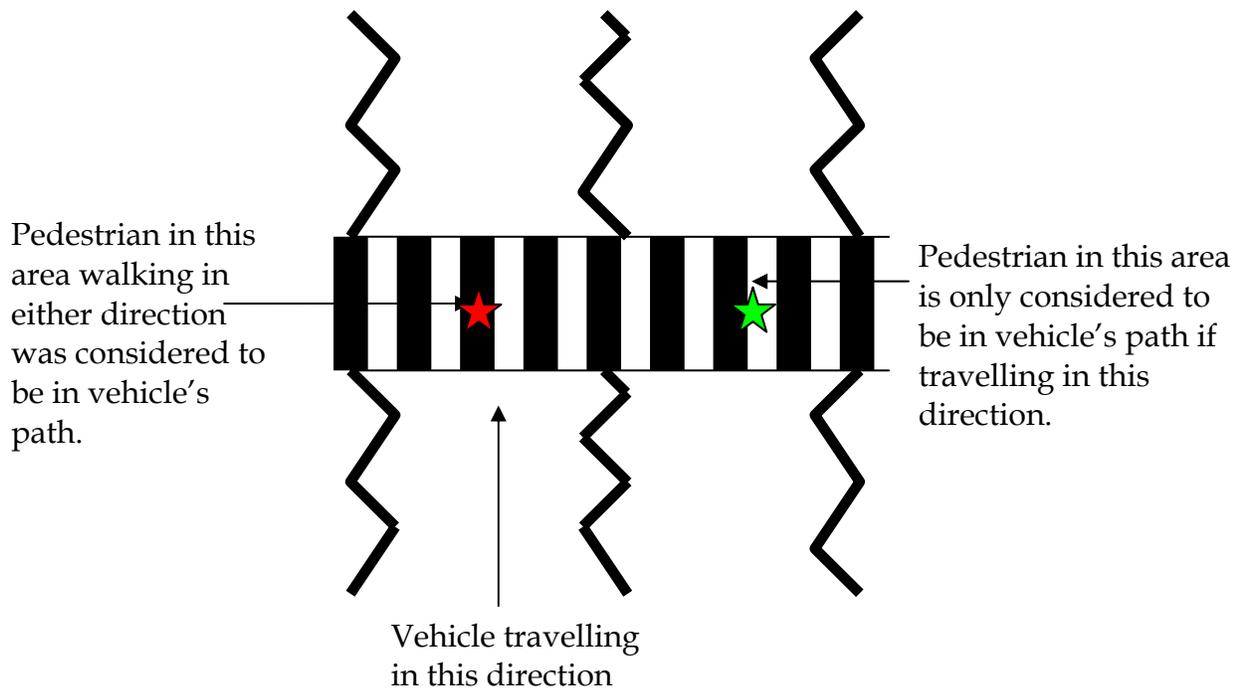


Figure 3.1: Definition of pedestrian's region

3.1.3 Response Variable

The response variable was defined as the proportion of drivers yielding to pedestrians on the crossing area. The guidelines on the use of priority crossings requires driver to accord pedestrian a precedence when the pedestrian is on the

crossing. This requires the driver to yield to a pedestrian, but do not specifically requires the driver to stop. In this study two levels of driver yielding were set at: 1) stopping and 2) at least slowing down (stop and slow). The compliment of proportion of drivers who at least slows down is the same as the proportion of drivers who do nothing to allow pedestrians to cross the road.

3.2 Drivers' Opinion

In 2005 a questionnaire survey was carried out to the general motorists to solicit drivers' views on pedestrian crossings and pedestrian safety, and to test drivers' understanding of selected crossing elements. The survey was administered through a mail questionnaire. While the major setback of mail questionnaire is the difficulty of attaining high response rate, methods that may yield higher response rates such as roadside survey or interview could not be used because of large number of questions and limited resources.

The island of Trinidad was stratified in three geographical regions of north, central, and south. A total of 1000 questionnaires were distributed to drivers at entrances of the shopping centres. The same number of questionnaires was distributed to each of the three regions. It was expected that majority of shoppers at these centres would constitute local residents. A self-addressed, business reply envelope was enclosed within the questionnaire package to enable respondent mail back the questionnaire at no postage cost on the part of the respondent.

3.2.1 The Questionnaire

A one-page questionnaire consisted of 10 short multiple-choice questions. The intent of multiple-choice questions was to offer convenience on the part of the respondent and easy of analysis on the part the research team. The questionnaire solicited information from the driver in three areas of 1) respondent's demographic factors; 2) driver's understanding and yielding behaviour at zebra

crossings, and 3) estimate of pedestrian crossing problem in the country. A sample questionnaire is shown in the Appendix.

3.2.2 Demographic Factors

Demographic factors sought were respondent's gender, age, and period of driving experience. Drivers with longer experience have learned from the past the driving environment, and therefore they are expected to be safer drivers. Young drivers especially teen drivers, on the other hand, they don't only lack sufficient knowledge and driving experience, but they are also known for their high-risk taking behaviour that may degrade road safety. High crash rates involving younger drivers reflect the effect of age, since older drivers who are similarly inexperienced has somewhat lower crash rates (Cooper et al., 1995). Males have were found higher risk takers than female drivers (Hemenway and Solnick, 1993), with men being more likely than women to report having driven after drinking, regularly exceeding the speed limit, and running a red light.

3.2.3 Drivers' Understanding of Crossing Elements

Traffic Control Devices (TCDs) are designed by engineers to be used by road users (drivers, pedestrians, cyclists, etc.). Sometimes road users understand TCDs differently from the intended meaning (Stokes et al., 1996; Ford and Picha, 2000). It is expected that drivers' understanding correctly the meaning of a TCD would be a prerequisite for its effectiveness. Some standards like the Manual on Uniform Control Devices (MUTCD) identify "conveyance of a clear, simple meaning" as one of the five requirements that should be met by a TCD (FHWA, 1988).

Three questions were included in the questionnaire to test the drivers' understanding of three main elements of a priority-pedestrian zebra crossing. The three elements are: - 1) zebra markings, 2) zigzag lines, and 3) flashing lights. A coloured photograph of the crossing was part of the questionnaire for easy

reference to these crossing elements. Respondents were also asked whether their understanding of the meaning of zebra markings is based on their understanding of traffic laws or/and through driving experience.

3.2.4 Self-Reported Yielding Behaviour

Apart from field observations, an alternative method of measuring drivers' yielding behaviour is to ask drivers themselves – self-reported behaviour. While the self-reporting method could be less costly, it suffers the self-reporting bias -- when the respondent tries to impress the interviewer thereby hiding bad behaviours. Questions were worded so as to minimize the magnitude of self-reporting bias, since it was thought that such magnitude depends on the method of interview used as well as wording of the question. Drivers were asked to indicate their responsibility at zebra crossings when a pedestrian is waiting to cross the roadway. We avoided asking directly what they do in order to minimize self-reporting bias.

3.2.5 Estimate of Pedestrian Crossing Problem

Four questions intended to estimate subjectively the magnitude of the pedestrian safety problem in the country. In these questions respondents were asked:-

- How often do they not yield to pedestrians;
- The frequency the respondent sees other drivers not yielding to pedestrians;
- If they know any pedestrian who was a victim of “crossing the road” phenomena.

3.2.6 Effectiveness of the New Zebra Crossing

Public and stakeholders' support for any project is essential in sustaining such project for long term. In this case we defined the effectiveness of the new crossing in terms of its ultimate goal of reducing pedestrian related crashes. Drivers were asked to give their opinions on whether installation of new pedestrian crossings would help in decreasing pedestrian related accidents.

3.3 Field Visits and Pedestrian Survey

Field visit to priority-pedestrian zebra crossings was intended to gain personal experience about the crossings and their usage. The survey was done through personal interviews to some pedestrians who used the crossings. They include school principals and pedestrian passing-by the crossings that showed interest, at the time the researchers were observing drivers' yield behaviours. Principals of schools that were in the vicinity of some of these crossings were interviewed. They were considered to represent views of school children who use those crossings.

CHAPTER FOUR: ANALYSIS AND DISCUSSIONS

Data were summarised and analysed using Statistical Package for Social Sciences (SPSS) software. Discussion of the results was based on the results of the analyses, together with authors' experience of pedestrian safety in Trinidad. Statistical differences between factors of interest were tested at 95 percent significance level.

4.1 Observed Drivers' Yielding Behaviour

A total of 1630 drivers were observed at 22 crossings. Nine hundred and nine drivers were observed at fourteen crossings in the treatment group (flashing lights-on), while seven hundred twenty one drivers were observed at nine crossings in the control group (flashing lights-off). Only one crossing was observed in both conditions of lights-on and -off. Table 4.1 summarises the crossings' information (name, number of observations, flashing light operation condition, and the year it was observed). To assess the effect of flashing lights operation on yielding behaviour of drivers, analysis was done either using one-tail t-test or chi-square (χ^2) test on drivers yielding behaviour. The effects of pedestrian walking direction, vehicle size and vehicle registration type were accounted for. Figure 4.1 indicates that, on the overall, 14 percent of drivers at all crossings stopped for pedestrians, while 66 percent slowed down to allow pedestrians cross the roadway, and 20 percent did not yield at all.

4.1.1 Effect of Flashing Lights Operation

Table 4.2 and Figure 4.1 shows that the proportion of drivers who stopped for pedestrians at crossings where flashing lights were activated, i.e., 22%, is five times greater than at crossings where flashing lights were not activated, i.e., four percent. The difference is statistically significant (p-value < 0.001). Similarly the corresponding proportions for drivers who stopped or slowed down to allow the pedestrian to cross the roadway were 83% and 75% respectively; the difference

being statistically significant (p -value <0.001). What could be concluded from these results is that flashing lights did increase the proportion of drivers who stopped and those who at least slowed down to allow pedestrians to cross the road. Since the proportion of drivers who at least slowed down is a compliment of those who did nothing, it is concluded that flashing lights reduced the proportion of drivers that neither stopped nor slowed down to allow pedestrians to cross the road.

Table 4.1: Summary of drivers' observed yielding behaviour data

Control Group: Flashing Lights Off		Treatment Group: Flashing Lights On	
Site Name	Observations	Site Name	Observations
Bossierre Village RC (2006)	80	3 rd St. & Access Road, Barataria (2005)	18
Monroe Rd. (2006)	80	3 rd St. & PBR, Barataria (2005)	61
Maraval RC Sch. (2006)	80	BWIA HQ, Piarco (2005)	77
Chaguanas Govt. Primary school (2006)	81	Enterp. Govt. School--Homeland (2006)	80
Orange Valley & Bay Rd. (2006)	80	Preysal Hindu School, Couva (2006)	80
San Fdo Boys R.C (2006)	80	Prison Golden Gr. Rd (2005)	33
Servila Private Primary School. (2006)	80	WMR West Moorings (2006)	80
SMR Curepe (2006)	80	SMR Curepe (2006)	80
SMR la Paille-Caroni (2006)	80	Warren ASJA-SMR (2006)	80
		Bryn Maur, Petit Valley (2006)	80
		Hindu sch., Freeport (2006)	80
		Marabella Sen. Comp. (2006)	80
		Charl. Presby (2006)	80
Total	721	Total	909

Table 4.2: Effect of flashing lights on driver's yielding behavior

Flashing Lights Status	% Stopping	p-value	% Stopping or Slowing	p-value
ON (n=909)	22.1	<0.001	83.5	<0.001
OFF (n=721)	4.4		75.1	

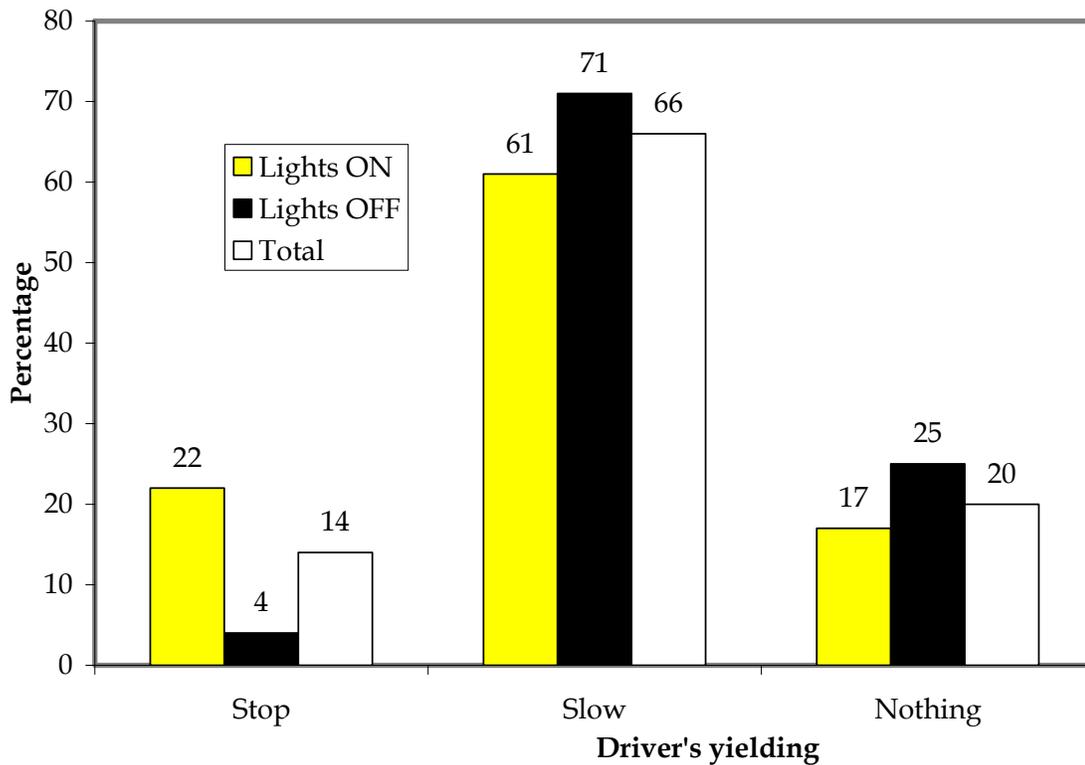


Figure 4.1: Effect of flashing lights on driver's yielding behaviour

4.1.2 Effect of Pedestrian's Walking Direction

In this section we are trying to answer the question of whether flashing lights effectiveness depends on the pedestrian walking direction with reference to driver/vehicle's projected path. First we investigate if pedestrian's walking direction affects drivers' yielding behaviour at all. Table 4.3 shows that 23.6%, of drivers stopping for pedestrians when a pedestrian was walking towards vehicle's path, is about four times higher than the corresponding proportion, i.e., 6.4% when a pedestrian was walking away from vehicle's path. The difference between the two proportions is statically significant ($p\text{-value} < 0.001$). Similarly the proportion (84.4%) of drivers who at least slowed down to allow a pedestrian to cross the road when the pedestrian is walking towards vehicle's path is higher than the corresponding proportion (75.9%) when a pedestrian is walking away from the vehicle's path. The difference between the two proportions is also

statistically significant ($p\text{-value} < 0.001$). It can be seen that more drivers yielded to pedestrians when incipient conflict was perceived, i.e., pedestrian walking towards the direction of the vehicle's path.

Table 4.3: Effect of pedestrian's walking direction on driver's yielding behaviour

Pedestrian's Direction	% Stopping	p-value	% Stopping or Slowing	p-value
Towards vehicle's path (n=751)	23.6	<0.001	84.4	<0.001
Away from vehicle's path (n=879)	6.4		75.9	

The effect of flashing lights on driver's yielding behaviour taking into consideration of pedestrian walking direction was also examined and is shown in Table 4.4. For the case of a pedestrian walking towards vehicle's path, the proportions of drivers who stopped for pedestrians at crossings with flashing lights activated (37.4%) was higher than at crossings with flashing lights off (5.3%). The difference is statistically significant ($p\text{-value} < 0.001$). Similar pattern is true for drivers who at least slowed down in which 87.6% and 80.2% at least slowed down for activated and inactivated flashing lights respectively.

For pedestrian walking away from driver's path, proportions of yielding drivers were lower but with the same pattern as with pedestrian walking towards driver's path situation, as depicted in Table 4.4. It could be concluded that flashing lights did increased the proportion of drivers stopping, and reduced the proportion of drivers that neither stopped nor slowed down to allow pedestrians to cross the road, irrespective of the pedestrian's direction.

Table 4.4: Effect of flashing lights and pedestrian’s walking direction on driver’s yielding behaviour

Flashing Lights Status	% Stopping	p-value	% Stopping or Slowing	p-value
Pedestrian walking towards vehicle’s path				
ON (n=428)	37.4	<0.001	87.6	<0.003
OFF (n=323)	5.3		80.2	
Pedestrian walking away from vehicle’s path				
ON (n=481)	8.5	<0.002	79.8	<0.001
OFF (n=398)	3.8		71.1	

4.1.3 Effect of Vehicle Size on Drivers’ Yielding Behaviour

Larger vehicles may require longer braking distances than smaller vehicles. It is therefore expected that larger vehicles will have difficulties of stopping for pedestrians than smaller vehicles. Table 4.5 indicates a trend of smaller vehicles stopping for pedestrians more than larger vehicles, and in turn larger vehicles slowing down than smaller ones. The differences are statistically significant. These patterns may suggest the differences between vehicle sizes in bringing them to a stop condition as expected. There also exist a trend of larger vehicles yielding (at least slowing down) more than smaller vehicles – it could be that drivers of smaller vehicles who don’t yield often are over-confident in their vehicle control capability thinking that they can manoeuvre around such hazards without even slowing down.

Table 4.5: Effect of vehicle size on drivers’ yielding behaviour

Vehicle size	% stopping	p-value	% stopping or slowing	p-value
Small (n=1189)	15.6	<0.016 (χ^2 -test)	76.4	<0.014 (χ^2 -test)
Medium (n=364)	12.1		81.0	
Large (n=77)	5.2		88.3	

The effect of flashing lights on driver’s yielding behaviour in each vehicle group is shown in Table 4.6. In all six cases of vehicle size and yielding criterion combination, proportion of drivers who yielded to pedestrians at crossings with

flashing lights-on was higher than corresponding proportion at crossings with flashing lights-off. The differences are statistically significant except in one case of large vehicles with at least slowing condition. It could be concluded that generally flashing lights increased drivers yielding for both small and large vehicle drivers. Difference between lights-on and lights-off across all vehicle groups in Table 4.6 shows that flashing lights were more effective in influencing driver to stop than yielding (at least slowing down).

Table 4.6: Effect of flashing lights within vehicle size on drivers' yielding behaviour

Flashing Lights	Small vehicles	p-value	Medium vehicles	p-value	Large vehicles	p-value
Stop condition						
ON	24.4% (n=664)	<0.001	17.2% (n=203)	<0.001	95% (n=42)	<0.03
OFF	4.4% (n=525)		5.6% (n=161)		0% (n=35)	
Stop or Slow conditions						
ON	82.5% (n=664)	<0.001	85.2% (n=203)	<0.01	90.5% (n=42)	<0.26
OFF	74.3% (n=525)		75.8% (n=161)		85.7% (n=35)	

4.1.4 Effect of Vehicle Use on Drivers' Yielding Behaviour

Experience indicates that drivers of "hire" vehicles are more aggressive thereby violating traffic laws more often. We want to find out if flashing lights had the similar effect for "hire" and "non-hire" vehicle drivers. Comparison of proportions of drivers who yielded to pedestrians between "hire" and "non-hire" vehicles in Table 4.7 & 4.8 did not include "large" vehicles because all "hire" vehicles were observed in "small" and "medium" vehicle groups. Proportion of drivers in "hire" group was slightly higher than in corresponding "non-hire" group for both yielding criteria of stopping and at least slowing down (Table 4.7). However, these differences are not statistically significant. It can be concluded that type of vehicle use had little impact on driver's yielding behaviour.

Table 4.7: Effect of vehicle use on driver’s yielding behaviour

Vehicle Use	% Stopping	p-value	% Stopping or slowing	p-value
For Hire (n=582)	15.3	<0.319	78.5	<0.255
Non-hire (n=971)	14.4		79.9	

Comparisons between flashing lights conditions by vehicle use are shown in Table 4.8. In all four cases the proportion of drivers yielded to pedestrians is higher at crossings with flashing lights-on than at crossings with flashing lights-off. The differences are statistically significant. It could be concluded that flashing lights did increase driver yielding in both “hire” and “non-hire” vehicle groups.

Flashing lights seem to have bigger effect for stopping condition. Proportions of stopped drivers at flashing lights-on and flashing lights-off in “hire” group was 22.9% and 5.2% respectively. The difference is 17.7 percentage points. The corresponding values in “non-hire” group are 22.6%, 4.4%, and 18.2 percentage points respectively. On the other hand, proportion of drivers that yielded (at least slowed) in “hire” group at flashing lights-on was 85.2% compared with 69.6% resulting into a difference of 15.6 percentage points. Corresponding values in “non-hire” group are 81.9% and 77.5% respectively, resulting into a difference of only 4.4 percentage points.

Table 4.8: Effect of flashing lights by vehicle use on driver’s yielding behaviour

Flashing Lights	% Stopping	p-value	% Stopping or slowing	p-value
Vehicles for hire				
ON (n=332)	22.9	<0.001	85.2	<0.001
OFF(n=250)	5.2		69.6	
Vehicles not for hire				
ON (n=535)	22.6	<0.001	81.9	<0.046
OFF(n=436)	4.4		77.5	

4.1.5 Modelling of Driver's Yielding Behaviour

While the analysis in previous sections looked at driver yielding factors (independent variables) one at a time, i.e. univariate analysis. In this section these factors are analysed together, i.e. multivariate analysis, in order to increase the statistical power of the analysis. Four issues that will be looked at as related to statistical modelling of driver's yielding behaviour at zebra crossing in a multivariate context are:-

- Research question(s),
- Approach and methodology,
- Model specification, and
- Results & interpretations.

Research Questions

Questions addressed include: what is the probability of a driver yielding to a pedestrian in the zebra crossing given set of conditions of attributing factors (predicting equation)? Does flashing lights operation, pedestrian region, vehicle size, or vehicle registration type make difference in driver's yielding behaviour prediction?

Approach and Methodology

To answer the above questions, we conducted logistic regression analysis with one dichotomous dependent variable (driver yielding) and four independent variables of flashing lights, pedestrian region, vehicle use, and vehicle size. Logistic regression analysis was preferred over other alternatives because of its flexibility, and the dichotomous outcome of the dependent variable. It has no assumptions about the distributions of the independent variables; the independent variables have not to be discrete, as it can accommodate a mixtures of discrete and continuous variables; it cannot produce negative predicted probabilities.

Model Specification

The model comprises four independent variables (covariates) and one binary or dichotomous dependent variable of driver yield (yes/no). Yielding condition defined as at least slow down condition. The four covariates were two levels each. They are: 1) flashing light operation (on/off), 2) pedestrian region (towards/away from vehicle's path), 3) vehicle use (hire/non-hire), and 4) vehicle size (passenger car/non-passenger car).

Results and Interpretations

The constant only model indicates that 79.8% of drivers were likely to yield to pedestrians. Incorporating independent variables in the model (full model) was justified at p-value less than 0.05. Of the four independent variables added, vehicle size and vehicle use were not significant in the model ($p > 0.05$). The reduced model retained only two variables of flashing light operation & pedestrian region. Figure 4.2 shows an extract of SPSS output for modelling drivers' yielding behaviour. The probability (p) that a driver will yield to a pedestrian on the crossing is evaluated using equation 4.1.

$$p = \frac{1}{1 + e^{-\text{Logit}(p)}} \dots\dots\dots(4.1)$$

Where: Logit (p) { =1.183+0.537X₁+0.506X₂-0.313X₃-0.046X₄ for full model;
=0.885+0.538X₁+0.507X₂ for reduced model}.

X₁ = Pedestrian walking direction { =1 if pedestrian is walking towards vehicle's trajectory path;
= 0 Otherwise}.

X₂ = Flashing lights operation { =1 if activated;
= 0 Otherwise}.

X₃ = Vehicle registration type { =1 If for hire;
= 0 Otherwise}.

X₄ = Vehicle size { =1 if passenger car;
= 0 Otherwise}.

e ≈ 2.718.

Pedestrian walking direction was found to influence driver yielding than flashing light operation factor. It has an odds ratio of 1.712 which is interpreted to mean that the odds that a driver will yield to a pedestrian walking towards vehicles trajectory path is 1.712 times the odds that when the pedestrian is walking away from vehicle’s trajectory path, with other factors held constant. It is more likely to yield to a pedestrian when the pedestrian is walking towards vehicle path than otherwise. Flashing lights operation has odds ratio of 1.66 meaning that the odds for a driver yielding to a pedestrian when flashing lights are operational is 1.66 times the odds when flashing lights are not activated, other factors held constant. In other words: drivers are likely to yield to pedestrian when flashing lights are activated than otherwise.

Full Model		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1(a)	lights	.506	.125	16.369	1	.000	1.658
	region	.537	.129	17.381	1	.000	1.711
	hire	-.313	.257	1.481	1	.224	.731
	veh_size	-.046	.211	.047	1	.828	.955
	Constant	1.183	.181	42.493	1	.000	3.264
Reduced Model		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1(a)	lights	.506	.125	16.369	1	.000	1.658
	region	.537	.129	17.381	1	.000	1.711
	hire	-.313	.257	1.481	1	.224	.731
	veh_size	-.046	.211	.047	1	.828	.955
	Constant	1.183	.181	42.493	1	.000	3.264

Figure 4.2: Extract of SPSS output of modelling drivers’ yielding behaviour

Probabilities Estimation

Probabilities (Pr(y)) for a driver yielding to a pedestrian under four different cases as computed from reduced model of equations 4.1 are:-

Flashing lights off, pedestrian walking away from vehicle’s path:

$$\Pr(y) = \frac{1}{e^{-0.885} + 1} = 0.71$$

Flashing lights off, pedestrian walking toward vehicle’s path:

$$\Pr(y) = \frac{1}{e^{-(0.885+0.538)} + 1} = 0.80$$

Flashing lights on, pedestrian walking away from vehicle's path:

$$\Pr(y) = \frac{1}{e^{-(0.885+0.507)} + 1} = 0.81$$

Flashing lights on, pedestrian walking toward vehicle's path:

$$\Pr(y) = \frac{1}{e^{-(0.885+0.538+0.507)} + 1} = 0.87$$

4.1.6 Comparison with Other Studies

Comparison of drivers' yielding rates from this study with other studies is an attempt to gauge the level of success of flashing lights with other comparable devices elsewhere. Comparison is limited to improved mid-block zebra crossings where vehicular traffic is not controlled by traffic lights, and there is no pedestrian activation. Table 4.9 summarizes the comparison. Drivers' yielding rates observed in Trinidad are within ranges of similar studies elsewhere despite differences in study methodologies and roadway environment.

Table 4.9: Comparison with other studies on drivers' yield rate

Study	Characteristics	Without Improvement	With Improvement
Dependent Variable: Driver Stopping or Slowing			
Trinidad (current study)	23 mid block zebra crossing; cross-sectional study; supplemented with flashing lights	75%	84%
Central Avenue, St. Petersburg, FL. (Van Houten, and Malenfant, 2001)	Mid block crosswalk on multi lane roadway; before-and-after study; treated with animated eye signal.	15%	62%
Salt Lake city in Utah and Kirkland in Washington (Fitzpatrick et al., 2006)	Cross-sectional study on four crossings, using pedestrian flags, at 2-6 through-lane, high-volume, high-speed roadways.	Not available	74%
Redmond, Washington (Fitzpatrick et al., 2006)	Cross-sectional study on three crossings, using in-street crossing sign, at 2-3 through-lane, high-volume, high-speed roadways.	Not available	90%
Tucson, Arizona and Austin, Texas (Fitzpatrick et al., 2006)	Cross-sectional study on two crossings, using high visibility signs and markings, at 4 through-lane, high-volume, high-speed roadways.	Not available	20%
Tucson, Arizona (Fitzpatrick et al., 2006)	Cross-sectional study on one crossings, using high visibility signs and markings, at 4 through-lane, high-volume, high-speed roadway.	Not available	91%
Wilcox Blvd. Chattanooga, Tennessee	Before-and-after on one mid-block crossing with actuated flashing lights at two locations in advance zone and at crossing location (Van Winkle and Neal, 2000)	48%	70-81%
Dependent Variable: Driver Stopping			
Trinidad (current study)	23 mid block zebra crossing, cross section study; supplemented with flashing lights	4%	22%
North Carolina (Clark et al., 1996)	11 un-signalized mid block crossings; cross-sectional study; treated by replacement of existing signs with fluorescent strong yellow-green	6%	10%
Wilcox Blvd. Chattanooga, Tennessee	Before-and-after on one mid-block crossing with actuated flashing lights at two locations in advance zone and at crossing location (Van Winkle and Neal, 2000)	9%	42-50%

4.2 Drivers' Opinion

Out of 1000 questionnaires, one hundred and ninety were returned (19% response rate). Fifty-five percent of respondents were females. Fifty-eight percent of returned questionnaires came from south region, 39 percent from central region, and 13 percent from north region. Table 4.10 gives descriptive statistics of the respondents' age and licensed period to drive. Table 4.11 shows that age and driving experience are highly correlated.

Table 4.10: Descriptive statistics for survey respondents

Parameter	N	Minimum	Maximum	Mean	Std. Deviation
Age	180	17 yrs	75 yrs	38.6 yrs	14.3 yrs
Driving Experience	174	1 yrs	55 yrs	17.3 yrs	12.7 yrs

Table 4.11: Correlation between respondents' demographic factors

Measure	Demographic factors		
	Age vs Experience	Age vs Gender	Gender vs Experience
Pearson	0.914 ^a	-0.107	-0.161
Kendall's tau-b	0.777 ^a	-0.062	-0.109
Spearman's rho	0.906 ^a	-0.075	-0.131

^a Correlation is significant at the 0.01 level (2-tailed)

4.2.1 The Meaning of Zebra Markings

One hundred and eighty-seven responded to the question on the meaning of zebra markings from the drivers' point of view. Gender, age, and driving experience were not statistically significant different on this issue. Distribution of responses is summarised as part of Table 4.12 from which the following observations are made:-

- 1) The proportion of drivers who understand that zebra markings means "stopping" is higher than for those who understand it to mean "slowing down", i.e., 60% and 9% respectively. This pattern is consistent in both cases of when the "pedestrian is about to enter the crosswalk" and when the "pedestrian is in the crosswalk", i.e., 23% and 5% respectively;

2) The presence of respondents, about 3%, who understand zebra markings to mean nothing to the driver, is a matter of concern. Zebra markings at pedestrian crossings are among the oldest traffic control devices used worldwide to facilitate pedestrians cross roads legally and safely. It would be expected that all drivers would at least understand that these markings mean something to the driver.

Logistic regression was performed to measure the contribution of gender, age, and driving experience on respondents' understanding the meaning of the zebra markings. First the dependent variable was collapsed from five responses to only two (correct and incorrect). One hundred and sixty-three cases were used in the analysis, which satisfies the requirement of 15 to 20 cases per independent variable. Table 4.13 is an extract from SPSS's output from which it is concluded that neither gender nor age nor experience were significant ($p > 0.05$) in predicting driver's understanding of the meaning of zebra markings.

4.2.2 The Meaning of Flashing Lights

Yellow flashing lights at priority-pedestrian zebra crossings are intended to indicate the presence of a pedestrian crossing so that a driver can prepare to yield in case a pedestrian is using the crossing. Inclusion of "prepare to stop" as one of optional answers in the questionnaire was to translate the meaning of flashing light to the respondent. Summary of the result is given in Table 4.12, from which it is noted that 12% of respondents misunderstood the meaning of these lights. Before the introduction of the new zebra crossing in Trinidad, yellow flashing lights in road traffic environment was only used at signalised intersection, when signals are operating in a safe mode. Such experience could have contributed towards misunderstanding of flashing lights as used at pedestrian crossings.

Logistic regression was performed to measure the contribution of gender, age, and driving experience on respondents' understanding the meaning of the flashing lights. First the dependent variable was collapsed from five responses to only two (correct and incorrect). One hundred and sixty-four cases were used in the analysis, which satisfies the requirement of 15 to 20 cases per independent variable. Table 4.14 is an extract from SPSS's output from which it is concluded that neither gender nor age or experience were significant ($p>0.05$) in predicting driver's understanding of the flashing lights.

Table 4.12: Understanding of priority-pedestrian zebra crossing elements

Response Category	Percentage
<i>Meaning of Zebra Marking to the Driver (N=187)</i>	
Stop for a pedestrian who is about to enter the crosswalk	60
Slow down for a pedestrian who is about to enter the crosswalk	9
Stop for a pedestrian who is in the crosswalk	23
Slow down for a pedestrian who is in the crosswalk	5
Mean nothing to the driver	3
<i>Meaning of Zigzag Lines (N=176)</i>	
Slow down	34
Proceed with caution	59
No parking	1
Stop	3
None	3
<i>Meaning of Flashing Yellow (N=187)</i>	
Prepare to stop	88
Changing green to red	3
Only for Pedestrians	1
None	8

Table 4.13: SPSS output on respondent attributes' significance in predicting their understanding of the meaning of zebra markings.

Factor	Estimate	S.E.	Wald	df	Sig.(p-value)
Gender	-.171	.378	.203	1	.652
Age	.057	.031	3.294	1	.070
Experience	-.013	.042	.097	1	.756

Table 4.14: SPSS output on respondent attributes' significance in predicting their understanding of the meaning of flashing lights

Factor	Estimate	S.E.	Wald	df	Sig.(p-value)
Gender	.398	.517	.593	1	.441
Age	.027	.051	.284	1	.594
Experience	-.013	.056	.050	1	.824

4.2.3 The Meaning of Zigzag Lines

The meaning of the zigzag lines was the most misunderstood element of the crossing. Only one percent identified the correct answer of “no-parking” (Table 4.12). Logistic regression was performed to measure the contribution of gender, age, and driving experience on respondents' understanding of the zigzag lines. First the dependent variable was collapsed from five responses to only two (correct and incorrect). One hundred and fifty-four cases were used in the analysis, which satisfies the requirement of 15 to 20 cases per independent variable. Table 4.15 shows the results of the analysis from which it is can be concluded that neither gender nor age or experience were significant in predicting driver's understanding of the zigzag lines.

Table 4.15: SPSS output on respondent attributes' significance in predicting their understanding of the meaning of zigzag lines

Factor	Estimate	S.E.	Wald	df	Sig.(p-value)
Age	-.302	.344	.769	1	.380
Gender	17.748	4511.555	.000	1	.997
Experience	.309	.371	.692	1	.405

Literature indicates that the meaning of zigzag lines has been illusive to others, locally as well as internationally. Misunderstanding of zigzag lines was noted in a T&T local newspaper article in which the reporter understood zigzag lines to mean, “warn motorists to slow down and exercise caution” (Peters, 2004). Coincidentally over 90% of respondents in this survey understand zigzag lines to mean one of these two meanings given in the newspaper. It is likely that the

newspaper article had an impact on public understanding of these lines. The newspaper article appears to have sourced the information from the government and some readers may easily conclude that this reflect understanding of some officials within the government.

Thirty-five percent of respondents in the Australia study gave the correct answer to the meaning of zigzag lines (Australian Road Research Board, 1989). This prompted reconsideration of use of zigzag lines at zebra crossings. Queensland prohibited the use of zigzag lines in 2002 because it was not a recognized standard and was considered a potential source of confusing motorists, thereby increasing the risk to pedestrians and motorists (Queensland, 2002).

Referring to application of zigzag lines at zebra crossing in Great Britain, Tan and Zegeer (1995) as well as Davies (1999) understood zigzag lines also to provide a cue to oncoming motorists that they are approaching a crosswalk, while others understand the lines to prohibit parking and overtaking only (Inman and Davis, 2007; MTC, 2007). In any event, for zigzag lines to provide a significant element of advance warning to the crossing more than zebra markings, they will have to extend a sufficient distance upstream the crossing such as the application in Australia (Figure 4.3). UK Highway Code 191 explicitly prohibits parking at zigzag lines on the crossing, and prohibits overtaking at all pedestrian crossings (Department of Transport, 2007).



Figure 4.3: Zigzag markings used for advance warning

In Trinidad, zigzag lines' length and their locations relative to crossing are not likely to add a significant element of advance warning. In Trinidad, parking restriction by zigzag pavement markings is used only at priority-pedestrian zebra crossings – it is likely the public is not familiar with the use of zigzag lines at pedestrian crossings, because at other locations parking prohibitions signs are used instead.

4.2.4 Awareness of Traffic Laws at Zebra Crossings

One hundred and eighty-five respondents indicated the source of understanding zebra markings. Fifty percent of respondents indicated that their understanding of zebra crossing markings comes from traffic laws alone. Twenty six percent thinks their understanding is a result of their driving experience or intuition alone, while the remaining 24 percent thinks it is a result of both traffic laws and experience. This indicate that majority of drivers understands that pedestrians are protected to some extent by existing traffic laws.

4.2.5 Drivers' Yielding Behaviour

In different ways five questions solicited information about driver's yielding behaviour in a self-reported manner. The first question asked respondents the meaning of zebra markings in light of yielding actions. Analysis of responses to this question was discussed in subsection 4.2.1 in light of zebra markings meaning. In this section we look at the same question in light of drivers' yielding behaviour. Assuming that drivers are likely to act according to their understanding of the meaning of a traffic control device, about 97% of respondents are likely to yield to pedestrians (Table 4.12). The majority reported that they would yield to pedestrian as early as when the pedestrian is about to enter the crosswalk. However, one respondent expressed the difficulty of understanding the intention of a pedestrian standing at the side of the road.

The second question asked what respondents thinks a driver is required to do for a pedestrian who is waiting to cross the road at a marked crossing.

Overwhelming majority (99%) indicated that they would at least slow down for a pedestrian, 92 percent indicating they would stop for a pedestrian (Table 4.16).

Logistic regression was performed to assess the predictive power of gender, age, and driving experience on drivers' understanding of this issue. Only one of the two respondents under "nothing" category gave all information on age, gender, and experience. This category was left out from the dependent variable leaving only "slow down" and "stop" categories. The number of cases used in this analysis was 165. As shown in Table 4.17 all three factors of age, gender, and driving experience were not significant (p-values of 0.613, 0.731, and 0.232 respectively) in predicting driver's response.

Table 4.16: Driver's requirement for a pedestrian waiting to cross (n=188)

Response Category	Percentage
Nothing	1
Slow down	7
Stop	92

Table 4.17: SPSS output on respondent attributes' significance in predicting their requirement for a pedestrian waiting to cross

Factor	Estimate	S.E.	Wald	df	Sig.(p-value)
Gender	.229	.666	.118	1	.731
Age	.024	.048	.256	1	.613
Experience	-.068	.057	1.428	1	.232

The third question asked respondents how often they yield for pedestrians at a pedestrian crossing. The fourth question asked how often they see other drivers yielding for pedestrians at pedestrian crossings. Results of these two questions are reported in Table 4.18. Age, driving experience, and gender factors were not statistically significant. Few respondents (about 8%) indicated they never or saw fellow drivers stopping for pedestrians. Difference between the proportions of respondents who “always” yield for pedestrians who “always” see fellow drivers yielding for pedestrians was statistically significant. The same is true for those who “sometimes” yield for pedestrians.

Table 4.18: Reported frequency on drivers' yielding for pedestrians at zebra crossings

Driver category	Driver's frequency for stopping for pedestrians		
	Always ¹	Sometimes ¹	Never ²
Reporting of fellow drivers (N=187)	29%	67%	4%
Self reported (N=188)	55%	41%	4%

¹ Statistically significant; ² Not statistically significant

The fifth question asked respondents what is the reason when they don't yield for pedestrians. Results are summarised in Table 4.19. Approximately three-quarters (73%) of 160 respondents indicated that late detection of pedestrian in a crosswalk is the major reason for failure to yield. Late detection could be attributed to distracted drivers or poor crossing & pedestrian visibility. Also it could be used as an excuse by drivers who don't want to reveal their unsafe driving practice (self-reporting bias).

Eight percent don't yield because they think that pedestrians take long time to cross roadways. These are likely to be drivers who are in hurry. Pedestrians taking long time to cross and late detection of pedestrian by drivers were also reported by Redmon (2003) in which drivers who reported late detection indicated sight obstruction and night environment as main reasons. Sixteen percent reported that slowing down is enough while three percent expects pedestrian to yield to motorists. Motorists think that roads are exclusively for vehicles, and therefore yielding to pedestrian is considered a courtesy.

“Pedestrian take long time to cross the road” and “expect pedestrian to yield to motorists” may represent aggressive driving habit. Some studies have reported significant differences between male and female drivers with regard to distraction and aggressive driving behaviour (Shinar and Compton, 2004; Lesch and Hancock, 2004). In this study however, there was no significant difference between genders.

Table 4.19: Reasons why drivers not yielding for pedestrians at zebra crossings

Reason (N=160)	Percentage
Don't see the pedestrian at enough time	73
Slowing is enough for pedestrian to cross the road	16
Pedestrian take long time to cross the road	8
Expect pedestrian to yield to motorists	3

4.2.6 Magnitude of Pedestrian Safety Problem

Respondents were asked if they knew a pedestrian who has been a victim to vehicle crash. Forty percent of respondents personally knew a pedestrian who has been involved in vehicle-pedestrian crash.

4.2.7 Effectiveness of New Zebra Crossing

Eighty two percent of 166 respondents think that marking crossings will increase pedestrian safety. Logistic regression was performed to assess the predictive power of gender, age, and driving experience on driver's view on effectiveness of

the crossing. As shown in Table 4.20, when all three factors are included in the model (model 1), only the age factor is significant. High correlation between age and driving experience, and higher p-values of greater than 0.1 for gender & driving experience prompted dropping the two factors resulting into model 2. The constant term was also dropped from model 2 because of its higher p-value, resulting into model 3. The final model (model 3) is superior in R², percent correctly classified, and -2LL (-2 x Log likelihood) criteria. An odd ratio of 1.045 (1.033 < 95% CI < 1.057) in the final model indicates that respondents who are one year older are 1.045 times more likely to support the crossing. These results indicate that the public appreciate the effectiveness of the project in improving pedestrian safety through new zebra crossing in the country.

Table 4.20: SPSS output on respondent attributes' significance in predicting their support for the new zebra crossing

Model	Factors	Estimate	S.E.	Wald	Sig.	Nagelkerke R ²	Correctly classified	-2LL
1	Age	.111	.056	3.964	.046	0.126	82%	143.58
	Gender	.685	.432	2.517	.113*			
	Experience	-.076	.061	1.540	.215*			
	Constant	-2.363	1.251	3.567	.059			
2	Age	.045	.016	7.521	.006	.078	82.8%	156.73
	Constant	-.044	.582	.006	.939*			
3	Age	.044	.006	59.552	<.001	0.537	82.8%	156.74

LL-Log Likelihood.

* dropped from the model.

4.2.8 Survey Reliability

Interviewing respondents on their driving behaviour is a less expensive method of data collection compared with field observations. However such surveys may suffer from self-reporting bias and lack of internal reliability problems. The extent of these problems is to some extent influenced by survey and questionnaire design. Self-reporting bias can be measured by comparing respondents' stated actions and observed actual actions. Internal reliability describes consistency of a respondent in answering more than one questions

demanding similar response. In this study, drivers' yielding behaviour was used to assess both self-reporting bias and internal reliability.

Self-Reporting Bias

Observed average drivers' yielding rate at zebra crossings in the field was lower than reported rates in the questionnaire, i.e., 80% (Figure 4.1) vs. 97% to 99% (Tables 4.12 & 16) respectively. Such a difference could be attributed by self-reporting bias in the questionnaire survey. Table 4.21 compares self-reported and field observed drivers' yielding rates. The following trends related to self-reporting are noted:-

- Reported "stopping" rates are higher than observed rates;
- Observed "non-yielding" rate are higher than reported rates;
- Reported higher "stopping" rates than "slowing" may as well reflect self-reporting bias since stopping for pedestrians would be considered a better practice than just slowing down.

The magnitude of the bias is higher for the question asking drivers' requirement at zebra crossings than the question asking the meaning of zebra markings - a possible effect of wording style.

Comparing reported frequencies in Table 4.18 we see a reversal trend between self-reported and reporting of fellow drivers between "always" and "sometimes" categories. This reverse of trend may signify self-reporting bias, as the driver tends to think that he/she yields for pedestrian more than anyone else.

Alternatively data in Table 4.18 was analysed by matching respondent's responses resulting in a two-way contingency table (Table 4.22). Highlighted diagonal cells of Table 4.22 makes up 39.4% of respondents who gave same answers for their behaviour as well as for fellow drivers. Cells above this diagonal make up 17.3% percent of respondents who think fellow drivers yield to pedestrians more than them. Cells below the diagonal make up 43.2 % of

respondents who think they yield more frequent than other drivers probably due self-reporting bias. Self-reporting bias has also been reported in similar surveys such as for seatbelt use (Paradaa et al., 2001; Charterjee et al., 1991; Robertson, 1992).

Table 4.21: Comparison between self-reported and observed drivers' yielding behaviour

Yielding Category	Self-reported yielding (%)		Observed yielding rate (%) (Figure 4.1)
	Meaning of zebra markings (Table 4.12)	Driver requirement at a zebra crossing (Table 4.16)	
Stopping	83	92	14
Slowing	14	7	66
Nothing	3	1	20

Table 4.22: Self-reporting and reporting others yielding behavior

		Other drivers		
		never	sometimes	Always
Self-reported	never	1(0.5%)	3(1.6%)	4(2.2%)
	Sometimes	3(1.6%)	47(25.4%)	25(13.5%)
	Always	3(1.6%)	74(40%)	25(13.5%)

Internal Consistency

A driver that yields for a pedestrian who is waiting to cross the road will likely yield to a pedestrian who is in the crosswalk as well. This analogy allows reclassification of the five response categories on the “meaning of zebra markings” (Table 4.12) to only three categories similar to those used in the question on drivers' requirement at a zebra crossing (Table 4.16). These two questions become technically similar because they demand similar answers. The difference in wording and phrasing makes difficult for the respondent to detect their similarity. Comparison of responses between these two questions allows an assessment of respondents' consistency shown in Table 4.23. Eighty percent of respondents were consistent on their responses between the two questions. The 80% consistency is made up of the sum of top-left to bottom-right shaded

diagonal cells of Table 4.23. The respondent was considered consistent if he/she provided the same response for the two questions.

Table 4.23: Respondent’s consistency between “meaning of zebra markings” & “driver’s requirement at zebra crossing”.

Reported meaning of zebra markings to a driver	Reported driver requirement for a pedestrian waiting to cross at a zebra crossing		
	Stopping	Slowing	Nothing
Stopping	145 (77.5%)	9 (4.8%)	0 (0%)
Slowing	22 (11.8%)	3 (1.6%)	2 (1.1%)
Nothing	3 (1.6%)	2 (1.1%)	1 (0.5%)

Reasons of why respondents don’t yield for pedestrian were matched with “meaning of zebra markings” as redefined in Table 4.23 and “driver requirement at zebra crossings” as follows:

- Not seeing the pedestrian in advance as the reason for not yielding to pedestrians was matched with understanding of zebra markings and driver requirement at zebra crossing to be “stopping”;
- “Slowing is enough for a pedestrians to cross the road” as the reason for not yielding to pedestrians was matched with understanding of zebra markings and driver requirement at zebra crossing to be “slowing”;
- “Pedestrians take long time to cross the road” & “expect pedestrian to yield to motorists” reasons for not yielding to pedestrians were matched with understanding of zebra markings and driver requirement at zebra crossing to be “nothing”.

Table 4.24 shows the matching between meaning of zebra markings & reasons for not yielding to pedestrians resulting into 66% respondents’ consistency. Table 4.25 shows the matching between driver’s requirement at zebra crossing & reason for not yielding to pedestrians with 70% consistency. Consistency rates obtained in this study (66% to 80%) are comparable with consistency rates obtained elsewhere. Williams et al. (2001) obtained a consistency rate of 70%.

Table 4.24: Respondent’s consistency between “meaning of zebra markings” & “reason for not yielding to pedestrian at zebra crossing”.

Reason for not stopping for a pedestrian	Meaning of zebra markings		
	Stop	Slow	Nothing
Don’t see the pedestrian in advance	99(61.9%)	16(10%)	2(1.2%)
Slowing is sufficient for pedestrian to cross	22(13.8%)	5(3.1%)	0(0%)
“Pedestrians take long time to cross” & “Expect pedestrians to yield for motorists”	11(6.9%)	3(1.9%)	2(1.2%)

Table 4.25: Respondent’s consistency between “driver’s requirement at zebra crossing” & “reason for not yielding to pedestrian at zebra crossing”.

Reason for not stopping for a pedestrian	Driver requirement at crossing when pedestrian waiting to cross		
	Stop	Slow	Nothing
Don’t see the pedestrian in advance	109(67.7%)	9(5.6%)	0(0%)
Slowing is sufficient for pedestrian to cross	23(14.3%)	3(1.9%)	0(0%)
“Pedestrians take long time to cross” & “Expect pedestrians to yield for motorists”	14(8.7%)	2(1.2%)	1(0.6%)

4.3 Field Visits and Pedestrian Survey

Field visits to the 21 priority-pedestrian crossings and interview with four school principals and two school crossing guards were the sources of unpublished information about zebra crossings application and usage in Trinidad.

4.3.1 Pedestrian Views

The Principal of Maraval RC Primary School has the opinion that the priority-pedestrian crossing at the vicinity of the school was not effective as expected, because drivers do not yield to pedestrian on the crossing to Principal’s satisfaction. The school has approached the Police Department to provide police officers to assist school children when crossing the road. However, the police do not have enough personnel to assist the school. As a precautionary measure, the principal have asked children to avoid the crossing by waiting to be picked by drivers at the school compound.

The crossing guard at the priority crossing located at St. Aidan's Anglican Primary School along Eastern Main Road (EMR) in Arouca believes that he is at work because the school administration does not trust motorists at this pedestrian crossing. The Guard has observed that women and young drivers of Indian descent do not respect pedestrians on the crossing. The assisted crossing at this location is during morning school-opening and afternoon school-closing hours.

The Principal of St. Pius Boy's Primary School in Arouca, through casual observations, revealed that drivers do not yield to pedestrians at the crossing. The crossing at this location was installed after principal's lobby at the MoW&T. It crosses high traffic volume Lapinot road, an arterial road for accessing Lapinot district. The road is the link between EMR and the Priority Bus Route (PBR) two of the three major arterials in the highly congested East-West corridor. Lapinot road is also used by high speed private vehicles to/and from Lapinot district. Traffic level and characteristics on Lapinot road makes it a dangerous road to cross on foot. The principal is planning to request a crossing guard and road humps at the location in the event the pedestrian accident happens.

The Principal of Boissierre Village RC Primary School observed that, drivers do not yield to pedestrians on the crossing that is located in front of the school. He plans one day to dart, at the crossing and see what the drivers will do. The Principal observed that apart from the problem of crossing the road, there are other traffic problems at the site, such as disrespect of one-way regulation in the morning up to 8:30 AM. The principal has witnessed several serious accidents at this section, although not involving pedestrians. In one incident the vehicle hit the bench outside the school where school children would have been sitting, luckily there were no students at that time. In another incident, the vehicle hit the school fence.

The Principal of Sevilla Private Primary School informed the research team that school children don't use the crossing located near the school entrance. All students are dropped and picked-up at the school compound. He knows many non-pedestrian traffic crashes at the area, and therefore he proposes traffic lights instead of yellow flashing lights. As discussed in subsection 4.3.2, the Principal perceives flashing lights at the crossing as substitute of normal traffic signals which regulate traffic between conflicting vehicular traffic streams.

The priority-pedestrian crossing at San Fernando RC Primary School spans a 2-lane, one-way street in the urban environment. The crossing has no zigzag lines. The school security guard has observed that drivers do not stop for pedestrians at the crossing. In some cases when a driver stops for a pedestrian, the following driver overtakes within the crossing area or a driver in the adjacent lane continues without stopping (multiple threats). One school child was hit when crossing the road after flashing lights were installed there.

One pedestrian at the Barataria site commented that drivers were not stopping for pedestrians at that crossing. On the use of yellow or red light colours at signalized intersection, he was of the view that flashing lights should be of red colour instead of yellow.

4.3.2 The Crossing at Sevilla Private Primary School

The crossing is located within the vicinity of a complex five-leg intersection in a rural set-up. The crossing crosses the road with high-speed, high-traffic volume with significant proportion of heavy trucks to- and from Point Lisas Industrial Estates. Short gaps in the main traffic and lack of turn bays on the main road approaches results in many conflicts between turning traffic and through traffic. There are no footpaths for pedestrian, nor did we see any pedestrian during the period we visited the crossing. The land in the vicinity of the crossing is so

underdeveloped to generate significant pedestrian traffic. No surprise, some people like the Principal of Sevilla Private Primary School do not relate this crossing with pedestrian activities.

4.3.3 Location of Priority-Pedestrian Crossing

Field visits revealed how decision making on where to place a priority-pedestrian zebra crossing could be challenging. Visibility of the crossing in terms of adequate driver's sight distance, short distance to cross the roadway, and pedestrian desire lines have to be taken into consideration. Visibility and short distance addresses the issue of crossing safety, while pedestrian desire lines, which depends on local land use and public transport vehicle stops addresses the issue of where the crossing will be highly utilised. Some agencies use roadway and traffic characteristics when developing guidelines for crossing location. The MoW&T requires that these crossings be located on low speed roads (below 65 kph). This being the only documented criterion, much of the crossing location decision depends on engineering judgement of the Traffic Engineer.

4.3.4 Installation of Priority-Pedestrian Crossing

Most crossings contain all elements, i.e., flashing lights mounted on strip painted posts, pavement markings (zebra and zigzag), and advance signs. However, in some cases one or two elements were missing or inappropriately installed such as:-

- Lacking pavement markings (Figure 4.4);
- Lacking flashing lights (Figure 4.5);
- One post not strip painted black & white (Figure 4.6);
- Lacking of advance sign;
- Zigzag lines painted over solid straight lines (Figure 4.7).



Figure 4.4: Priority crossing without pavement markings



Figure 4.5: Priority crossing without flashing lights



Figure 4.6: Non-striped post(s)



Figure 4.7: Straight line painted over zigzag line

4.3.5 Motorists' Behaviours

In this section we discuss some observed motorists' behaviours other than drivers' yielding behaviour. The most common misuse at the crossing was disrespect of zigzag lines. In many instances vehicles were seen parking, stopping and overtaking within zigzag lines at the crossings (Figures 4.8, 4.9, 4.10), despite restriction of parking at pedestrian crossings by article 54 of the Highway Code (Ministry of Works, 1972). Tall commercial vehicles parked at a crossing not only hinder pedestrians in the crossing, they could also hinder the visibility of flashing lights.



Figure 4.8 Parking within the crossing



Figure 4.9: Stopping within the crossing



Figure 4.10: Overtaking within the crossing

CHAPTER FIVE: CONCLUSION & RECOMMENDATIONS

The following are the main conclusions and recommendations based on the results of this study:

5.1 Conclusions

1. Flashing light operation was associated with increased drivers' yielding to pedestrian behaviour irrespective of perceived incipient conflict with pedestrian, vehicle size, and vehicle registration use. However, some stakeholders, especially school principals think the improvement is not satisfactory.
2. Flashing light operation appears to have higher effect for stopping condition than for yielding (at least slowing down).
3. Flashing lights have attained successful levels of drivers yielding to pedestrians on the crosswalks; however there is a room for improvement because higher yield rates have been attained elsewhere.
4. Pedestrian walking direction had a higher influence on drivers' yielding behaviour, followed by flashing light operation. Vehicle use and size had no significant effect on drivers' yielding behaviour.
5. Priority-pedestrian zebra crossing is likely to be more beneficial where driving culture marginalize pedestrians and where level of road maintenance is inadequate.
6. The safest and most effective pedestrian crossings often use several traffic control devices or design elements to meet the information and control needs of both motorists and pedestrians (CUTC, 2000). Likewise priority-pedestrian crossing to a great extent solves most of visibility problems facing conventional zebra crossing because it uses several traffic control devices.
7. The public appreciate the effectiveness of marking pedestrian crossings to alleviate pedestrian safety problem, more so by older drivers.

8. Zigzag lines at priority-pedestrian zebra crossing are highly misunderstood by drivers, this is associated with frequent vehicles parking, stopping, and overtaking within the crossing area thereby jeopardizing pedestrian safety. This case demonstrates a phenomenon in which engineers would design and place traffic control devices, which are not properly understood by road users.
9. Drivers' reported yielding behaviour from this study, although reliable should be reviewed in light of possible non-response bias. Non-response bias is a systematic tendency for selected elementary units with particular characteristics not contributing information while other such units, with other characteristics do.

5.2 Recommendations

1. Drivers' misunderstanding of zigzag lines zebra markings, and flashing lights signifies the need for more education and public information on the crossing features and its use. Furlonge (2004) suggested that: *"before all the fancy zigzag traffic markings and wigwag traffic signals are installed, there must be a strategic traffic safety education programme, identifying the purpose of these measures; otherwise there is simply a waste of materials and the risk of endangering users of the crosswalks"*.
2. Observed parking violation at priority pedestrian crossings may need mitigations more than public information and education. Supplementing zigzag lines with standard signs which are familiar to most drivers in T&T for restricting parking and stopping; addressing the demand of parking in the vicinity of a crossing are among considerations.
3. The length of "no-parking" zone at priority pedestrian crossing need to be reviewed, the current length of up to eight metres appear too short compared with other agencies worldwide.

4. There is a need to develop comprehensive guidelines for selection of treatment type at specific crossing location, taking into consideration traffic level, number of lanes, and roadway speed limit.
5. There is a need to formulate and implement enforcement at priority-pedestrian crossings.
6. For the crossing to command attention from drivers, installation should include all traffic controls in the design specifications, i.e., flashing lights, pavement markings, advance signs, and reflectorization of flashing light posts.
7. There is a need to differentiate flashing lights at signalised intersection and those at priority crossings in order to create and preserve a unique image for this crossing. Activated flashing lights with pedestrian pictorial inscription at intersection were found to increase driver yielding behaviour (Van Houten et al., 1998).
8. The crossing could further be improved by providing pedestrian activation system, use of red colour instead of yellow, use of advance stop lines, use advance signing, and use of LED instead of incandescent because of its brighter and economical in long term. Advance signing instructing drivers to yield to pedestrian when flashing lights are activated were found to increase driver yielding behaviour at intersections (Van Houten et al., 1998).
9. Overhead flashing lights could solve visibility problem that might be created by tall trucks parking in the vicinity of the crossing or overgrown tree branches.
10. Use of solar energy instead of standard power would free the crossing from power cuts and also make them feasible in some rural areas where there is no conventional power supply.
11. Study on pedestrian behaviour at priority pedestrian crossings is recommended in order to qualify their effects on pedestrians.

12. There is a need to repeat field observations on drivers' yielding behaviour to determine the long-term effect of this crossing.
13. Because of positive effect by flashing lights on drivers' yielding behaviour and positive opinion by drivers on the effectiveness of the new crossing, the government should continue her current effort to install the new pedestrian crossing.

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APPENDIX: QUESTIONNAIRE

Pedestrian Crossings & Traffic Red Light Questionnaire

Most traffic accidents involving pedestrians and at signalised intersections are severe. Most of them occur when the pedestrian is trying to cross the road and when some driver disregard traffic lights. The department of Civil Engineering at the University of the West Indies is undertaking a study on these issues in Trinidad. Your sincere response of this questionnaire will help in understanding these problems, hence their solutions. The information you provide will be kept confidential and used only for research purpose.--- **Thank you.**

Driving experience (yrs.) ____

Gender: M / F

Age (yrs) ____



1. (a) What do zebra paint marking (in this photograph) at pedestrian crossing mean to the driver? **(tick only One)**
 - Driver to stop once a pedestrian is about to enter the crosswalk.
 - Driver to stop when the pedestrian has entered the crosswalk.
 - Slow down for pedestrian(s) in the crosswalk.
 - Slow down for pedestrian who is about to enter the crosswalk.
 - It means nothing to the driver, it only indicates to the pedestrian the place to cross the road.

(b) Your response in (a) above is based on: **(tick all that apply)**

 - Traffic laws of Trinidad & Tobago.
 - Experience/intuition
2. How often do you observe fellow drivers not yielding or stopping at a pedestrian crossing? **(tick only One)**
 - Never. Sometimes
 - Always.
3. What is required from a driver at a marked pedestrian crossing a pedestrian is waiting to cross the road? **(tick only One)**
 - Stops and allow the pedestrian to cross.
 - Slow down to allow pedestrian to cross the road
 - Nothing. Only pedestrian should look for his/her own safety.
4. What does the zigzag lines (in this photograph) at an approach of a pedestrian crossing indicate to the driver? **(tick only One)**
 - Slow down.
 - Proceed with caution.
 - No parking. Stop
 - None of the above
5. What does flashing amber (yellow) lights mounted on the post (in this photograph) mean to the driver? **(tick only One)**
 - Prepare to stop for pedestrian(s) crossing the roadway.
 - Light is changing from Green to Red.
 - It means nothing to the driver, it only indicates to the pedestrian the place to cross the road.
 - None of the above.
6. (a) How often do you stop at a painted (zebra) to allow pedestrian crossings? **(tick only One)**
 - Never. Sometimes
 - Always.

(b) When you do not stop is because:

 - Pedestrians take long time to cross the road.
 - You do not see the pedestrian at enough time before reaching the crosswalk.
 - You are expecting the pedestrian to stop once he/she sees you approaching.
 - Slowing down is enough for the pedestrian to cross the road.
7. Do you personally know of a pedestrian who has been injured or killed by a vehicle when attempting to cross the road? **(tick only one)**
 - Yes No
8. Are you of the opinion that the marking of pedestrian crossings will help in the decrease of pedestrian related accidents as opposed to unmarked ones? **(tick only One)**
 - Yes No