A Review of In-pavement Warning Lights for Safety

Nitish Shekhawat[1] Nitin Thakur[2]
[1]Research Scholar [2]Assistant Professor
[1,2]Department of Civil Engineering
[1,2]Om Institute of Technology and Management, Hisar, India

Abstract— Pedestrian is one of the important component in urban transportation system and also vulnerable at unprotected mid-block locations under mixed traffic conditions. At unprotected mid-block locations, some of the vehicles may yield to pedestrians who are already at crosswalk location. However, some of the pedestrians are using forced gaps to cross the road. Hence, while pedestrians use the mid-block crosswalk with forced gaps, which decreases the vehicular flow characteristics. The pedestrian sidewalks do not show a direct effect on the vehicular flow characteristics when the pedestrian have pleasant walking facilities.

Key words: NHAI, Pedestrian, Crosswalk, ESPRIT, WSF

I. INTRODUCTION

Despite the increased emphasis on promoting the accommodation of pedestrians within the transportation system, pedestrians have the highest risk of injury among users of the road system. Specifically, there is a high risk of death or injury due to the interaction of pedestrians and drivers, particularly with the prevalence today of higher speeds: only 15 percent of pedestrians hit at 40 miles per hour survive, while at 20 miles per hour or less, 95 percent survive (4). Given the prevalence of walking as a critical mode of transportation, and the particular vulnerability of pedestrians, pedestrian safety is among one of the most important concerns in the transportation industry. Crashes involving pedestrians are a frequent occurrence and make up two percent of all people injured in traffic crashes and more than 70 per cent of fatal road crashes in 2017 involved adults in the 18-45 years age group, according to a report. As many as 1.47 lakh people died on Indian roads in 4.64 lakh accidents reported during 2017, the report by the Ministry of Road Transport and Highways said. Fatal road accident victims largely constitute young people in the productive age groups. Young adults in the age group of 18 - 45 years accounted for 72.1 per cent of victims during 2017. People in working age group of 18- 60 years accounted for a share of 87.2 per cent in the total road accident fatalities, as per the report from . In terms of accidents on road categories, the National Highways accounted for 30.4 per cent of total road accidents and 36 per cent of deaths in 2017. Extensive research and innovative strategies have been employed in an effort to counter the failures to keep the roadways safe for pedestrians in just the past few years with varying results. The Ministry of Road Transport and Highways has taken a number of steps to prevent road accidents and road accident fatalities. Traffic Control Devices which the governs the use of traffic control devices and presents recommendations for regulatory, warning and guide signs, pavement markings, and traffic control and pedestrian signals, is the Crosswalk In-Roadway. The Government has approved a National Road Safety Policy. This Policy outlines various policy measures such as promoting awareness, establishing road safety information data base, encouraging safer road infrastructure including application of intelligent transport, enforcement of safety laws etc. The threshold for four laning of national highway has been reduced from 15,000 Passenger Car Units (PCUs) to 10,000 PCUs. About 52,000 Km of stretches of State Highways has been identified for conversion to national highways.

II. PROBLEM STATEMENT

The Providing pedestrian safety is a critical objective of the transportation profession and in recent years, increasing amounts of time have been spent researching strategies to reduce the conflicts, or consequences of conflicts, between pedestrians and motor vehicles. Achieving pedestrian safety while simultaneously maintaining a desirable level of service for vehicles is a challenging process for transportation professionals. 789 black spots based on fatalities in 2011, 2012, 2013 and 2014 calendars years have been identified. So far 189 spots have already been rectified. Rectification measures at 256 spots have been sanctioned which are in various stages of implementation. 138 spots are on State Government roads / with other agencies. The balance 206 spots would be taken separately or would be rectified as part of ongoing projects.

As a measure of supplementing the efforts of States/ UTs for minimizing the accident potential at the identified locations / stretches through engineering improvement on state roads, Ministry of Road Transport & Highways had taken a decision to sanction road safety works on state roads with an earmarked allocation of 10% of funds allocated to the state roads under Central Road Fund.

The largest proportion of pedestrian fatalities occurs at night when pedestrians are commonly less conspicuous (1). Most of the pedestrian treatments currently employed do not make it easier to see crosswalks; rather they only make drivers aware that a crosswalk exists. The following sections describe how crosswalks are used, the Crosswalk with In-Pavement Warning Light System, and how it interacts with pedestrians and drivers.

III. LITERATURE REVIEW

The designing of pedestrian crossing facilities at proper location is a complex problem under mixed traffic conditions in countries like India. The choice of a particular type of pedestrian crossing facilities (at grade or grade separated) influences the safety of pedestrian and results in change of vehicular flow characteristics. It is very important to avoid the sudden change of vehicular flow characteristics caused by unexpected pedestrian crossings by improving typical crossing locations usually by implementing refuge median islands or signalized crossings or complete segregation (grade separated) by considerations of both vehicle as well as pedestrian volume. In this line, Bak and Kiec (2012) studied

the influence of mid-block pedestrian crossings on roadway capacity by the simulation model. The results indicate that the vehicular driver willingness to give a right of way to pedestrians on urban roads results in decrease in capacity reduction and increase in delays and it is also observed that there is significant reduction in roadway capacity at zebra crossing locations. Schroeder et al. (2012) found that effect of pedestrian non-complaint behaviour on vehicular capacity at the multilane roundabout as a function of the driver yields behaviour. Duran and Cheu (2012) studied the effect of crosswalk location as well as pedestrian volume on roundabout capacity by the simulation model. From the results, they concluded that if the crosswalk is placed further upstream from the yield line then the entry capacity of roundabout approach increases. But, there is no significant change in the entry capacity whenthe crosswalk is beyond three car-length upstream from the yield line. Silva et al. (2013) studied the effect of crosswalk location on roundabout performance, it was considered with vehicular flow and travel times by the simulation model. The results proved that there is a significant influence of the pedestrian crossing in terms of average travel time and for high vehicle traffic. Ashalatha et al. (2013) studied the effect of bus stops on capacity reduction of urban roads under mixed traffic conditions. From the results, they concluded that bus bays and curb side bus stops can reduce the capacity of urban roadways by 8.1% and 25.6% respectively. Chandra et al. (2014) studied the effect of pedestrian cross flow on capacity of urban arterials in mixed traffic condition. From the results, they concluded that pedestrian volume of 100 ped/hour crossing the road will reduce its capacity by 3.52 percent. Farouki and Nixon (1976) studied the effect of the carriageway width on speed of cars in the special case of free flow conditions in sub-urban roads. From the results, it was found that the mean free speed of cars in suburban area increases linearly with increase in the carriageway width over a certain range of width (5.2m to 11.3m). Yagar and Van Aerde (1983) found that vehicular traffic speed changes exponentially with change in lane width. Raymond and Knoblauch (2000) studied the effect of crosswalk markings on vehicle speed. From the results, it was found that drivers slightly reduce vehicle speed by yielding to the pedestrians. Hakkert et al. (2002) evaluated the effect of the pedestrian crosswalk warning system on vehicle speed by means of embedded flash lights in pavement. The results inferred that vehicle speed will reduce by 2 to 5 kmph due to the yielding to pedestrians. Some authors addressed the characteristics of vehicles and pedestrians on different crossing conditions by studying the three conditions of the pedestrian crossing, including crossing freely, crossing at nonsignalized crosswalk, and crossing at the signalized crosswalk. From the results, they concluded that selecting appropriate crossing mode for pedestrians can effectively decrease the vehicle delay, especially when the heavy pedestrian flow exists (Shumin and Yulong, 2007). The yielding behaviour is affected by various aspects of the roadway and driving environment, including vehicle dynamics, pedestrian's behaviour, roadway function and design. The driver yield behaviour is rarely observed (those pedestrian waiting at curb location) at un-signalized intersection under mixed traffic conditions. The noncomplaint behaviour of pedestrian and non- driver yield behaviour the interaction between pedestrian-vehicle increases at un-signalized mid-block crosswalk locations. Dulaski and Liu (2013) studied the interaction between the pedestrian and vehicular driver at un-signalized mid-block locations when pedestrian is waiting at curb and stepping off the curb. From the results, it was concluded that, the driver yield behaviour is more when the pedestrian steps off from the curb and it is more during morning peak hours. Safety at mid-block crosswalks depends on the ability of drivers and pedestrians to recognize potential conflicts. Some of the researchers explored pedestrian safety at mid-block crosswalk location and they concluded that pedestrian safety is governed by driver yield behaviour (Brumfield et al., 2013) and some researchers have carried pedestrian road crossing behaviour comparative study between signalized and un-signalized midblock locations (Khatoon et al., 2013).

IV. Methodology

SA zebra cross marked location was selected to allow for a minimum pedestrian cross flow at mid-block location to study the effect of pedestrian crossings on vehicular flow. The selected second location is approximately 300 m away from the previous location on the same roadway corridor with same geometry (mid-block location) and there was a full barrier to prevent the pedestrian crossings for the stable vehicular flow condition

V. Field Evaluation Results and Analysis

AnWalking has always been the primary means of human motion. And that's why we considered the pedestrians are the basic elements of transportation. In ancient ages there was a huge pedestrian walking take place and walking is the only mode of transportation. For every transport related to travel and journeys must begin and end in walking. This pedestrian walk is an effective mode of transportation for short trips. Walking is a major mode of transportation in Indian cities also. In order to provide the best design spaces for human motion or circulation like at airport corridors, shopping malls, subways etc. for that pedestrian motion is studied empirically in all aspects. It is carried away by two levels. At macroscopic level one can analyze the basic flow parameters like speed, density of pedestrian motion and at microscopic level one may track the paths followed by individual pedestrians while moving respectively. From this it is clear that the pedestrian may create own paths in their journey trip. Coming to the pedestrian crosswalks there were several cross walks like zebra crossing are designed for a road, provide gainful work to assist the pedestrians to move from one side to the other side of road, and which plays a significant role in the mobility and safety mode of signalized intersections. In some other places like where the busy traffic takes place, pedestrian choose the mid blocks to cross the road. But there is no safety as compared to signalized intersections. Even many pedestrian crosswalks are taking place in these midblock sections. Depend on the vehicular pedestrian motion demand cross walk width is defined. Some existing manuals are published about the crosswalk width, but they do not provide clear specifications for the required crosswalk widthregarding different pedestrian demand volumes and properties. Pedestrian flow consists of two types,

unidirectional (single file motion) and bidirectional. In unidirectional flow, pedestrian motion is in one direction only, whereas in bidirectional pedestrian can walk from the both direction and interact with each other. Pedestrian road safety is one of the major aspects of transportation engineering in urban areas. The illegal crossing behaviour of the pedestrian is a major fact in the road safety issue. The un-protected mid-block location is one of the important components in the urban transportation system for pedestrian activities under mixed traffic conditions especially in countries like India. The number of such un-protected mid-block pedestrian road crossing activities has been increasing in Indian context and growth of these activities may also result in pedestrian accidents. The increase in un-protected midblock pedestrian road crossings has been significant effect on vehicular characteristics such as an increase in travel times and decrease in vehicle speed. At signalized midblock and intersection, there is the complete right-of-way to pedestrians and vehicles as it results decrease in pedestrian and vehicle conflicts as well as severity of conflicts. There are numerous studies which deal with the pedestrian road crossing behaviour at intersection and mid-block locations. The importance of these crossing studies is related to the evaluation of pedestrian facilities, traffic control features and road safety treatments by means of before and after crossing studies on pedestrians' behaviour as well as safety. Pedestrians need to cross the road at some location during the course of travel and crosswalks are important for pedestrians to cross the road. The crosswalk locations should provide safe and comfortable movement (Persson, 1988). In general, there are two types of crossings i.e. at-grade and grade separated. If the pedestrians are completely segregated (grade-separated) with vehicular traffic, then there is no effect of pedestrian crossings on vehicular flow characteristics. The grade separated facilities are provided exclusively based on the vehicle as well as pedestrian traffic intensity. If, such grade separated crosswalks are too apart from each other, then pedestrians either change their road crossing choice according to their destination which will result in more travel time or pedestrian will use forced gaps to cross the roads. Also, due to poor construction of grade separated facilities and road side development, pedestrians usually cross the road at unprotected mid-block locations under mixed traffic conditions. However, in mixed traffic condition it is very rare to get adequate vehicular gaps to cross the road. Hence, pedestrians will exhibit non-complaint road crossing behaviour, causing more interference with vehicles. It leads to rigorous change in vehicular flow characteristics such as speed and flow. A number of research studies have been carried out on vehicular f low characteristics on freeways, bottlenecks, merged lanes etc., but studies on effect of pedestrian crossing on vehicular flow characteristics are very few.

Pedestrian safety has been the focus of many research projects in just the past few years with the increased implementation of many new pedestrian treatments. To develop a framework from which to consider in-pavement lights systems and identification of potential candidate locations for such systems it is important to consider the following topical areas: increased safety of in-pavement lights systems over traditional, unsignalized midblock crosswalks and drivers' behavior at in-pavement crosswalks, specifically where are they looking and drivers reaction to different colored warning lights. The following sections provide a review of the literature associated with in-pavement treatments and traffic signals and the safety research that has resulted from implementation. Additional discussion involves driver scan patterns when faced with different events on the roadway. Lastly, research covering the human factors, specifically reaction (i.e. braking and scanning), of different color lights can be used.

A. In-Roadway Treatment

The Indian transportation system is highly skewed towards road based transportation. After the economic liberalization in the 1990s, the road infrastructure has progressed rapidly; highways are being expanded, new technology vehicles with good operational capabilities are on the roads and car ownership has increased significantly in last two decades. The country has a total road network of around 4.689 million km giving a road density of 1.423 km per square km of land, which is much higher than that in the United States (0.65). The road network in India is classified as national highways (NH), state highways (SH), district roads and village roads, and almost two-third of the total road network is comprised of village roads, which connect villages to either district roads or to SH. Remaining one-third length is of expressways (~1200 km), NH (~92,000 km) and SH (around 180,000 km). Length of NH is less than 2 %, but it carries almost 40 % of the total traffic. SH also carry heavy to very heavy traffic. It has resulted into severe congestion on Indian highways. Government of India is spending enormous amount of money on widening of NHs from two-lane to four-lane and six-lanes. Similar efforts are being made by the state governments also on widening and strengthening of the state and district roads. Upgradation of a road is justified only when capacity of the road is related to the projected requirement of traffic. The manuals for four-laning and six-laning of highways published by the Indian Roads Congress (IRC), New Delhi have indicated certain values of design service volume for two-lane undivided and four-lane divided roads to facilitate highway development projects in the country. However, these values are ad hoc and not based on field studies. It is mainly due to very less and scattered research on the subject of highway capacity in India. The objective of this paper is to present the status of research work carried out in India on Interurban roads during last few decades. The research is compiled in three parts; undivided roads like single lane, intermediate and two-lane roads, divided roads like multilane highways, and expressways.

VI. CONCLUSION

The preceding sections describe current topics in the transportation industry related to pedestrian safety improvements and scan pattern evaluation. First, many different pedestrian treatments at crosswalks both with the pavement markings, in pavement lighting systems, and alternative signals have been evaluated by researchers in recent years. Researchers have found that some treatments are more successful than others at increasing safety for pedestrians; however research is needed to evaluate the

effects on safety of in-pavement warning lights systems versus traditional, unsignalized midblock crosswalks. Second, driver eye scan patterns has been successful in evaluating permissive left-turns, airport terminal signs and comparing novice and experienced drivers when looking for hazardous events. Third, in-pavement warning lights are typically amber, but there is a lack of research about using other colors or color combinations. Research has been conducted involving construction vehicles with different colors and color combinations other than the standard amber only. The use of blue and amber lights has produced better results than amber alone, but more research is needed. Additional research indicates blue lights had greater visibility than yellow when shown in snowy conditions.

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