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A Study on Pedestrian Level of Service on Footpaths of Hyderabad

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ABSTRACT:

In urban India version of transportation, the traffic planners mostly give stress on motorized mode of movement. All kinds of steps are taken for development of roads in terms of safety, speed or time interval at intersections in case of motorized vehicle. But in present traffic condition, the non-motorized mode of traffic is also increasing. The pedestrians and bicyclists are occupying the track of motorized vehicle as no separate grades are provided for them. It leads to traffic congestion as well as the safety factor of pedestrian is at stake. According to HCM 2010, for this heterogeneous traffic, we can't just increase the level of service by developing the quality of roads for vehicles. Steps have been taken to reclaim pavement for pedestrians by removing the encroachment on footpath.

Study is carried out at random locations in Hyderabad city. The users were asked to answer the questions the quality of service provided by the system in terms of questionnaire formed .The format of questionnaire was based on the factors that user perceive. From the ratings, an analysis was carried out to find the level of service based on perception of the interviewers .The analysis consisted of five factors as safety, Comfort level vendors encroachment ,accessibility and side walk performance, climate condition. The analysis was done on SPSS and the area was categorized to a specific level of service out of 6 degrees of level of service (LOS). It is difficult to have LOS value for an area based on perception as it varies from person to person. So the trail is made to its best possible value of LOS depending on majority of the majority of user's perception.

INTRODUCTION:

Under the project "Walkable City Hyderabad" several stakeholders of civil society, cultural institutions, universities and consultancies have gathered to promote a sustainable and integrated traffic and transportation development in Hyderabad with a special focus on pedestrians and walkability. The activities are part of the Sustainable Hyderabad Project and have been initiated by nexus Institute (Berlin, Germany) and the PTV Group (Karlsruhe, Germany). Previous activities in the field of traffic and transport in Hyderabad in 2009, namely the Citizens` Exhibition "Ready to move..?!" in Tarnaka, a conference that formulated a "Citizens` Charter on Urban Transport" and an accompanying Online-Discussion Forum identified safe pedestrian mobility as one of the city´s key issues. In Hyderabad, with its already approximately seven million inhabitants, a high percentage of travel is done by walking, mainly because a big proportion of the population is too poor to afford motorized or even public transport.

But walking has become increasingly difficult in recent days. Pedestrian space has been converted into road space in order to accommodate the constantly rising number of vehicles in Hyderabad: In 2008, there were a total of 2.4 Million vehicles and is projected to reach 7.4 Million by 2025. The sole prioritization of motorized vehicular traffic has left the pedestrians with virtually no space along the busy arterials of the city. Walking along and crossing of these arterials has become life threatening, especially for the elderly, disabled, women and children. Several fatal accidents with pedestrians happen every week. Consequently, those who can choose their mode of transportation have been discouraged from walking.

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This trend is supported by the 4 decentralization and expansion of the city: Increased trip distances have made nonmotorized modes of transportation unfeasible. Still, public transportation has a significant share of the total trips and walking is essential for the use of this mode of transportation. But this fact has not been adequately recognized in the current layout of the transit system. In this context, the project activities of "Walkable City Hyderabad" aimed to: o analyze and present the perspectives of individuals that use the open space in different ways (lorry and rickshaw drivers, street vendors, waste pickers, merchants, retailers, residents, visitors, customers, traffic policemen, transportation agencies) o map the relevant actors, especially of the civil society sector o map the responsibilities in planning and infrastructure of pedestrian and related facilities o include the perspectives of civil society groups, practitioners and academia in the planning and management of a traffic system o investigate the solutions proposed by experts to make Hyderabad a walkable city o raise awareness regarding the declining options for non-motorized transport, especially walking and cycling.

Due to rapid urbanization in India, the traffic volume is increasing on the roads. The motor vehicle industry is demanding with an annual production rate of 5 million vehicles. This leads to clumsiness on roads giving an unsuitable condition for movement. For some time, transportation engineers and planners have focused on the development vehicular transportation system. Even today, the motorized transportation system receives an overwhelming priority over systems that serve the needs of non-motorized users such as pedestrians and bicyclists. However, in recent years, emphasis has been shifted towards multimodal approaches for improvement in pedestrian facilities and operations in order to counteract the challenges of congestion, air quality, improving safety and quality of life. The researchers are promoted to step forward in improvements of traffic behavior in all aspects.

There has been progress in measuring quality-of-life of pedestrian facilities and in walkability. For example Saelens et al.(2003) mentioned this from the way of users' walking decision and neighboring environmental conditions such as population density, connectivity to different transitions ,land use pattern are also the factor of influence. Sidewalk performance can be assessed by many ways. Pedestrian input can be used for determining adequate levels of service from the road user's perspective. In past studies, Parasuraman et al. (1988) studied the scale for measuring service quality in the private service sector and developed an instrument (called SERVQUAL) for assessing customer perceptions of service quality in service and retailing organizations.

The original SERVQUAL scale included five factors i.e. (1) Tangible: physical facilities, equipment, and appearance of personnel, (2) Responsiveness: willingness to help customers and provide prompt service, (3) Reliability: ability to perform the promised service dependably and accurately, (4) Assurance: knowledge and courtesy of employees and their ability to inspire trust and confidence, and (5) Empathy: caring, individualized attention the firm provides its customers. These five factors are considered generic service quality factors and applicable to any type of service. In highway applications, Burde (2008) evaluated road users' overall perceptions of highway maintenance service quality.

Referring to SERVQUAL factors, two factors were proposed, namely, safety and reliability. The safety factor is a combination of two service dimensions: assurance and tangible. Most of previous sidewalk performance studies were performed with quantitative variables such as pedestrian space, pedestrian and/or vehicle traffic, and sidewalk width (e.g. TRB, 2000., Landis et al. 2001., Huang et al. 2007). Tan et al. (2007) collected pedestrian perception about their feeling of safety and comfort. The pedestrian level of service model has been proposed based on quantitative variables: bicycle traffic, pedestrian traffic, vehicle traffic, driveway access quantity, and distance between sidewalk and vehicle lane. This paper attempts to determine factors affecting sidewalk's performance based on pedestrians' perception. Information collected from pedestrians is used to predict a set of qualitative variables to determine the extent to which sidewalk's current level of service meet pedestrian's expectation. In addition, improvements that can be achieved based on pedestrian's perception of the condition of the sidewalk were discussed. In this study, field observation is performed in the sidewalk where street vendors exist along the sidewalk. Therefore, the pedestrian opinions can incorporate the street quality.

As stated by Litman (2007) an improved pedestrian safety and a safer walkable environment will help the community in achieving the following:

1. For non- drivers the accessibility would improve.
2. Cost of transportation will sharply reduce.
3. The parking efficiency in the area would be greatly enhanced.
4. There would be improvement in aesthetics.
5. Reduction in land needed for road construction.
6. Reduction in the level of pollution and it acts as a support for transit.

STATEMENT OF THE PROBLEM:

Rapid urbanization has taken its toll on pedestrian safety levels, often the traffic engineers in order to provide better transportation facilities either fail to provide pedestrian facilities on the roadside or compromise the safety of pedestrians. So the need of the hour is to provide a safe environment for pedestrians without any conflicts with other modes of transportation. This paper attempts to determine factors affecting sidewalk's performance based on pedestrians' perception. Information collected from pedestrians is used to predict a set of qualitative variables to determine the extent to which sidewalk's current level of service meet pedestrian's expectation.

In addition, improvements that can be achieved based on pedestrian's perception of the condition of the sidewalk were discussed. In this study, field observation is performed in the sidewalk where street vendors exist along the sidewalk. Therefore, the pedestrian opinions can incorporate street vendor's presence in correlation with sidewalk performance.

OBJECTIVE AND SCOPES:

The objective of this study is to develop an instrument for determining factors affecting sidewalk performance based on pedestrian perception. A questionnaire with different items is developed to measure pedestrian perception in five different areas: (a) safety, (b) comfort/convenience, (c) vendors presence, (d) movement easiness and accessibility, (e) environmental condition. It is believed that each item could potentially impact on sidewalk performance. The main objectives are: To provide higher safety to pedestrians without obstructing/hampering the inflow and outflow of traffic.

1. To devise a yardstick for calming the traffic and to design the streets in such a way that it improves the pedestrian walking environment.
2. Very little study has been carried out to perk up the pedestrian walking environment and the factors which define it.

While there are complaints about obstructions on the footpaths like trees, junction boxes, vendors and others, the Hyderabad Metro Rail (HMR) is planning for 'inclusive' footpaths having all these, yet wide enough for pedestrians to walk. The elevated metro rail is being built across the three dense traffic corridors of the twin cities – L.B.Nagar to Miyapur, Falaknuma to JBS and Nagole to Shiparamam — totalling about 72 km, it means little above 140 km of footpaths on both sides. HMR authorities are keen on having proper and aesthetically built footpaths with the near required widths of two to three metres going up to 15 feet near the stations in at least 100 km of the road stretches

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where the project is being built. "A sidewalk is the soul of the city. All over the world, there is a movement for reliable public transport, public spaces and footpaths," says HMR Managing Director N.V.S. Reddy. Enabling citizens to walk is the solution to most urban problems because "if you don't have public transport it will only lead to more private vehicles, more air pollution and bigger carbon footprint," he avers. Besides, making footpaths accessible to all users including the disabled, safe, continuous, etc., Mr. Reddy is confident of incorporating most of the existing "obstructions" into the overall design. "We cannot wish away streetlights or trees or vendors. With innovative designs we can better utilise the space between the kerb and walking zone.

STAKEHOLDER ANALYSIS:

The Hyderabad Metropolitan Development Authority (HDMA), Greater Hyderabad Municipal Corporation (GHMC), their common subcommittee Unified Metropolitan Transport Authority (UMTA) and – for the enforcement of regulation – local traffic police have been identified by nexus as particularly important stakeholders for footpaths on the local level of public authorities. Above those local institutions there is Andhra Pradesh Roads and Building Department, which is generally responsible for the building and maintenance of roads in the state. In consequence, this situation "is giving rise to overlapping of functions and spatial and functional fragmentation"1 especially when it comes to traffic issues in general. Within the civil society sector there are also different organizations dealing with transport and traffic, but as the most important stakeholder the Right to Walk Foundation (R2W) has to be named. After its establishment in 2005 and under the leadership of its president and founder, Ms. KanthimathiKannan, R2W started different activities to raise public awareness and pressure on local authorities at the same time. The conducted activities in the field of walkability comprise several student projects realized within an Indo-German student exchange program, an expert workshop with a field trip, a citizen's exhibition at Begum Bazaar, the planning and inauguration of a "Centre for Pedestrian Infrastructure and Planning" (CPIP), a students design competition and various policy implementation efforts.

STEPS TOWARDS A PEDESTRIAN POLICY:

In order to enhance the awareness concerning the walkability of Hyderabad improvements of the infrastructure for pedestrians will first have to be implemented and monitored on an exemplary (temporary) basis. In combination, a participative decision making process is envisioned to include the citizens' perspectives into the design and planning of pedestrians facilities (e.g. Planning Cell / Citizens Report etc.). The results of such a process shall demonstrate how these exemplary improvements are assessed and adopted by the users and how such approaches can be transferred and implemented on a larger scale (planning, building, and maintenance). However, it has been difficult to get an official mandate for this kind of participatory process because a general lack of awareness among politics and administration can be observed regarding the needs of pedestrians.

In April 2011 the "Greater Hyderabad Municipal Corporation" (GHMC) introduced a special cell to deal with pedestrians' problems.2 Moreover, GHMC officials, attended by the Right to Walk Foundation (R2W) and other NGOs, also encouraged a comprehensive pedestrian policy. The policy is said to comprise a general widening of roads and footpaths including standardized designs, barriers wherever necessary, standard height, and other aspects as well as regulations regarding encroachment by parked vehicles and hawkers.3 In September 2011 GHMC decided to start a pilot program with model footpaths in five roads with a total length of 100 km.

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The selected roads were Road No.11 & 12 Banjara Hills, Road No.36 Jubilee Hills, opposite Salar Jung Museum and Himayatnagar. 4 In order to prove the convenience of the new pavements R2W has conducted a walkability survey at Road No. 36 Jubilee Hills. The results of this survey laid the foundation for future research and complemented further actions within the project. In April 2012, the R2W foundation in cooperation with the Consumers Association of India (CAI) and Vadaa, a NGO based in Hyderabad, organized a "Walkability Dialogue" which was attended by several government officers and GHMC commissioners. Subsequent to the "Walkability Dialogue" the project team was requested by GHMC commissioners to take part in the development of a "Pedestrian Policy". The idea is to develop a "Walking Guideline" for Hyderabad that includes necessary regulations for the building of sidewalks and that predominantly addresses authorities, planners, architects and property owners. It should serve as normative as well as practical guide line that enhances activities towards a sustainable pedestrian infrastructure. The Delhi Pedestrian Design Guidelines are a good and comprehensive best practice example for such a binding determination of all general measures concerning the way of building sidewalks.

CENTRE FOR PEDESTRIAN INFRASTRUCTURE AND PLANNING (CPIP)

In 2009, the "Walkable Hyderabad Consortium" has been established by concerned citizens, researchers, social activists and professionals to address the growing neglect of pedestrian needs in the public sphere. In this initiative partners joined hands whose work and impact has been recognized nationally as well as internationally. The consortium is a collaborative network of organizations that have come together to involve in discourse related to the documentation, survey, research, planning, advocacy, awareness, community outreach and professional services in the areas of pedestrian infrastructure and public spaces usage. Its members include: Goethe Zentrum, Hyderabad; Indian National Trust for Art and cultural Heritage (INTACH), Hyderabad; The Right to Walk Foundation/ Hyderabad; Nexus Institute/ Berlin; The PTV group/ Karlsruhe; The Indian Institute of Architects (IIA), A.P Chapter/ Hyderabad; Institute of Town Planners India (ITPI), A.P Chapter/ Hyderabad; Karmayog Hyderabad and Heritage Conservation Initiative Consultancy (HCIC)/ Hyderabad. In order to expand on the previous activities and to foster further projects and cooperation the "Walkable Hyderabad Consortium" in collaboration with the School of Planning & Architecture (SPA/ JNIAS) came forward to establish a "Centre for Pedestrian Infrastructure and Planning (CPIP)" at JNIAS, Secunderabad. The purpose of this centre is to impart training, conduct research and related activities for students and professionals leading to capacity building in pedestrian infrastructure and usage of public spaces.

It is further to develop pedagogical material to be used as part of the curriculum at JNIAS –School of Planning & Architecture (SPA), and in due course, at institutes across India. The CPIP will become a forum that provides a physical location to host all initiatives related to pedestrian rights and issues in the city. The centre is foreseen to set up a permanent exhibition/ laboratory open to the public, to establish a library and database centre for information related to the centre's activities, to develop training, certificate and degree programs and to organize public events. A coordination committee will manage the centre, thus be responsible for decision making involved in day-to-day activities, be responsible for financial planning and provide outreach to the public and to institutions. It will be composed of the chairman Dr. Pramod S. Shinde, Director, JNIAS – SPA, the convenor Ms. KantimatiKanan, President, Right 2 Walk Foundation and 9 more regular members. The inauguration of the CPIP took place on February 15th 2013 at the School of Planning & 11 Architecture (SPA) at JNIAS in Secunderabad.

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CONCEPT OF LEVEL OF SERVICE:

Level of service is defined as measurement of satisfaction level traffic system is providing to user in terms of density, speed, congestion etc. The 2010 HCM incorporates tools for multimodal analysis of urban streets to encourage users to consider the needs of all travelers. Stand-alone chapters for the bicycle, pedestrian, and transit have been eliminated, and methods applicable to them have been incorporated into the analyses of the various roadway facilities.

The primary basis for the new multimodal procedures is NCHRP Report 616: Multimodal Level of Service Analysis for Urban Streets. This research developed and calibrated a method for evaluating the multimodal LOS (MMLOS) provided by different urban street designs and operations. This method is designed for evaluating "complete streets," context-sensitive design alternatives, and smart growth from the perspective of all users of the street. It is used to evaluate the tradeoffs of various street designs in terms of their effects on the perception of auto drivers, transit passengers, bicyclists, and pedestrians of the quality of service provided by the street.

The Highway Capacity Manual has defined levels of service (LOS) as "qualitative measures that characterize operational conditions within a traffic stream and their perception by motorists and passengers." LOS (designated as A through F, with LOS F being the least desirable) includes speed, travel time, freedom to maneuver, interruptions in traffic, comfort and convenience. The LOS concept was introduced to qualify the characteristics associated with various levels of vehicles and people passing a given point during specified time periods. Hence, LOS has been a qualifier of conditions relating to vehicle or person throughout rather than aqualifier of conditions relating to individual comfort level. According to HCM-2010, level of service can be classified into 6 categories LOS-A to LOS-F.

FACTORS AFFECTING PEDESTRIAN LEVEL OF SERVICE:

Traffic volume: We would observe that as the traffic volume increases the PLOS consequently tends to decrease. One can easily observe that during heavy traffic the pedestrians are more apprehensive of their safety than other time. On street parking: this factor has a positive influence on LOS as it acts as a buffer in between the traffic and the pedestrian thus providing a sense of security. As the people perceive they are safe, hence it results in higher LOS. Sidewalk width: greater the width of sidewalk greater is the level of safety being perceived by pedestrians as they feel more comfortable which results in a higher LOS. Roadway width: with increase in width of road the pedestrian feels it more difficult to cross the road from one end to another thereby decreasing the LOS. Normally now a days in order to accommodate the traffic we find carriage ways of large widths resulting in a lower LOS. Speed limits:

The speed limit for the road surveyed was 40 km/hr. with increase in speed there is a drastic decrease in the pedestrian level of service. It is due to the fact that at higher speeds the pedestrians perceive higher threat levels to their life hence resulting in a decrease in LOS. Number of lanes: With increase in number of lanes there's a increase in the total width of the road hence there is greater probability of pedestrian-vehicle interaction which leads to lower safety levels and hence it leads to lower LOS score. Encroachment by vendors: Footpath in India is mostly occupied by vendors resulting in traffic congestion. So the user has to occupy the road for movement which leads to risk exposure. It reduces LOS. Pavement condition: Good pavement condition leads to comfortable movement which increases Los. Several other factors such as lighting, marking (crosswalk), presence of buffer (trees,manholes), accessibility to transit areas, driveway, space between road and footpath speed of vehicle on road also affect pedestrian Los.

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Pedestrian Time-Space Concept:

A New Approach to the Planning and Design of Pedestrian Facilities - Gregory Benz: In the time-space approach of Benz methodology pedestrian activities generate time-space needs. The areas where these activities take place are time-space zones. Mathematically, the time-space concept can be described as:

$$T\text{-}Sreq. = \Sigma\, PiMiTi$$

Where, T-Sreq. = time-space required

Pi = number of people involved in activity i

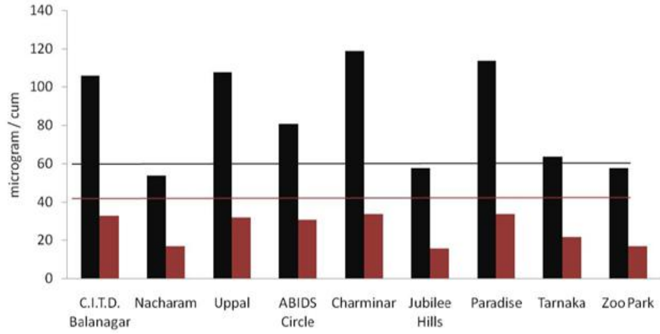
Mi = space required per person for activity i

Ti = time required for activity i

T-Sreq is then compared with the time-space available. The time-space available (T-Savail.) is simply the product of the area available (Aavail.) and the time it is available (Tavail.). Multi-Modal Levels of Service (Abridged) - David Mozer: The work area width volume(WWV) is determined using an equation which includes measures of peak hour pedestrian volumes, mode split that is not pedestrian (wheelchairs, bicyclists, skaters, runners, etc.), usable width of the walk area, and a "travel pattern factor" representing the one way or bi-directional nature of the facility's pedestrian traffic. Quality of Service for Uninterrupted Pedestrian Facilities in the 2000 Highway. Capacity Manual - Joseph S. Milazzo et al: For platooning movement, the major flow does not undergo a significant change up to a pedestrian density of about 0.8 to 1.0 peds/ m2. The minor flow begins to change when densities approach 0.7 to 0.8 peds/m2. Field Studies of Pedestrian Walking Speed and Start-Up Time - Richard L. Knoblauch, Martin T. Pietrucha, and Marsha Nitzburg: The mean speed for pedestrians 65 years old and younger was 4.95ft/sec. The mean speed for pedestrians older than 65 was 4.11 ft/sec. Meanwhile, females 65 years old and under walked 0.32 ft/sec slower than males, while 65 and above females walk 0.4ft/sec slower than males. Obstacles in Pedestrian Simulations - Pascal Stucki, Christian Gloor and Kai Nagel:A person requires a 0.3m lateral spacing on each side and extra longitudinal space for speed deviation. On this basis the measured distance to obstacles are 0.45m for wall, 0.35m for fence and roadway, 0.3m for poles. Walking Behavior in Bottlenecks and its Implications for Capacity - Serge P. Hoogendoorn: For bottleneck condition, due to lack in speed of movement the pedestrians make layer like trails.one layer is formed inside neck and one outside. The space between the two layers is 45 cm which is less than effective width of single pedestrian (55 cm).This is called"zipper" effect.

Many locations have critical levels of PM10

Note: These are NAMP locations. APPCB monitors air quality in 21 locations.



Change in air quality status of monitoring location after the tightening of the National ambient air quality standards

Monitoring Locations	RSPM		Nitrogen dioxide	
	Previous air quality status	New air quality status	Previous air quality status	New air quality status
Nacharam	Low	Moderate	Low	Low
C.I.T.D. Balanagar	Moderate	Critical	Low	Moderate
Uppal	Moderate	Critical	Low	Moderate
Paradise	Critical	Critical	Moderate	Moderate
Charminar	Critical	Critical	Moderate	Moderate
Tarnaka	High	High	Low	Moderate
ABIDS Circle	High	High	Moderate	Moderate
Jubilee Hills	Moderate	Moderate	Low	Low
Zoo Park	High	Moderate	High	Moderate

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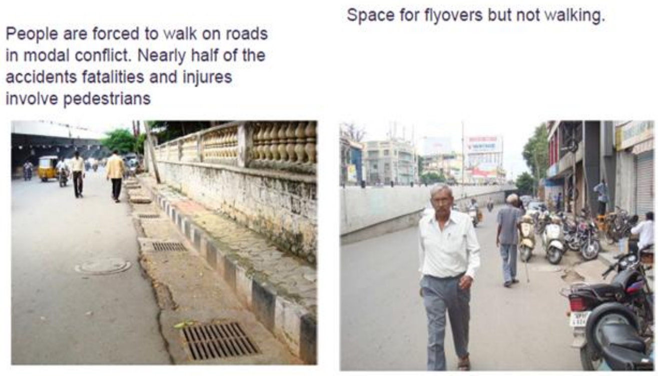

METHODOLOGY AND STUDY AREA:

The major steps involved in this study are: (1) selection of suitable site for field survey (2) field data collection and extraction (3) analysis of pedestrian demographic characteristics and pedestrian behavioural aspects (4) model development for pedestrian road crossing behaviour.

SITE SELECTION:

The selected site is an uncontrolled (unmarked and no right of way to the pedestrian) mid-block location and two lane per direction two way road in Hyderabad, India. The snapshot of study section is shown in Figure 1. The selected mid-block section is 135 m away from the signalised intersection. It has an adequate volume of pedestrians as well as vehicular traffic to allow for collection of pragmatic behavioural data using video graphic survey.

DATA COLLECTION AND EXTRACTION:

Videography survey was conducted on 21st October 2016 at the selected mid-block location during the working day in normal weather conditions. The video camera was placed on the roof of a building. The video camera viewed a total of 40 m length along longitudinal direction, out of this only 15 m (which is marked in the Figure 1) is used for data collection where the pedestrians are usually crossing the road. In this study it has been observed that because of high traffic flow, realistic lag (first gap) could be obtained based on the coverage length (40 m) of video graphic survey. The video was captured and thirty JPEG files were obtained from each second of video recording with the help of Snapshot Wizard software. From each snapshot, pedestrian demographic data have been collected which includes pedestrian gender, age and platoon size. The average observed vehicular traffic during the survey at study location was 4722 vehicles per hour and the mean speed of vehicular traffic was 24.28 kmph which were calculated based on the analysis of the video data.

DEMOGRAPHY AND PEDESTRIAN BEHAVIOURAL CHARACTERISTICS

The pedestrian demographic characteristics comprises of gender, age groups (i.e., < 15 years-children, 15-30 years-young, 30-50 years-middle aged and > 50 years-elders) by visual appearance. Also the data collected from video observation contains waiting time and gap acceptance condition. Pedestrians' and drivers' behavioural data were extracted from the video. In this study, the pedestrian rolling gap is the one of the important parameter influencing pedestrian behaviour. Pedestrians are rolling over the small vehicular gap which is characterised as rolling gap as depicted as path A-A in Figure 3.

It is a usual pedestrian behaviour in mixed traffic condition in developing countries. From the field, it has been observed that drivers are more unlikely to yield to pedestrians waiting at curbs. So, in this study driver yielding behaviour is considered as whether they stop or reduce speed or change the vehicular path while a pedestrian is in the middle of the crossing. After arriving at the curb, most of the pedestrians may look at the traffic to check the suitable gap for crossing the road.

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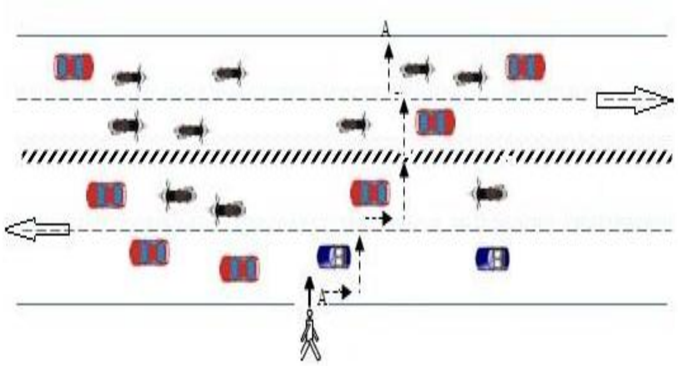

Figure 4.3 Pedestrian rolling gap movement

MODEL FRAMEWORK:

The effect of selected variables on the pedestrian road crossing behaviour at uncontrolled mid-block location is modelled with the help of multiple linear regression technique. In this model, the minimum accepted vehicular time gap size by pedestrian was estimated with pedestrian behavioural characteristics. The probability of accepting vehicular time gap was modelled with discrete choice model technique. In discrete choice models, instead of increase or decrease in gap value like in MLR model, it is regressing for the probability of a categorical outcome. In simplest form, it means that considering a binary outcome variable i.e., pedestrian accepts available gap or rejects in terms of probability. The behaviour of the pedestrian can be predicted by choices made with different available gaps with the binary logit model by discrete choice modelling technique. In both the models, the functional relationship between input and output variables can be easily represented.

MULTIPLE LINEAR REGRESSION MODEL (MLR MODEL):

The MLR model is useful for finding out the accepted gap size for pedestrians. The minimum pedestrians' gap acceptance value is represented by a regression model. The collected vehicular gap data is with an accuracy of 0.033 second. The pedestrian may reject more number of available small gap size values and they may accept higher gap size values.

To develop the minimum gap acceptance model, a log normal regression was selected by considering that pedestrian accepted gaps which followed a normal distribution. The accepted gap sizes are best fitted by a normal distribution by considering logarithm of the gaps. The general model framework is given below: $\text{Log-Gap} = \beta 0 + \beta 1\ X1 + \beta 2\ X2 + \beta 3\ X3 + \ldots\ldots\ldots\ldots + \beta n\ Xn$ (1) Where Log-Gap= logarithm of accepted gaps; Xi-n= explanatory variables; β1-n= are estimated parameters from the model; β0= constant

BINARY LOGIT MODEL (BL MODEL):

In this study, the pedestrian decision making condition is described by the binary logit model (BL Model). The probability of selecting an alternative (accept/reject) is based on a linear combination function (utility function) expressed as: $Ui = \alpha i + \beta i1\ X1 + \beta i2\ X2 + \beta i3\ X3 + \beta i4\ X4 + \ldots\ldots\ldots\ldots + \beta in\ Xn$ (2) Where Ui=the utility of choosing alternative i; i= the alternative (accept/reject) n= number of independent variables; α= constant; β = coefficients The utility of alternative 'i' has to be transformed into a probability in order to predict whether a particular alternative will be chosen or not. The probability of choosing alternative 'i' is then calculated using the following function: $P(i)=1/ [1+ \exp (-Ui)]$

RESULTS AND DISCUSSION:

The pedestrian road crossing behaviour is quite unpredictable at uncontrolled midblock location. Different pedestrian behavioural characteristics were considered for minimum gap size model, out of which only few (eight) variables could explain the pedestrian road crossing behaviour. Among the different variables driver yielding behaviour, rolling gap and vehicle speed are the most influencing variables. Variables such as waiting time, observation duration at curb or median, observation duration while crossing and number of observations at curb or median does not affect the pedestrian road crossing behaviour in this study.

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Whereas, number of observations while crossing is one of the significant variable and very useful while using the rolling gap. At midblock locations pedestrians are accepting vehicular gap size without much waiting after arriving at the curb. They rely on rolling gap and driver yield behaviour. Due to the increase in use of rolling gap there is a decrease in pedestrian safety. Incidentally, rolling gap and driver yielding behaviour are highly significant factors in reducing the accepted gap size. It is also observed that the driver yielding behaviour does not have much effect on the pedestrians' waiting time at the curb and median. When pedestrian reaches the middle of the road it affects the pedestrian road crossing behaviour. Generally, type or size of vehicle is an important factor for accepting the gaps (Yannis et al., 2010), but in this study it is observed that pedestrians are accepting vehicular gaps with respect to vehicle speed.

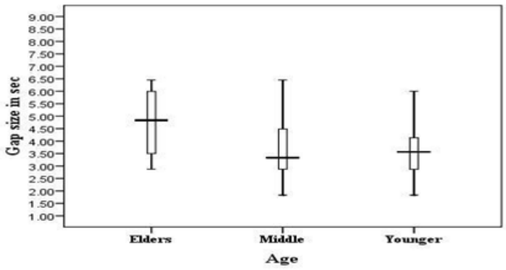

Figure 4.4 Mean accepted gap size for different age group of pedestrians

Pedestrian age is statistically significant for minimum gap size and there is a significant difference between elders and young pedestrian age groups, which can be observed in Figure 4. Also this figure shows the mean accepted gap size for different pedestrian age groups. It indicates that the pedestrian chooses small gap sizes with decrease in age at uncontrolled mid-block location, but there is not much difference between middle and young age groups. The mean accepted gap sizes in seconds for elders, middle and young age groups are 4.75, 3.35 and 3.504 respectively. The maximum and minimum accepted gap sizes in seconds for different age groups are 6.496 and 2.81 for elders, 6.49 and 1.79 for middle, 6.6 and 1.79 for young.

It is also logical from the field data, that selecting the rolling gaps by young and middle age group is very high when compared to elders groups. So the rolling gap criteria makes the age as one of the important factor to reduce gap sizes at uncontrolled mid-block location.

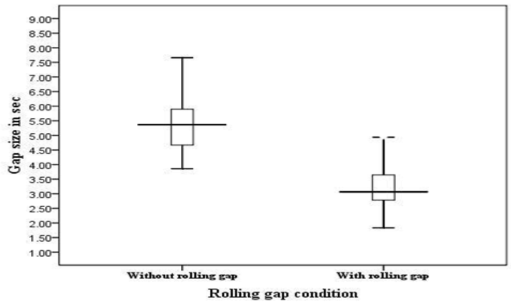

Figure 4.5 Mean accepted gap size under pedestrian rolling gap behaviour

Pedestrian rolling gap behaviour is the most important variable introduced in this study. While pedestrians roll over the gaps they choose small gap sizes and in this situation other pedestrian tactics (speed change condition, crossing path change condition etc.) also comes into picture. Figure 5 shows the pedestrian rolling gap behaviour with available vehicular gap size. The mean accepted gap sizes in seconds without rolling and with rolling gap are 5.38 and 3.05 respectively. It can be observed that there is a drastic change in mean accepted gap size when pedestrians use rolling gap. If pedestrians choose rolling gap they are more likely to accept the minimum gap sizes. Hence, it is a statistically significant variable for the minimum gap size in the MLR model.

Figure 4.6 Pedestrian mean accepted gap size based on driver yielding behaviour

Driver yielding behaviour also plays a major role as observed in this study. If pedestrians are already in the middle of the carriageway, the driver yielding behaviour becomes important. While pedestrians are commendably crossing the road, drivers may effectively reduce vehicular speeds or may change their vehicular paths to yield to the pedestrians. Due to this driver yielding behaviour (reducing vehicle speeds or change their vehicular paths), pedestrians are accepting small vehicular gap sizes. Figure 6 shows the pedestrian driver yielding behaviour with vehicular gap size. The meanaccepted gap sizes in seconds without driver yielding and with driver yielding are 4.05 and 2.84 respectively. It can be observed that there is a significant reduction in mean accepted gap size when vehicular drivers yield to pedestrians. If vehicular drivers continuously yield to pedestrian, then the vehicular flow characteristic decreases drastically. However, the pedestrian may be benefited with this driver yielding behaviour, but driver may not always yield. Hence, it is a statistically significant variable for the minimum gap size in the MLR model.

CONCLUSIONS:

In this study the pedestrian behavioural aspects are considered at the microscopic level which includes variables such as observation duration at curb and median, number of observations at curb and median, observation duration while crossing, number of observations while crossing, speed change condition, crossing path change condition, frequency of attempt and rolling gap. These behavioural characteristics are principally dynamic for gap selection and gap acceptance under mixed traffic condition. These behavioural characteristics are very useful to control pedestrian jaywalking behaviour and for improving pedestrian safety. As pedestrian waiting time increases at the curb or median they may lose their patience and this leads to increase in the rolling gap behaviour to cross the road. Rolling gap behaviour is observed more with younger age groups, so the increase in age results in increase in accepted gap size.

This study highlights the importance of driver yielding behaviour at uncontrolled mid-block locations. If the driver yielding behaviour increases there is a drastic increase in pedestrian accepting small gap sizes. If pedestrian accepts the lag, it indicates that the accepted lag value is higher than the usual gap size. So, from the model used in this study (MLR and BL model) it can also be concluded that the accepted gap size will increase when the pedestrian accepts lag (first vehicular gap). In accepting lag (first vehicular gap) case the pedestrian shows normal behaviour (no use of rolling gap condition) and they cross the road with higher safety. However, the available lag in mixed traffic condition is very rare so the pedestrian usually apply tactics to reduce their waiting time. In general vehicle type is important factor for accepting the gaps, but this study it is found that pedestrians are accepting vehicular gaps with respect to vehicle speed. It can be justified by the fact that small vehicles may come with higher speeds.

So, the pedestrian may not accept the available gaps with small vehicles in mixed traffic condition at higher speeds and sometimes heavy vehicle gaps may be accepted due to less speed. So due to this, speed of the vehicle plays important role in both the models (MLR and BL models). This study also addresses the frequency of the attempt, due to increase in waiting time at the curb or median when pedestrians may frequently attempt available gaps. When they succeed with small vehicular gaps, the probability of gap acceptance also increases. Due to absence of protected walkways (footpaths) at midblock location pedestrians are waiting at paved shoulder. When vehicles are coming with high speed or close to pedestrians, the efforts of searching vehicular gap reduces because of this frequency of disturbance of the vehicle. In this condition pedestrian may look for higher vehicular gap size. Moreover, based on the field survey it has been observed that the pedestrian jaywalking behaviour is higher at uncontrolled mid-block location due to less regulation of pedestrian activities.

Obviously it leads to less safety at an uncontrolled mid-block location as compared to the other locations. Hence, it appears realistic that a decrease in driver yielding behaviour at an uncontrolled mid-block location further reduces safety. Another interesting observation from this study is that the frequency of attempting gap and pedestrian rolling gap behaviour at uncontrolled mid-block locations increased the probability of accidents. However, this pedestrian rolling gap behaviour may increase the probability of pedestrian gap acceptance with small gap size. It is believed that the developed models and study findings may be quite useful to the policy makers to regulate pedestrian jaywalking behaviour at uncontrolled mid-block locations. It is our opinion that the developed models perform quite well in mixed traffic condition in developing countries.

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