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SUITABLE ROAD CROSSING FACILITY IDENTIFICATION FOR PEDESTRIANS

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ABSTRACT

Crossing the roads is different from walking on sidewalk or footpath. Cross walking may interact with the moving traffic and these conflicts leads to high risk of accidents and pedestrian safety. The separation is required to reduce such risks, and this can be at-grade or grade-separated. Most conventionally, grade separator is being suitable based on safety requirement which provides complete separation of pedestrians from moving vehicles. However, reluctance of pedestrians in using foot over bridges and subways raise a question about their suitability for pedestrians.

The most common parameters being considered for making a decision regarding identification of suitable road crossing infrastructure, the worldwide guidelines in this regard have been studied. Delay being the most common parameter, needs to be considered to make a decision regarding most suitable crossing facility.

This study proposes a method based on delay to compare suitability of alternate crossing facility. This includes delay caused to pedestrians as well vehicle passengers. To estimate the average delay caused to pedestrians and vehicle passengers, videography data have been collected at three locations in Delhi. This includes a signalized mid-block crossing, foot over bridge crossing and subway road crossing. Delay based methodology minimizes the total delay caused to vehicle passengers and pedestrians. Average delays for pedestrians and vehicles have been estimated using most suitable existing models for Indian traffic conditions and behavior. Using this method existing signal cycles have been modified to minimize the total delay to all users i.e. pedestrians and vehicle users.

1. INTRODUCTION

Cross walking may interact with the moving traffic and these conflicts leads to high risk of accidents and pedestrian safety. To reduce such risks, a separation is required which may be at-grade or grade-separated. Most conventionally, grade separator is being justified based on safety reason as it provides complete separation of pedestrians from the vehicles. However, reluctance of pedestrians in using foot over bridges and subways raise a question about their suitability for pedestrians.

As complete separation of pedestrians from vehicular traffic is not possible, some form of planned road sharing principle must be applied. Being the most vulnerable road user, pedestrian should be given the place and time to legally claim the right to cross the road. Pedestrian crossing are to be provided where they will be well used. Hence, it is necessary to follow certain criteria for establishing the right of pedestrian crossing at a particular location.

Two broad categories of road crossing facilities could be (1) at-grade and (2) grade separated facilities. At-grade pedestrian crossings are those where the pedestrians cross the carriageway at the same level as that of vehicular movement. Grade separated crossings are those where the pedestrians are required to cross the carriageway at the level different from that vehicular movement. Thus, the latter may be in the form of a pedestrian subway or a foot over bridge across the road. further, when movements of pedestrians has been controlled by at-grade designs, automatic signals, users' controlled signals, sensors, etcetera have been categorized as controlled crossings. This may be applied at intersections or at mid-blocks.

The guidelines are available for decision makers to choose the most suitable road crossing facilitites for any location. These have been studied carefully in literature study.

2. LITERATURE REVIEW

Various guidelines have been studied to understand the parameters they have considered in making decision regarding particular road crossing facility among various options. This includes Australian Guidelines (2012), New South Wales Guidelines (1987), Queensland Guidelines (2013 edition), Americans with Disability Act Accessibility Guidelines (ADAAG)(2010), Portland Design Guide (1998), African Guidelines (2004), Georgia Guidelines (2003), Unified Traffic and Transportation Infrastructure (UTTIPEC) Guidelines for Pedestrian Design, New Delhi, India and Indian Road Congress (IRC: 103, 2012)

IRC-103 guidelines classify pedestrian crossings into two broad categories 1) at-grade crossings and 2) grade-separated crossings.

1) At-grade Crossings:

a. pedestrian crossings at intersection: uncontrolled and controlled crossings

b. at-grade away from intersection (e.g. mid-block)

2) Grade Separated Crossings

a. hump subways

b. full subways

c. Foot over bridges (FOB)

Further, it is mentioned that FOB is of least priority since the walking length increases considerably. It is mentioned that control measures at mid-block crossings may be warranted when one of the following conditions exist:

1. The peak hour volume of pedestrian(p)and vehicle(v) are such that $Pv^2>10^8$ For undivided carriageways and $Pv^2>2*10^8$ for divided carriageway
2. Approach speed of vehicles exceeds 65 kmph.
3. Waiting time for pedestrian becomes too long
4. Accident records 5 or more injuries to pedestrian in a year due to collision with vehicles at that time controlled crossing at mid block should be provided.

As per IRC-103 guideline for the grade separated crossing like subway and foot over bridge should be provided when

1. Volumes of pedestrian and vehicular traffic are so large that intersection of an exclusive pedestrian phase will increased the cycle time for traffic signals beyond 120 seconds
2. Vehicular traffic demands uninterrupted flow as associated with major arterial roads and expressways
3. Control at –grade pedestrian crossing decisively fails to mitigate the problems of pedestrian –vehicle collision.
4. Viability of a grade separated pedestrian facility must be checked against delay costs for both pedestrian and vehicle drivers/users including increase in vehicle operating costs inflicted by increased delays.

Studied guidelines have included various parameters in consideration to make a decision regarding suitable road crossing infrastructure at particular location. These parameters are: Delay to pedestrians, Delay to vehicles, Pedestrian volume, Vehicle volume, Age distribution of pedestrians, Availability of safe sight distance and Accidental records. Delay has been observed as the most common parameter considered by various guidelines for comparing alternate designs for road crossing facilities. It is equally important for the passengers traveling by bus, a person in a car or a pedestrian walking/crossing the road. Researchers have developed different models to estimate such delay at signalized intersection. These models can be broadly divided into two categories. 1) Delay caused to vehicles and 2) Delay caused to pedestrians. Table 1 and Table 2 provide the suitability of various delay estimation models for pedestrians and vehicles respectively.

Table 1: Summary of pedestrian delay models and their suitability

Author/s	**Formula**	**Suitability**
Webster's Model(1958), (HCM, 2000)	$D_p=(c-g)^2/2c$ Where, D_p=average pedestrian delay (s/person) C=total cycle length (sec.) G=green time for pedestrian(sec.)	This model assumes a uniform arrival rate of pedestrians and complete signal compliance.
Braun and Roddin (1978)	Dp=f(c-g)2/2c Where, Dp=average pedestrian delay(s/person) C=total cycle length (sec.) G=green time for pedestrian(sec.) F =Fraction of pedestrians who arrives during pedestrian non green phase and comply with traffic signals,	Considers the fraction of pedestrians who arrives during pedestrian non green phase and comply with traffic signals,
Virkler (1998),	Dp=$\frac{(c-(g+0.69A))^2}{2c}$ Where, Dp=average pedestrian delay(s/person) C=total cycle length (sec.) G=green time for pedestrian(sec.) A= Clearance time	Pedestrians walking on amber time are 69 percentage of the number who would be expected to arrive at the curb during these periods if arrivals were random and their delay is 22 percentage lower than those that would be predicted with complete signal compliance
Li et al., (2005)	D=Dg+$\frac{K_{nu}KR^2{}_e}{2C}$ Dg = average pedestrian delay during green phase K_{nu}=Adjustment factor for non-uniform arrival rate Re =effective red time=$(c-(g+0.69A))$ C= cycle time	There is relationship between average pedestrian delay and arrival sub phase,
Vedagiri and Nagraj (2013)	Total delay= Delay during green phase (Dg) + Delay during non-green phase (Dng) Dng=Kc*Knu*$\frac{(C-G)^2}{2C}$, Knu=$\frac{C*(N_t-N_g)}{N_t(C-G)}$, C=total cycle length (sec.) G=green time for pedestrian(sec.) Kc =Factor showing compliance Knu= non uniform arrival rate N_t== total number of pedestrians and N_g=pedestrians arriving during green phase Dg=Ideal time taken to cross- Actual time	Separate delay calculation for green phase and non-green phase, includes factor of compliance

Table 2: Comparison of Vehicle delay methods and criteria

Author(s)	Formula	Suitability
Webster delay When v/c < 1	$UD=\frac{C(1-\frac{g}{c})^2}{2*(1-\frac{v}{s})}$ UD = uniform delay (sec/vehicle) C = cycle length (sec) g/C = ratio of effective green to cycle length v/s = ratio of demand flow rate to saturation flow rate.	This delay model based on the assumption of uniform arrivals and stable flow of vehicle in which there is no signal cycle failure occurs.
Webster random delay When v/c<1	$RD=\frac{X^2}{2V(1-X)}$ D=0.9(UD+RD) UD= as per discussed above RD=random delay per veh (s/veh) X= degree of saturation (v/c ratio)	In this model there is some delay occurs to the vehicle due to random arrival of the vehicle is also calculated
Webster overflow delay method for v/c>1	$TOD=\frac{T^2}{2}(V-C)$ TOD=total overflow delay T =analysis period in sec. V=vehicle arrival rate C=capacity	This delay model based on when the situation occurs the demand flow of the vehicle is greater than the capacity of the road.
Akcelik Delay Model(Australia)	$OD=\frac{CT}{4}((X-1)+\sqrt{(X-1)^2+\frac{12(X-X_0)}{CT}})$ Where, $X>=X_0$ if $X<=X_0$ then overflow delay is zero and $X_0=0.67+\frac{SG}{600}$ T=analysis period X=v/c ratio C=capacity veh/hr. S=saturation flow rate (veh/sg)(veh. Per sec. green) G=effective green time sec.	In this delay model it calculates delay due to acceleration, deceleration and stopped delay of the vehicle due to queuing formation.
Highway Capacity manual 1994 Model	d = d1 X (CF or DF) + d2 $d1=0.38C\frac{(1-\frac{g}{c})^2}{(1-\frac{g}{c}*X)}$ $d_2=173X^2((X-1)+\sqrt{(x-1)^2+\frac{M}{c}X}$	In this model uniform delay calculated by Webster uniform delay method in which minor changes regarding the field observation is added and the another random delay is calculated by keeping in mind the different scenarios like platoon of vehicles, capacity of the road
d=stopped delay per veh. (sec/veh) d_1=uniform stopped delay(sec/veh) d_2= incremental, or random, or stopped delay (sec/veh) DF= delay adjustment factor for quality of progression and control type CF= adjustment factor for control type		

<table>
<tr><td colspan="3">X= volume to capacity ratio of lane group
c= traffic signal cycle length (sec)
C= capacity of lane group (veh/h)
G= effective green time for lane group (sec)
M= an incremental delay calibration term</td></tr>
<tr><td>Highway Capacity manual 2000 model</td><td>d = d1 X PF + d2 + d3
$d_1=0.5C\frac{(1-\frac{g}{c})^2}{(1-\min(1,X)\frac{g}{c})}$
$d_2=900T((X-1)+\sqrt{(X-1)^2+\frac{8KlX}{cT}}$
$PF=\frac{(1-P)f_p}{(1-\frac{g}{c})}$</td><td>This model is develop after earlier one in this the uniform delay calculated by the Webster uniform delay method and one progression factor added by which exact delay we can calculate and the second delay D_2 is developed formula of the Akcelik model and the third criteria D_3 is the initial queue delay.</td></tr>
<tr><td colspan="3">d = control delay per vehicle (sec/veh)
d1 = uniform delay (sec/veh)
d2 = incremental, or random delay (sec/veh)
d3 = residual demand delay to account for over saturation queues that may have existed before the analysis period (sec/veh)
PF = adjustment factor for the effect of the quality of progression in coordinated system.
k = incremental delay factor dependent on signal controller setting (0.50 for pretimed signals; vary from 0.04 to 0.50 for actuated controllers)
I = upstream filtering/metering adjustment factor (1.0 for an isolated intersection)
T = analysis period (hours)
P = proportion of vehicles arriving during the green interval
fPA = supplemental adjustment factor for platoon arriving during the green</td></tr>
</table>

3. NEED FOR THE STUDY AND OBJECTIVE

The Guidelines given by different countries provide information regarding the parameters they have considered in making decision regarding road crossing facilities. It has been observed that delay of pedestrians as well as vehicle remains a most common parameter. However, there is no specific method for estimating such delay has been covered in guidelines which may otherwise lead to common decision making process.

There is a need to compare various existing models for estimating delay for pedestrians as well as vehicles. Based on the most suitable model for delay estimation a methodology needs to be developed for making decision regarding choice of road crossing infrastructure.

According to the need realized, objective of this study is:

- To develop a delay based methodology to identify the most sustainable road crossing facility for any location
- To compare various scenarios based on vehicle delay, pedestrian delay, vehicle-passenger delay and with/without priority for non-motorized and public transport users.

Scope of the study is limited to three existing locations. First location is a signalized mid-block crossing, second location is a Foot over bridge road crossing and third location is a subway crossing.

4. METHODOLOGY

A broad methodology has been presented in Figure 1 through flow chart. As presented, all existing data/information regarding classified traffic volume count, pedestrian volume, signal cycle details and road width has been collected for selected three locations during peak hours for 2 hours duration. For observed vehicle and pedestrian flow, average delay has been estimated using HCM 2000 method and Vedagiri Method (2013) for vehicles and pedestrians respectively. Considering the average occupancy of various types of vehicles; total vehicle passenger delay and total pedestrian delay has been calculated. Gross delay (vehicle passenger delay + pedestrian delay) has been minimized for three scenarios to obtain the most suitable road crossing facility. These scenarios have been developed based on consideration of vehicle occupancy and higher priority for non-motorised vehicles and public transport vehicles. This means if based on policy, higher priority has to be given to non-motorised transport and public transport users; higher weightage to the delay caused to such users needs to be given i.e. weightage of a person waiting in car at siganlised intersection would be lower than a person waiting in a public transport vehicle or on a cycle.

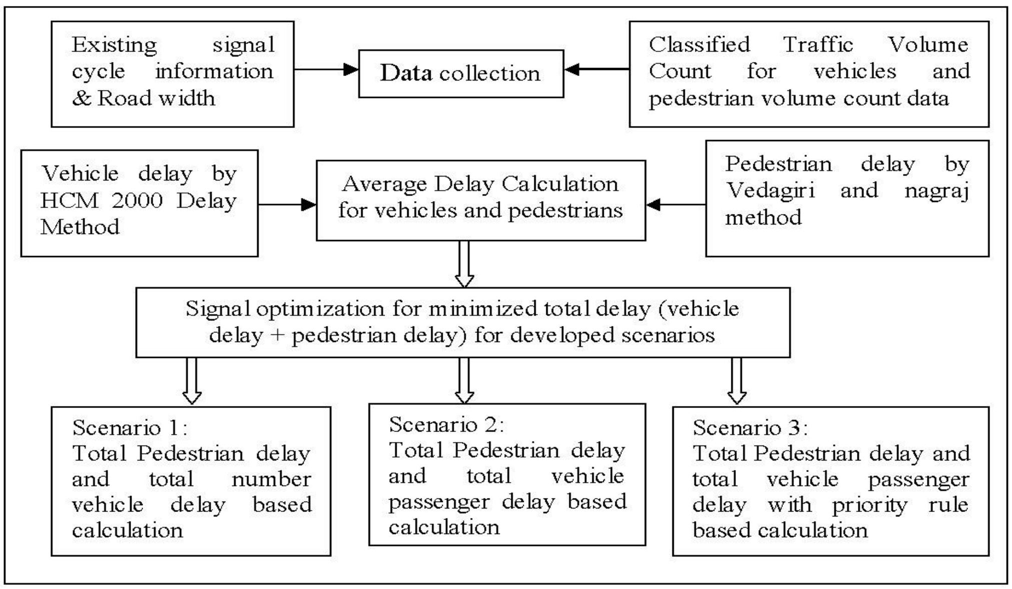

Figure 1: Concept Methodology

5. DATA COLLECTION AND EXTRACTION:

Three locations for the study have been selected based on variety in existing road crossing facilities (signalized crossing, Foot Over Bridge and Subway) are shown in Figure 2. These are: Harkesh nagar (signalized mid-block), Maharani Bagh (Foot Over Bridge) and Andrews Ganj (Subway). All three locations are on major arterial roads of Delhi. These roads are 6 lane divided roads. Existing single cycle has been observed and noted for the first location.

Figure 2: Locations selected for the study

The data have been collected for 2 hours duration during the evening peak time at all three locations. Data collection includes bi-directional vehicle flow captured through videography keeping at required height to cover marked trap length. Two cameras have been positioned so that it can capture the vehicle flow for marked trap length of 20 meters in each direction. Pedestrian data have been collected manually on-site simultaneously by videography. For pedestrians, time required to cross the road has been observed using stop-watch at all three locations by random sampling method during each signal cycle. The data have been extracted for classified traffic volume counts and also for space mean speed through timestamp at two reference lines of trap length.

6. DESCRIPTIVE ANALYSIS:

Observed classified traffic volume count and pedestrians' volume count at all three locations have been presented in Table 3 below:

Table 3: Classified Traffic Volume Count at selected locations

Location	Direction	Car	Motorized 2w	Mini bus	Bus	LCV	Truck	Cycle rickshaw	Bicycle	Auto	Pedestrians
Harkesh nagar	Inwards	4659	3290	34	223	194	180	67	122	815	830
	Outwards	5163	3095	39	338	125	110	70	78	734	
Maharani bagh	Inwards	4942	3847	14	335	25	43	16	46	961	2072
	Outwards	4248	2592	22	479	25	35	14	34	1297	
Andrews ganj	Inwards	5365	3811	26	487	22	41	20	16	1534	2275
	Outwards	5098	3133	22	411	38	43	41	49	1400	

It can be observed from Table 3 that apart from truck traffic, all vehicular traffic is almost in same range at all three locations.However, pedestrian traffic at location 1 signalised mid-block crossing is low compared to other two locations where grade separated facility has been provided. Table 4 provides the information of speed of various types of vehicles. It has been observed that mean and standard deviation of speed is nearly the same each vehicle type at all three locations.

Table 4: Speed characteristics at selected three locations

Location	Direction	Speed characteristics	Car	Motorized 2w	Mini bus	Bus	LCV	Truck	Cycle rickshaw	Cycle	3w auto
Harkesh nagar	Inwards	Mean	42.66	43.23	31.55	31.12	30.69	29.25	16.21	16.04	32.31
		Std. Dev.	9.43	9.09	2.38	4.42	4.38	1.93	2.22	1.92	7.09
	Outwards	Mean	46.83	44.57	29.19	29.79	29.10	28.82	17.77	18.58	29.98
		Std. Dev.	8.23	8.34	2.95	5.09	3.98	2.61	2.27	2.46	6.36
Mahara-ni bagh	Inwards	Mean	38.58	41.36	30.22	29.41	29.37	29.47	45.92	14.30	31.73
		Std. Dev.	10.14	9.81	3.17	4.82	2.09	2.78	5.56	2.64	6.71
	Outwards	Mean	39.47	40.01	28.21	31.31	32.78	29.05	13.68	14.32	34.95
		Std. Dev.	10.09	9.74	3.31	6.94	7.969	2.77	1.84	4.34	8.59
Andre-ws ganj	Inwards	Mean	37.28	38.79	29.01	29.31	28.83	28.60	13.13	15.49	33.40
		Std. Dev.	9.99	9.52	2.54	4.80	2.583	5.89	1.39	5.14	7.71
	Outwards	Mean	40.79	39.97	28.89	29.96	31.8	29.67	15.75	20.53	35.74
		Std. Dev.	8.22	8.34	2.95	5.09	3.98	2.61	2.27	2.46	6.36

*** LCV=light commercial vehicles, Truck= truck, multi axle vehicle cranes**

Average pedestrian crossing time at all three locations has been collected on site. Summary of this has been shown in Table 5: Pedestrian crossing time at selected locations below:

Table 5: Pedestrian crossing time at selected locations

	Location1: At grade mid-block crossing	Location 2: Foot over bridge	Location 3: subway
Pedestrian average crossing time(sec)	**20**	**89**	**63**
Standard Deviation	**0.00018**	**0.000381**	**0.000267**

At location 1, at-grade crossing time is observed. At location 2 & 3, time required to on stairs including walking is considered as value for standard deviation is almost zero, it can be said that all pedestrians took same time to cross irrespective of gender and age.

7. MINIMIZING GROSS DELAY

As presented in methodology, to identify the most suitable road crossing facility (at grade/grade separated), minimization of gross delay (total delay of pedestrians plus total delay of vehicles) has been performed to obtain optimized signal cycle. Detailed methodology for optimization has been shown in Figure 3. This optimal signal cycle would be later on compared with the grade-separator alternatives in terms of delay for vehicles as well as pedestrians.

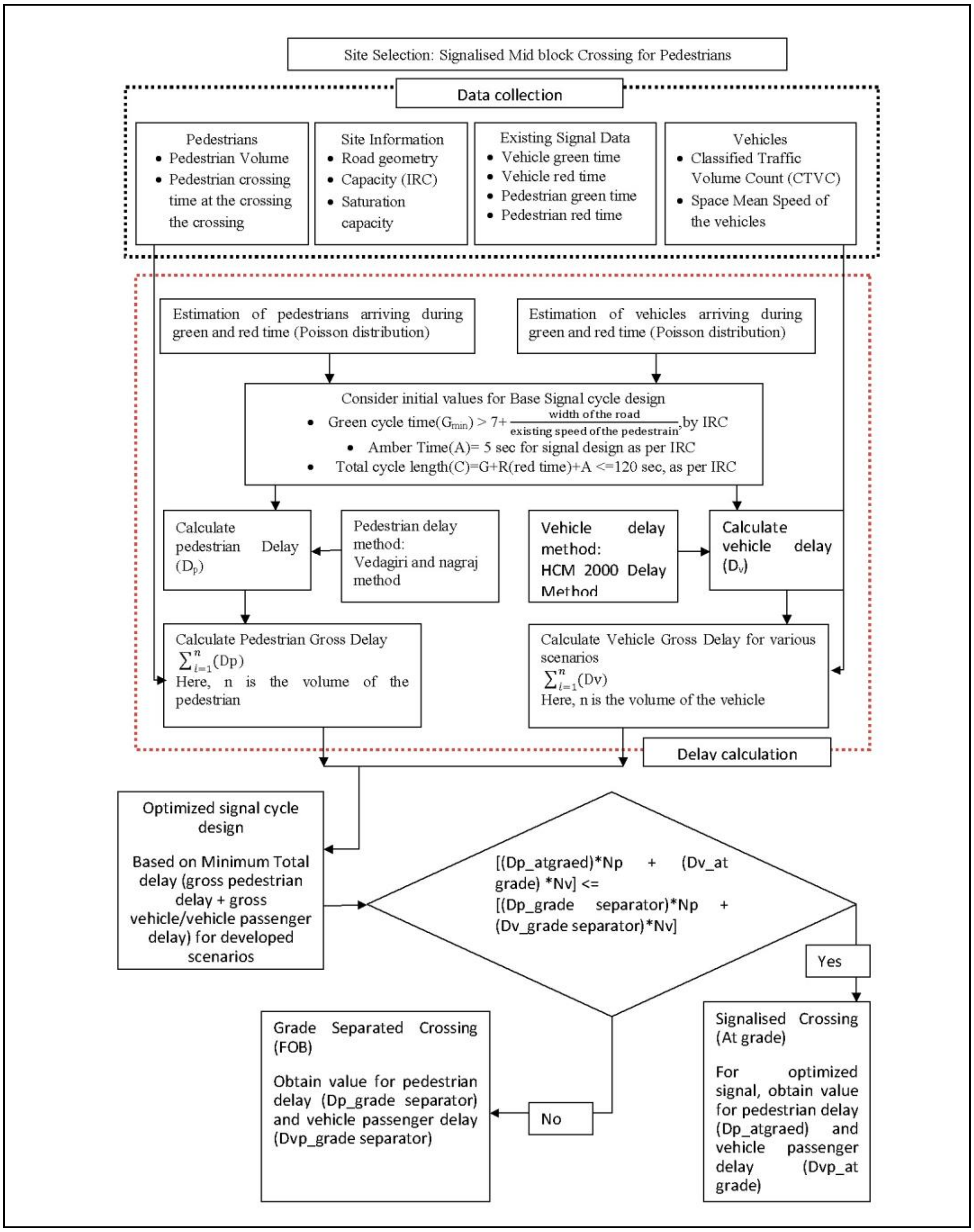

Figure 3: Methodology for minimizing gross delay

As shown in methodology, HCM (2000) method and Vedagiri (2013) method have been found most suitable (Prajapati at. el., 2015) to estimate the vehicle delay and pedestrian delay respectively at signalized intersection. Accordingly, delay has been estimated for selected locations.

As shown in methodology, a signal cycle needs to be designed so that gross delay of vehicle/vehicle passengers and pedestrians is minimized. Theoretically, to identify the values for optimized signal cycle; a log-log graph has been plotted for vehicle passenger delay and pedestrians' delay for signal cycle ranging from 30 seconds to 300 seconds at interval of 10 seconds as shown in Figure 4. The point of conflict shows optimized signal cycle.

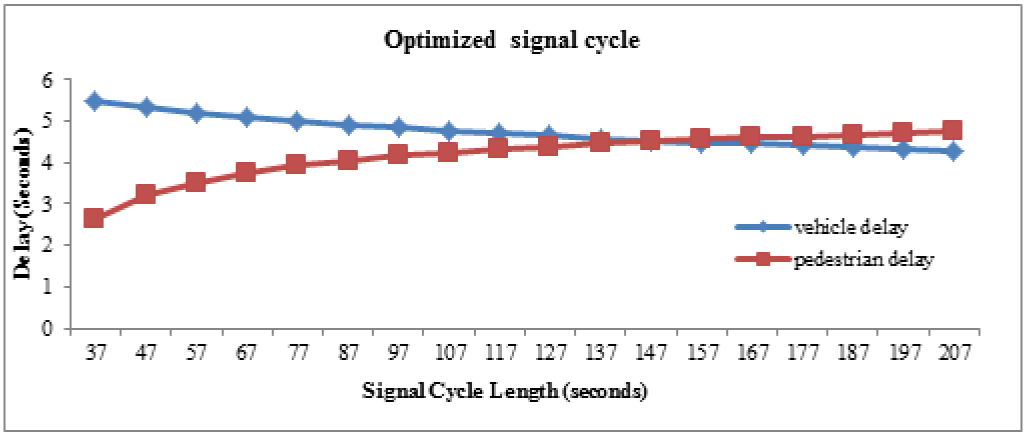

Figure 4: Theory for obtaining optimal signal cycle theory

This has been performed for the interval of 10 seconds, however, needs more accuracy by reducing the interval size. Therefore, these iterations have been performed in SOLVER. To obtain optimized signal cycle; iterations have been made by changing the red and green time of the signal with the constraints of minimum pedestrian green time are equal to road crossing time (road width/average pedestrian speed) and setting target of minimizing gross delay.

8. DELAY CALCULATION FOR GRADE-SEPARATOR CONDITIONS

For measuring pedestrian delay for grade separated crossing facility, HCM (2000) method has been used. This defines delay as the additional travel time experienced by a driver, passenger or pedestrian due to circumstances that impede the desirable movement of traffic. It is measured as the time difference between actual travel time and free-flow travel time. Accordingly, pedestrians' base crossing time is the time taken by the pedestrian to cross the whole stretch of the road at their ideal/comfortable speed and there is no influence of the traffic on the road. Pedestrians' crossing time at FOB and subway has been measured on site itself for the sample of 100 pedestrians at each location i.e. location 2 and 3. Based on this method and collected data regarding crossing time, delay at location 2 (FOB) and 3 (subway) has been calculated by the difference of crossing time on FOB/subway and base crossing time for existing scenario. Vehicle delay in case of grade-seperator is taken as zero. This has been used for comparison with other scenarios developed in this study.

9. RESULTS

At location 1, signalized mid-block crossings; signal cycle has been redesigned to minimize gross delay i.e. designing a signal cycle to minimize total delay of vehicle (vehicle passengers) and pedestrians. To obtain optimized signal cycle; iterations have been made by changing the red and green time of the signal with the constraints of minimum pedestrian green time are equal to road crossing time (road width/average pedestrian speed) and setting target of minimizing gross delay. These iterations have been carried out in SOLVER. Similarly for location 2 and 3, optimized signal have been designed to compare existing situation (grade separated) with alternate (at-grade) road crossing facilities.

Further, for minimizing gross delay time; all commuters (pedestrians, personalized vehicle users and public transport users) have been weighted equally. However, scenarios have been developed for including vehicle occupancy and giving higher weightage to the non-motorised transport users and public transport users.

Scenario 1: Number of vehicles and pedestrians for delay calculation

Scenario 2: Number of passengers in vehicle and pedestrians for delay calculation (based on assumed average occupancy)

Scenario 3: Higher priority for non-motorised transport and public transport users (by assigning higher weighatage see Table 6)

Table 6 shows the priority weightages assigned to various vehicle types. These have been assigned based on policy of promoting non-motorised transport and public transport vehicles compared to personalized vehicles.

Table 6: Vehicle priority weightages for various vehicle types (to be considered in scenario 3)

vehicle category	Car	Motorized two wheeler	Mini bus	Bus	LCV	Truck	Cycle rickshaw	Cycle	Three wheeled auto rickshaw
Priority weightage	1	1	2	2	1	1	2	2	1.5

Table 7 compares the vehicle delay and pedestrian delay for the existing and proposed signal cycles at location 1 for scenario 1, 2 and 3. Similarly, Table 8 shows for location 2 and 3.

Table 7: Delay comparison at location 1for existing and proposed signal cycle for developed scenarios

Time/delay (seconds)	Existing signal design			Proposed signal design		
	Scenario1	Scenario2	Scenario3	Scenario1	Scenario2	Scenario3
Vehicle green time	124	124	124	70	118	109
Vehicle red time	21	21	21	21	21	21
Vehicle amber time	5	5	5	5	5	5
Average Vehicle delay	5.706	5.706	5.706	7.597 (+33.14%)	5.86 (+2.69%)	6.136 (+7.53%)
Average Pedestrian delay	47.712	47.712	47.708	23.079 (-51.63%)	44.99 (-5.71%)	40.483 (-15.14%)
Total veh delay (sec)	9479.6	29999	49545	19634 (+107.12%)	32037 (+6.79%)	59244 (+19.57%)
Total ped delay (sec)	34057	34057	68108	14984 (-56%)	31905 (-6.31%)	56721 (-16.72%)
Gross delay (sec)	43537	64056	117562	34618 (-20%)	63941 (-0.18%)	115965 (-1.35%)

Gross delay is reduced in all three scenarios at location 1. However, average vehicle delay is increased in all three scenarios. Interestingly, average increase in vehicle delay for scenario 2 and 3 is very less (<1 second) and this has resulted significant decrease of average pedestrian delay (3 to 7 seconds) in scenario 2 and 3 respectively. This indicates that the minor increase in average vehicle delay can improve pedestrian crossing facilities including higher priority to non-motorised and public transport users. Though gross delay does not major saving in delay, pedestrians, non-motorised and public transport users are benefitted.

Similarly, delay calculations have been done for location 2 and 3 as shown in Table 8 where FOB or subway exists for pedestrian road crossings. Based on traffic volume and pedestrian volume, signal has been designed and delay has been calculated for both the scenarios. As shown in Table 8,

Table 8: Delay comparison at location 2&3 for existing and proposed signal cycle for developed scenarios

Time/delay (seconds)	Andrew ganj			existing scenario	Maharani bagh			existing scenario
	Scenario1	Scenario2	Scenario3		Scenario1	Scenario2	Scenario3	
Vehicle green time	49	104	98	0	48	90	84	0
Vehicle red time	21	21	21	0	21	21	21	0
Vehicle amber time	5	5	5	0	5	5	5	0
Average Vehicle delay	10.48	80.083	8.275	0	9.455	7.333	7.573	0
Average Pedestrian delay	13.986	38.453	35.772	67	13.479	32.014	29.213	69
Total veh delay (sec)	41145	85403	162199	0	34114	64050	119885	0
Total ped delay (sec)	22906 (-84.97)	73380 (-51.85)	135312 (-11.23)	152425	19972 (-86.03)	54359 (-61.98)	97983 (-31.46)	142968
Total delay	64051 (+57.98)	1587783 (-4.17)	297510 (-95.18)	152425	54086 (+62.16)	118404 (+17.18)	217869 (-52.39)	142968

Results shown in Table 8 indicates increase in average vehicle delay as well as total vehicle delay results also indicates decrease in average pedestrian delay as well as total pedestrian delay for all three scenarios and for both the locations. However, gross delay (total vehicle delay plus total pedestrian delay) shows reduction in case of scenario 3 i.e. in case, higher priority is given to non-motorised transport and public transport users, existing facility of grade separator needs to be converted into signalized crossing faculties.

10. CONCLUDING REMARKS:

The various guidelines available worldwide considers delay as the most important parameter in making choice among alternate road crossing facilities. IRC-103 also considers delay of vehicle as well as pedestrians important in design of road crossing facilities. This study develops a methodology based on delay to compare various road crossing facility alternatives.

Study has been carried out at three locations of Delhi at three locations have been compared for three scenarios based on number of vehicles, number of vehicle passengers and higher priority for the passengers travelling by public transport and non-motorised transport. For all developed scenarios, average and total pedestrian delay as well as vehicle delay has been calculated and a signal cycle has been designed to minimize the gross delay.

Results shows that at location 1, an increase of 1 second for vehicle can reduce 7 seconds of decrease with proposed signal cycle. At location 2 and 3, if higher priority for non-motorised and public transport users is considered, signalized at-grade crossing is proposed for given traffic volume and composition.

This study proposes a methodology which can be applied to any location. However, present data collection is based on one city and therefore results are for specific traffic composition. However, with minor modifications, model can be transferred to any location.

Future scope of the study includes consideration of wider range of traffic composition to develop ready-to-use charts for optimal signal cycle for specific traffic volume and pedestrian volumes.

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