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Pedestrian Modeling at Multi Modal Junction: A Case Study

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Abstract : *Traffic is the major problem in all the metropolitan cities. Due to increase in traffic, pedestrians are facing the problem of crossing the roads and intersections. More focus is given on vehicular traffic while designing transport facilities and less focus is given to the pedestrian facilities. Jedhe Intersection being a major intersection in Swargate, Pune is facing such a problem. It is a four – legged signalized intersection and also a multi modal junction. A reconnaissance survey and road inventory survey are performed to determine geometry of existing intersection. Micro simulation software like, PTV Viswalk, PTV Vissim and Pedestrian Dynamics are studied and comparison is carried out between above software based on various parameters such as use, inputs, outputs, user interface and suitability, etc. PTV Vissim is selected as the best alternatives for this study. A new signal is designed by Webster's Method with additional pedestrian phase considering safety of pedestrians. Base model and newly designed signal model are the two models developed in Vissim. The most efficient solution for improving pedestrian safety and convenience at the intersection is provision of skywalk (from Hanuman Temple to Swargate Traffic police Station). If it is not economically feasible then traffic signal with separate pedestrian phase can be provided.*

Keywords:*Pedestrian, pedestrian modeling, multimodal junction, simulation*

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I. Introduction

In Pune, safety of pedestrians is a matter of concern. In first 6 months of 2017 alone almost 594 accidents were recorded by the Pune Police Commissionerate. Traffic on roads is heavy and walking on road is a challenge for pedestrians. Even though pedestrians represent the largest single road user group, the modern city has not been designed keeping pedestrian safety in mind. This is evident from pedestrian-vehicle crashes worldwide.

Pedestrians make up an important group in the transport system, but their role in traffic planning is often neglected. The aim of this study is to analyze the utility and possibilities for integration of pedestrians in microscopic traffic simulation.

1.1 Objectives of this study

1. To carry out pedestrian flow and traffic survey at Jedhe intersection (Swargate)
2. To do comparative study of different software available for pedestrian modeling and selecting the suitable software
3. To develop pedestrian modeling in software
4. To propose efficient solution for pedestrian safety

II. Case Study Area

Swargate is one of the busiest areas in Pune city. It has roads leading to various areas like Hadapsar, Fursungi, Dhankawadi, Bibwewadi. Major intersection in Swargate is Jedhe intersection which connects various areas viz. Sarasbaug, Hadapsar, Tilak road, Shivaji road and has an SH 114 (Pune- Satara SH) passing through it. Jedhe intersection has a Major bus terminus for Pune. It serves as PMPML terminal for Katraj to Swargate and Hadapsar to Hadapsar bus routes located at Jedhe intersection. Swargate metro Terminal is also proposed at Jedhe intersection. Auto Rickshaw stand is also located here. Fig. 1 shown below shows the study area and the use of Jedhe intersection area by different modes of public and private transport.

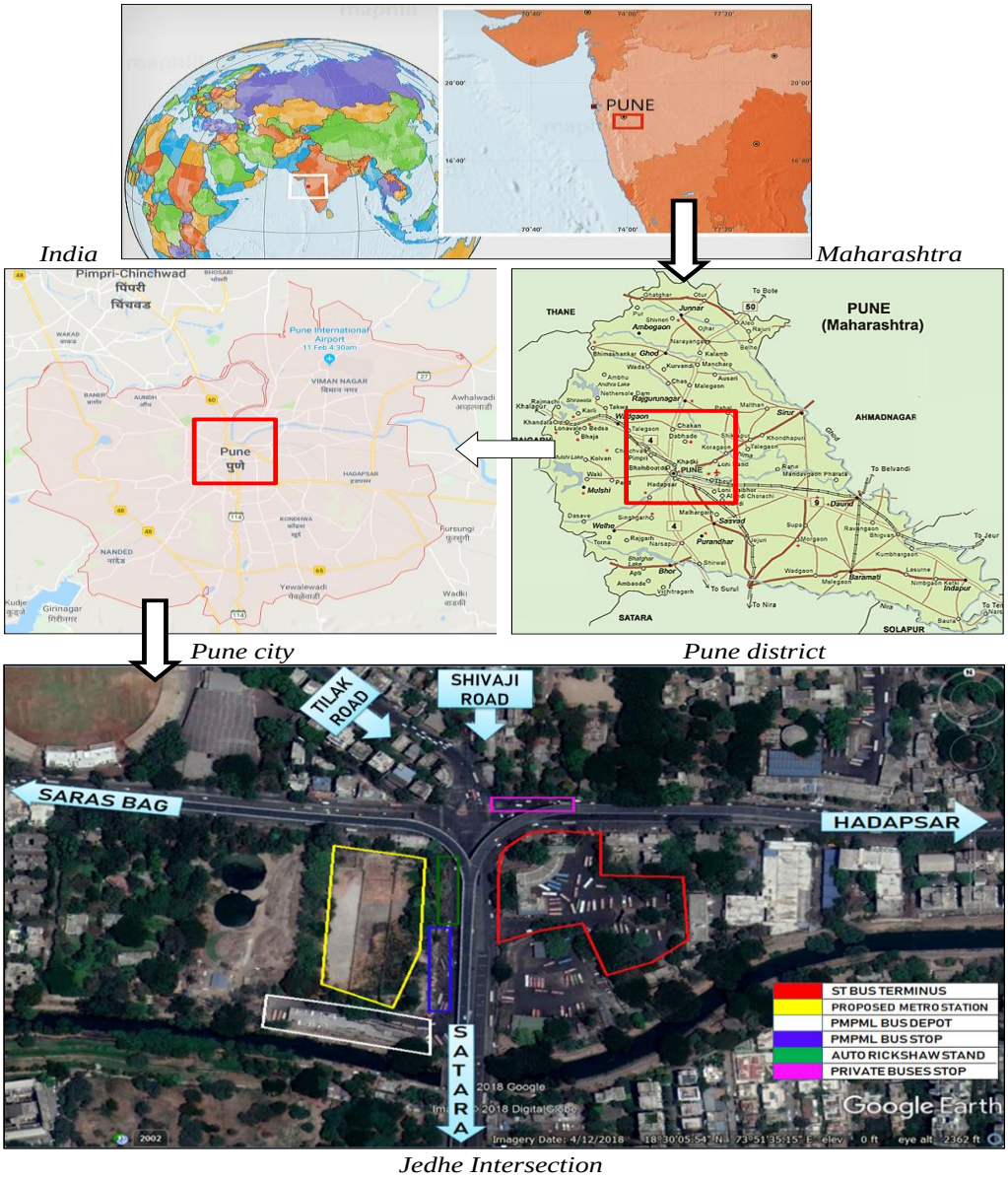


Fig. 1: Study Area

III. Data Collection and Extraction

3.1 Road Inventory Survey

The Road Inventory survey was carried out to measure the various road features like road characteristics and road dimensions which include width & height of footpath, width of carriageway, median, width of shoulders, traffic islands dimensions, height of underpass, width of underpass, embankment height, pedestrian crossing and type of pavement, height of flyover, entry and exit dimensions of ST bus terminus, PMPML bus depot, etc. Metallic tap and EDM were used for measuring dimensions.

Table 1: Road dimensions

Sr. No.	Road Characteristics	Dimensions (m)
1	Width of main road (Dual carriageway)	22 to 34
2	Width of Tilak road (Single carriageway)	9.5 to 10
3	Width of Shivaji road (Single carriageway)	15.5 to 16
4	Width of footpath	1.1 to 3
5	Width of median	7

Table 2: Entry/Exit gates description

Sr. No.	Description	Dimensions (m)
1	ST bus terminus Entry	22
2	ST bus terminus Exit	12
3	PMPML bus depot entry/exit	14

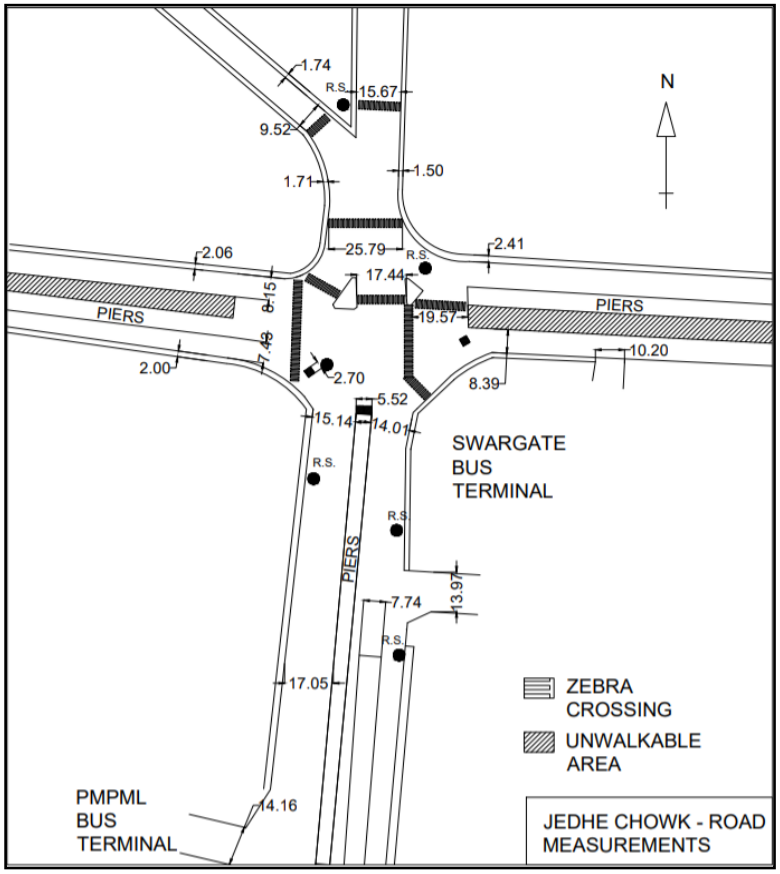


Fig. 2: AutoCAD drawing of Jedhe Intersection

3.2 Questionnaire Survey

The questionnaire survey was carried out on 12th November 2018. In this survey, the pedestrians, vehicle drivers and nearby shop owners were selected at random and questions related to accidents, safety, serviceability, traffic signals, regulations at intersection were asked and their responses were recorded.

3.3 Traffic volume and Pedestrian count Survey

Videography survey was carried out for 4 days for three time slots viz. morning, afternoon, evening. The vehicular & pedestrian count has been recorded for all the legs of the intersection. The cameras were setup on traffic police surveillance tower with prior permission of traffic department. Three cameras were placed pointing at three different directions such that it covered all the required area of Jedhe intersection.

The given points brief us about the real time conditions and problems seen at the site. The discussions below are based on visual observations seen during the survey:

1. At Jedhe intersection, pedestrians face problem of crossing the road since there is interference with vehicles. Hence there is need of developing this intersection as a pedestrian friendly one.
2. The road connecting SarasBaug and Hadapsar is of rigid pavement type while rest all are flexible pavements. Footpaths are provided almost along all roads but their dimensions are different along each road. Some footpaths are not suitable for walking.
3. Pedestrian signals are not provided in Jedhe intersection, so there is need of proper signal synchronization for traffic and pedestrians as well.
4. Simulating software need to be used for pedestrian and traffic simulation, to have the advanced ideas about the user's characteristics. By comparing the different software, PTV Vissim is found more suitable & user friendly for simulation.
5. Traffic police are required to be deployed near Swargate bus stop to regulate traffic and hawkers have encroached the roads and footpaths which cause disturbance to traffic and pedestrian flow.

Pedestrian count and vehicle count in each direction was carried out from videography survey. From the data maximum pedestrian count was observed on 15th Nov. 2018 as 953 per hour. From the data maximum vehicle count was observed on 17th Nov 2018 of vehicles from Shivaji Road to Satara as 3028 PCU per hour.

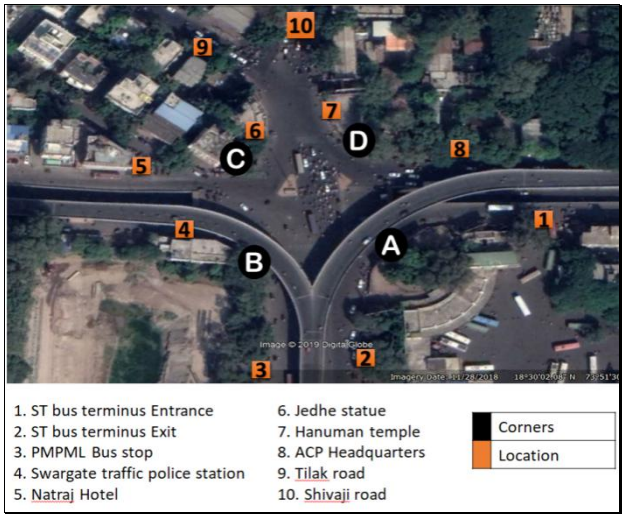


Fig. 3: Locations considered for Pedestrian Count

IV. Existing Traffic Signal at The Intersection

The Fig. 4 and 5 show the phases and signal timing for each phase respectively, which was observed during data collection surveys.

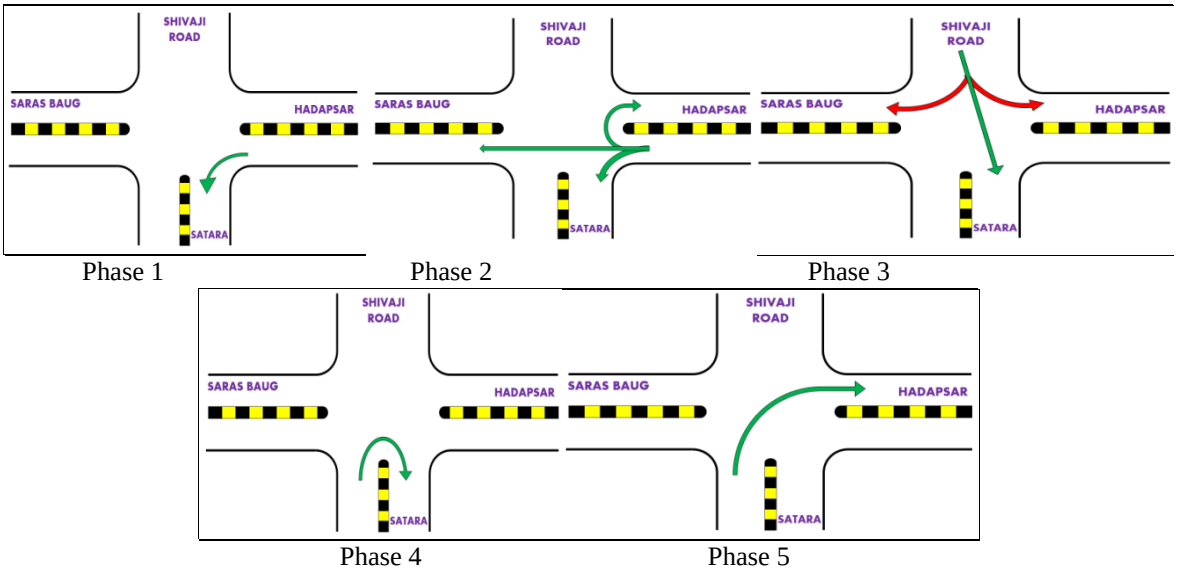


Fig. 4: Types of phases on the Intersection

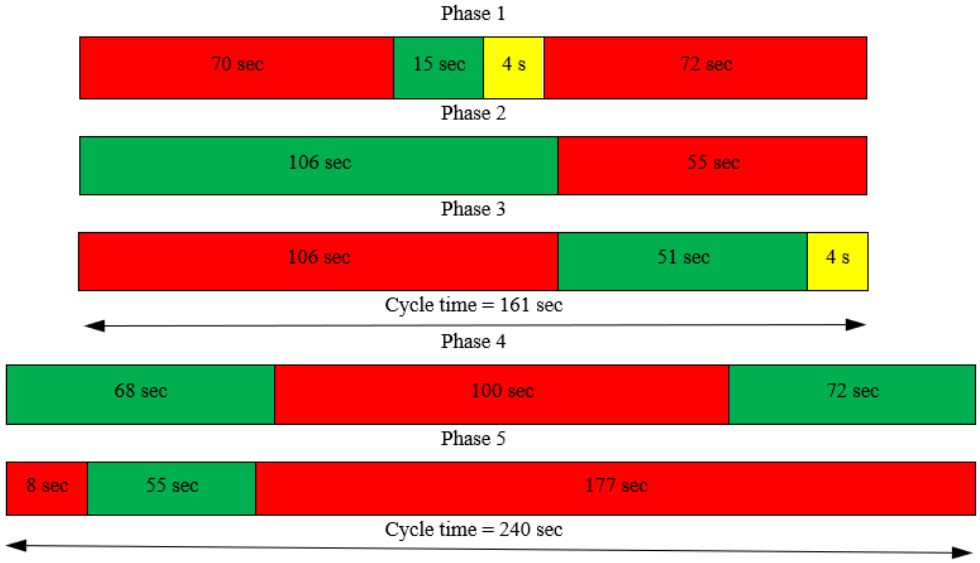


Fig. 5: Current phase diagram for each phase

V. New Signal Design andLOS Calculations

There are several types of vehicles available on roads like cars, trucks, trailers, motorbikes. Their impact on traffic-flow is also varies due to variation in their sizes, shapes and speeds. It is very difficult to deal with such types of vehicles from the design and engineering point of view. Therefore, a standard vehicle unit has been defined known as Passenger Car Unit, PCU. There is a set of PCU values according to IRC: 106-1990 for urban roads. Based on the type of road the PCU values are worked out. After conversion of collected data into PCU/hr, the 7 days average PCU/hr value is obtained by taking maximum values of PCU/hr for 2 hours on the day of maximum traffic i.e. (17^{th} Nov 2018, 05:00-07:00PM). The peak value obtained is used for design consideration as it satisfies for all the condition.

As per IRC guidelines, 160 PCU per 0.3 metre is considered as saturation flow value. So, saturation flow value is calculated as 13754.66 PCU/hr for maximum road width of 25.79 m.

Currently, there is signalized intersection in Jedhe Chowk. It is designed to serve only the management of traffic and no pedestrian phase is included in its signal. Thus, by considering the same movements, signal design is carried out by Webster's Method and a pedestrian phase was included in it. To avoid extension of cycle time due to pedestrian signal, pedestrian phase is allotted such that the turning movements of vehicles do not affect pedestrian crossing.

Following are the data considered for signal re-designing:

Lost time per phase (L) = 2 seconds

Amber time = 4 seconds per phase

Cycle length, $C_0 = \frac{1.5L+5}{1-Y}$

Effective green time, $G_i = (C_0 - L)$

Green splitting time for each phase, $g = \frac{y_1}{Y}(C_0 - L)$

Actual green time, G = g – Amber time + L

Pedestrian signal time, $G_p = t_s + \frac{dx}{up}$

Where, t_s= Start – up loss time = 4.7 Second (Assumed)

u_p = Pedestrian walking speed = 1.2 m/s (Assumed)

d_x = longest distance to be travelled by a pedestrian at the intersection = 61m

Fig. 6: Improved Phase Diagram for each phase

LOS Calculation:
Pedestrian delay is calculated as per HCM 2000. The average delay per pedestrian for a crosswalk is given by,

$$dp = \frac{0.5(C - g)^2}{C}$$

Where,
dp = average pedestrian delay (s)
g = effective green time (for pedestrians) (s)
and C = cycle length(s)
LOS criteria for pedestrians at signalized intersections (as per HCM 2000) based on pedestrian delay

Table 3: LOS criteria for pedestrians

LOS	Pedestrian Delay (s/p)	Likelihood of Noncompliance
A	< 10	Low
B	≥ 10-20	Moderate
C	> 20-30	
D	> 30-40	
E	> 40-60	High
F	> 60	Very High

After designing new signals with consideration of pedestrian safety, LOS of intersection has improved from F to B for pedestrian.

VI. Microscopic Simulation, Calibration andValidation

VISSIM is a microscopic simulation software which is used to analyze and optimize traffic flow. This software provides variety of applications for urban roads and expressways for complex heterogeneous traffic flow. The base model is prepared in the software by giving all the input parameters as per Vissim 6 User Manual.

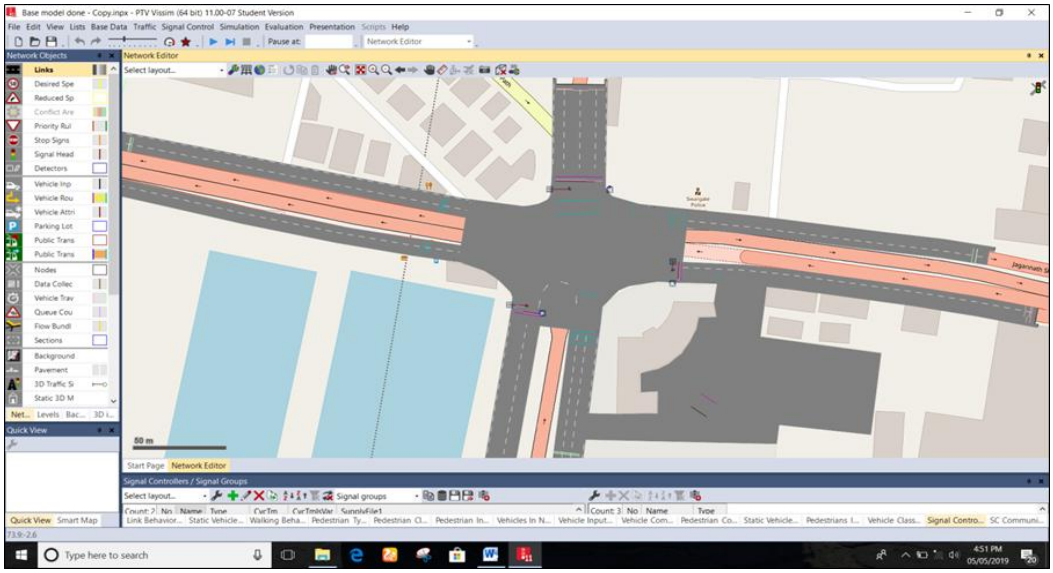


Fig. 7: Base model in VISSIM 11

6.1 Calibration & Validation of model:

Calibration is a process of evaluating the delays by the evaluation of effective traffic management. The observed data on field is used as an input for creating a base model. The input parameters are given as an input to simulation model and simulation runs are carried out to estimate the output. Validation is a process of comparing the behavior of a model with the actual field condition trial and error method is used for calibration & validation.

Base model is validated for delay time, travel time, queue length and volume. To obtain the delay and travel time required by the vehicle Speed and delay survey was carried out. From the survey queue length was found out, where the queue length was calculated manually using measurement tape. From this process model's similarity with the actual site is checked in terms with the three parameters stated above. Once the values obtained are permissible, then the base model is validated.

6.2 Results of Validation:

MAPE (Mean Absolute Percentage Error) is found out by trial and error method. The values for MAPE are observed on the random seed no. 8, 16, and 32. Also the trial and error method are carried out till the errors in field measured and simulated travel time is observed to be less than 20%as shown in TABLE 4.

Table 4: Travel Time Errors for Validated Model

Sr. No.	Direction	Distance (m)	Average Travel Time Observed Values	Average Travel Time of Simulated Value	Error
1	A – D	46	59	48.521	18.64%
2	B – A	45	47	38.621	19.14%
3	D – B	67	57	56.189	1.754%
4	C – B	40	34	34.919	-2.7%
5	A – C	61	59	50.833	13.84%
6	D – C	40	28	25.952	7.134

VII. Results

To control the increasing traffic problem at Jedhe Chowk, we have proposed two solutions.

7.1 Design of new signal and replacing with old signals

This intersection is a signalized intersection and but is controlled by the traffic police. Thus, it was decided to design new signals for the current traffic flow. The signal is designed for the highest volume of flow for peak hour of pedestrian movement and vehicle movement respectively. The newly designed signal is a pedestrian phase signal, designed by Webster method. The total signal cycle time is 125 seconds. This newly designed signal timings were entered in the software and the model was developed.

LOS criteria for pedestrians at signalized intersections, as per HCM 2000, is checked by calculating pedestrian delay for current traffic signal and for newly designed traffic signal. LOS was found to change from F to B after provision of pedestrian phase.

7.2 Provision of Skywalk

As there exists already a vehicle underpass at the intersection, providing a skywalk can be the solution. It is feasible to construct a skywalk along the direction which has maximum pedestrian flow and also at a point where by using the skywalk pedestrians can have more safety and can cover more distance in less time by using the skywalk. Diagonal path at the intersection from Hanuman Temple to Swargate Traffic Police Station is suitable for provision of skywalk.

Advantages of providing diagonal skywalk:

- ❖ Maximum travel time is recorded when pedestrian cross the intersection diagonally, due to interference of vehicles. Provision of skywalk will reduce travel time of pedestrian crossing the intersection.
- ❖ Safety of pedestrian will increase as there will be minimum interaction with vehicles
- ❖ Useful for pedestrian using PMPML bus service as well as it can be used in future by pedestrian entering and leaving Swargate Metro Station

7.3 Before – after analysis

a) Connector Links Results

The tables below depict the before after analysis of existing field condition along with proposed solution on simulation software.

Table 5: Summary of Before – After analysis

Road name	Before improvement				After improvement			
	Volume (ped/hr)	Relative delay (%)	Density (ped/km)	Speed (km/hr)	Volume (ped/hr)	Relative delay (%)	Density (ped/km)	Speed (km/hr)
A – B	89.647	0.00	16.898	5.305	22.50	0.00	4.381	5.135
A – D	240.00	44.19	89.778	2.673	152.85	15.04	40.051	3.816
C – B	322.50	1.09	66.377	4.859	127.50	0.00	26.679	4.779
B – D	112.70	76.99	99.374	1.134	62.282	80.80	66.862	0.932

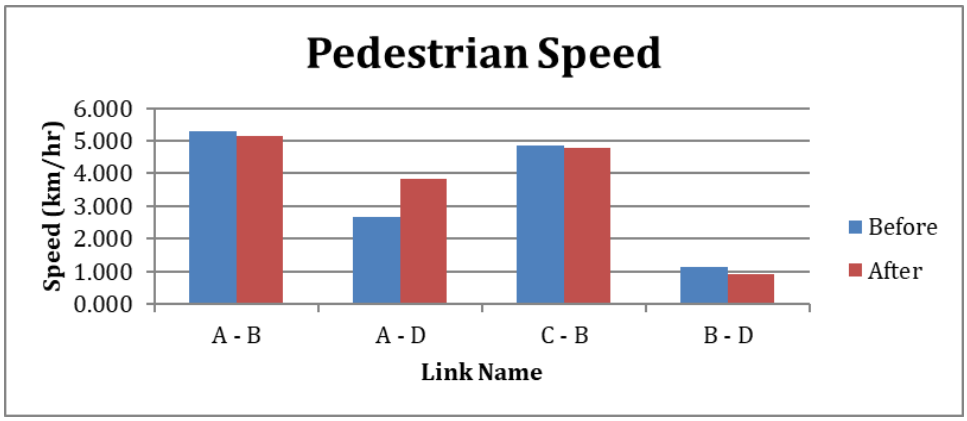


Fig. 8: Graph of pedestrian speed at different links

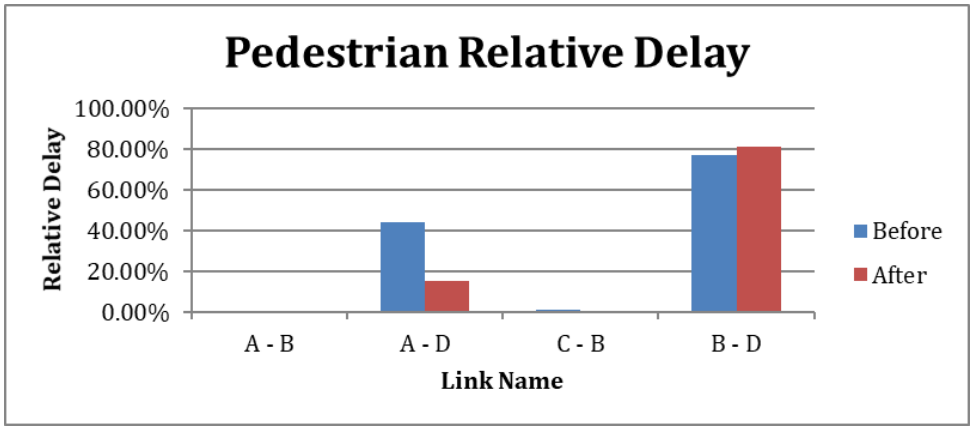


Fig. 9: Graph of pedestrian relative delay at different links

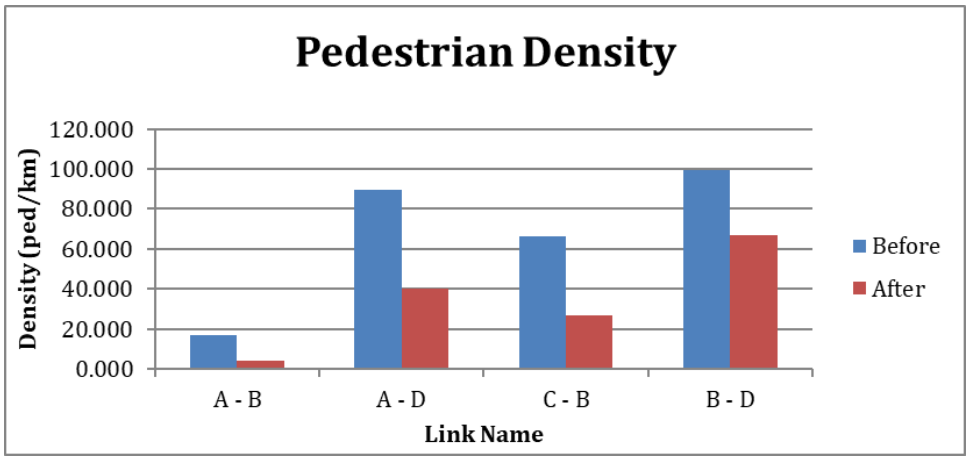


Fig. 10: Graph of pedestrian density at different links

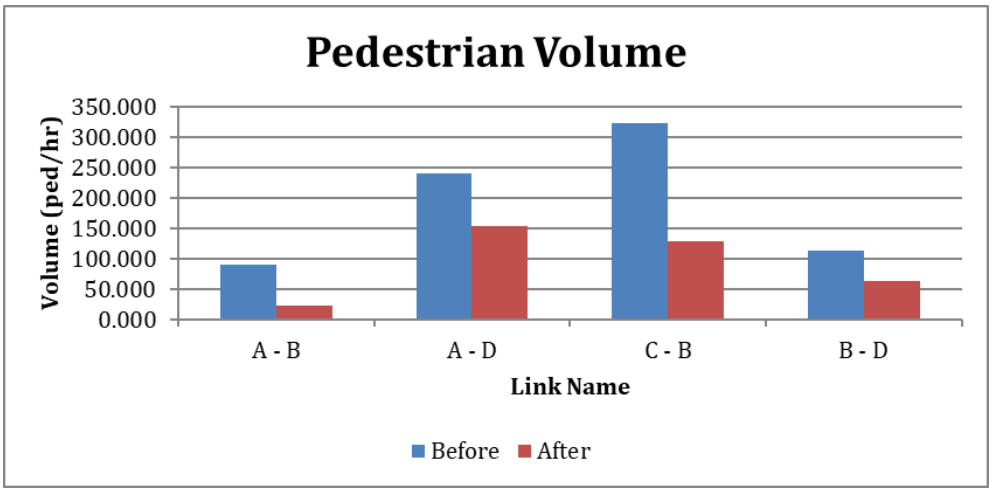
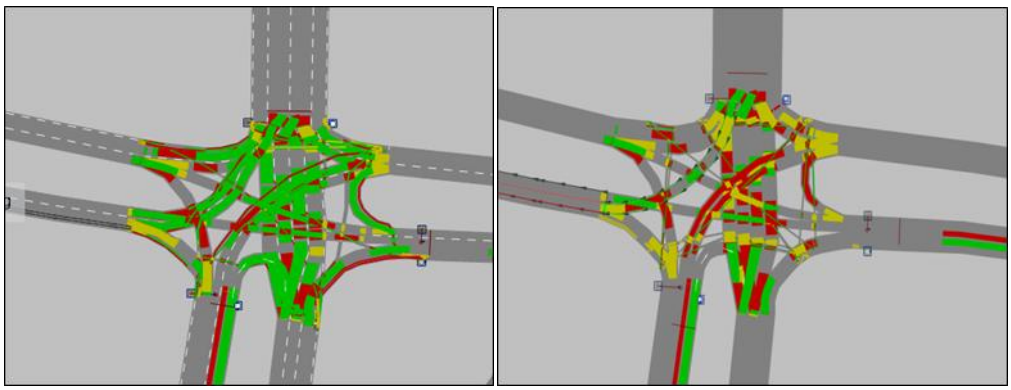


Fig. 11: Graph of pedestrian volume at different links

From the Fig. 10 and Fig.11, it can be seen that there is a drastic change in pedestrian volume and density. Due to this there will be accumulation of pedestrian on footpath due to provision of pedestrian signals and redesigning of vehicle signals.

b) Conflicts points comparison



Before Improvement After Improvement

Fig. 12: Conflict points Before-After Improvements

Conflict points were reduced from 259 to 191 because of decrease in obstructions due to vehicles on the path of pedestrians

c) Road links and pedestrian links results

Table 6: Road Links Results Before and After Improvement

Link Name	Before Improvement					After Improvement			
	Link No.	Density	Relative Delay	Speed	Volume	Density	Relative Delay	Speed	Volume
		(veh/km)	%	(km/hr)	(veh/hr)	(veh/km)	%	(km/hr)	(veh/hr)
To Saras baug	1	16.440	0.010	17.031	580.000	37.207	0.012	18.813	700.000
	2	26.677	0.000	18.843	502.659	41.838	12.373	14.415	603.088
From Satara	12	152.199	0.961	0.657	100.000	28.616	0.103	14.334	410.176
	9	266.320	0.894	1.879	500.478	216.133	0.813	3.497	755.867
	11	201.426	0.956	0.772	155.543	194.136	0.951	0.845	163.976
To Satara	6	55.029	0.000	17.445	960.000	39.78	0.00%	19.607	780
From Hadapsar	4	20.411	0.000	19.597	400.000	23.183	0.030	19.842	460.000
	7	129.792	0.877	2.160	280.397	98.644	85.064	2.824	278.578
To Hadapsar	3	78.737	0.048	17.759	1398.313	98.314	0.008	19.037	1871.560
From Shivajinagar	5	483.538	0.845	3.009	1454.940	286.978	0.742	4.997	1433.926
	8	613.122	0.959	0.862	528.817	333.634	0.904	1.762	588.013
	10	28.218	0.244	14.749	416.178	24.406	0.045	17.209	420.000

Table 7: Pedestrian Links Results Before and After Improvement

Link Name	Orientation	Before Improvement					After Improvement			
		Link No.	Density	Relative Delay	Speed	Volume	Density	Relative Delay	Speed	Volume
			(ped/km)	%	(km/hr)	(ped/hr)	(ped/km)	%	(km/hr)	(ped/hr)
From Satara	Left	16	326.981	0.728	1.300	424.918	442.995	0.619	1.834	812.421
	Right	25	202.057	0.026	4.687	947.103	260.194	0.025	4.549	1183.733
To Satara	Left	26	73.935	0.000	5.188	383.558	22.480	0.512	5.591	125.688
	Right	22	46.118	0.983	0.081	3.732	14.659	0.000	5.457	80.000
From Hadapsar	Left	23	286.312	0.341	3.116	892.160	289.916	0.190	3.782	1096.401
	Right	20	28.947	0.000	4.982	144.214	40.026	0.000	5.629	225.328
To Hadapsar	Left	21	33.178	0.011	4.823	160.000	30.159	0.000	5.077	153.115
	Right	24	2.948	0.000	5.482	16.160	23.183	0.000	5.176	120.000
From Shivajinagar	Left	18	145.406	0.005	4.767	693.171	141.631	0.002	4.844	686.024
	Right	19	56.654	0.035	4.402	249.388	64.673	0.014	5.257	340.000
To Shivajinagar	Left	29	2.611	0.000	7.068	18.456	11.102	0.000	5.404	60.000
	Right	30	48.160	0.000	5.399	260.000	32.441	0.000	5.549	180.000
From Saras baug	Left	27	26.397	0.000	4.960	130.930	24.213	0.000	5.782	140.000
	Right	14	23.374	0.000	5.134	120.000	22.156	0.000	5.416	120.000
To Saras baug	Left	28	13.371	0.000	4.487	60.000	13.174	0.00%	4.554	60.000
	Right	17	6.657	0.000	5.084	33.842	52.402	0.000	4.783	250.656

Slight improvement in delay results and speed of pedestrians was obtained after suggesting shortest and safer possible routes for pedestrians.

VIII. Conclusions and Recommendations

1. Videography survey at Jedhe intersection was carried out and data required was collected in form of vehicles per hour and pedestrian per hour. Maximum pedestrian and vehicle flow were observed on 15th Nov. 2018 (10.00-12.00 am) and 17th Nov. 2018 (5.00-7.00 pm) respectively. The data of vehicles was converted to PCU/hr and both the values were used as input for modeling in software.
2. Comparative study between software available- PTV Viswalk, Pedestrian Dynamics and PTV Vissim was carried out. PTV Vissim is selected for this study as its Student Version was available and modeling was carried out in it.
3. A new signal is designed by Webster's Method with additional pedestrian phase considering safety of pedestrians. The LOS is improved from F to B after provision of pedestrian phase.

4. Base model and newly designed signal model are the two models developed in Vissim. Both scenarios when simulated showed slight improvement in delay results and speed of pedestrians after suggesting shortest and safer possible routes for pedestrians. Decrease in conflict points after redesigning of signal indicates increase in ease of travel for pedestrians.
5. The most efficient solution for improving pedestrian safety and convenience at the intersection is provision of skywalk (from Hanuman Temple to Swargate Traffic Police Station). If it is not economically feasible then traffic signal with separate pedestrian phase can be provided.

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