Study and Performance of Signalised Intersections in Urban Areas with Mixed Traffic Conditions Using Microsimulation-Based Approach

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Abstract- This paper investigates the performance of signalised intersections in metropolitan areas with mixed traffic conditions using a micro simulation-based approach facilitated by the VISSIM software. The study aims to enhance understanding of intersection dynamics and inform traffic management in complex urban settings. Methodology involves VISSIM for accurate microsimulation, incorporating traffic volumes, vehicle types, and signal timings for scenario creation. Various simulations assess intersection performance across diverse traffic flows and signal strategies. Results reveal insights into intersection behaviour under different conditions. Analysis of trends, congestion patterns, and signal effectiveness underscores the importance of adaptive signal control strategies in addressing mixed traffic challenges. The research contributes to signalised intersection knowledge, showcasing VISSIM's utility in such analyses of Four signalised intersections were selected as situated at the signalised intersection of Maharana Pratap (M.P. Nagar) Square in Bhopal, Madhya Pradesh, India. Practical implications extend to traffic engineers, urban planners, and policymakers, guiding strategies to improve intersection performance and urban mobility.

Keywords- Urban Traffic Conditions, microsimulation-based approach, VISSIM Software, Mixed traffic conditions, traffic flows and Delay signal strategies

1. Introduction

Signalised intersections are critical nodes in urban transportation systems, often challenged by mixed traffic conditions due to the coexistence of diverse vehicle types, such as private cars, buses, trucks, and bicycles. A level road intersection is a meeting place for vehicle flows from various directions bothtowards the intersection and leaving the intersection, so that at the intersection there is the potential for vehicle conflicts to occur which are at the same time at the same point. This causes the vehicle to reduce speed. Reducing vehicle speed at intersections results in the potential for queues and delays. Evaluation of the performance of the intersection needs to be done to find out the current performance of the intersection, so that anticipatory steps can be taken so that the performance of the intersection can be maintained in good condition (Sarwanta and Hamdani Abdulgani et. al., 2022). Efficiently managing traffic flow at these intersections is vital for reducing congestion, improving safety, and enhancing overall urban mobility. This study focuses on the imperative task of investigating signalised intersections within metropolitan areas characterized by such mixed traffic conditions. Microsimulation emerges as a powerful tool in understanding complex traffic dynamics at intersections. Unlike macroscopic models, microsimulation offers a detailed representation of individual vehicle movements, enabling a granular analysis of traffic behaviour and intersection performance. Microscopic traffic simulation is a powerful tool for studying complex traffic systems when analytical or empirical approaches cannot define response patterns adequately and accurately. The application of simulation techniques for evaluating the characteristics of controlled intersections is effective due to their quick and reliable outcomes (Mondal and Gupta et. al., 2023).

2. Objectives of the study

1. The primary objective is to assess the performance of signalised intersections in metropolitan areas with mixed traffic conditions.

2. To identify and analyze congestion patterns that arise at signalised intersections due to mixed traffic conditions.

3. To assess how well various signal control strategies reduce traffic and increase intersection efficiency.

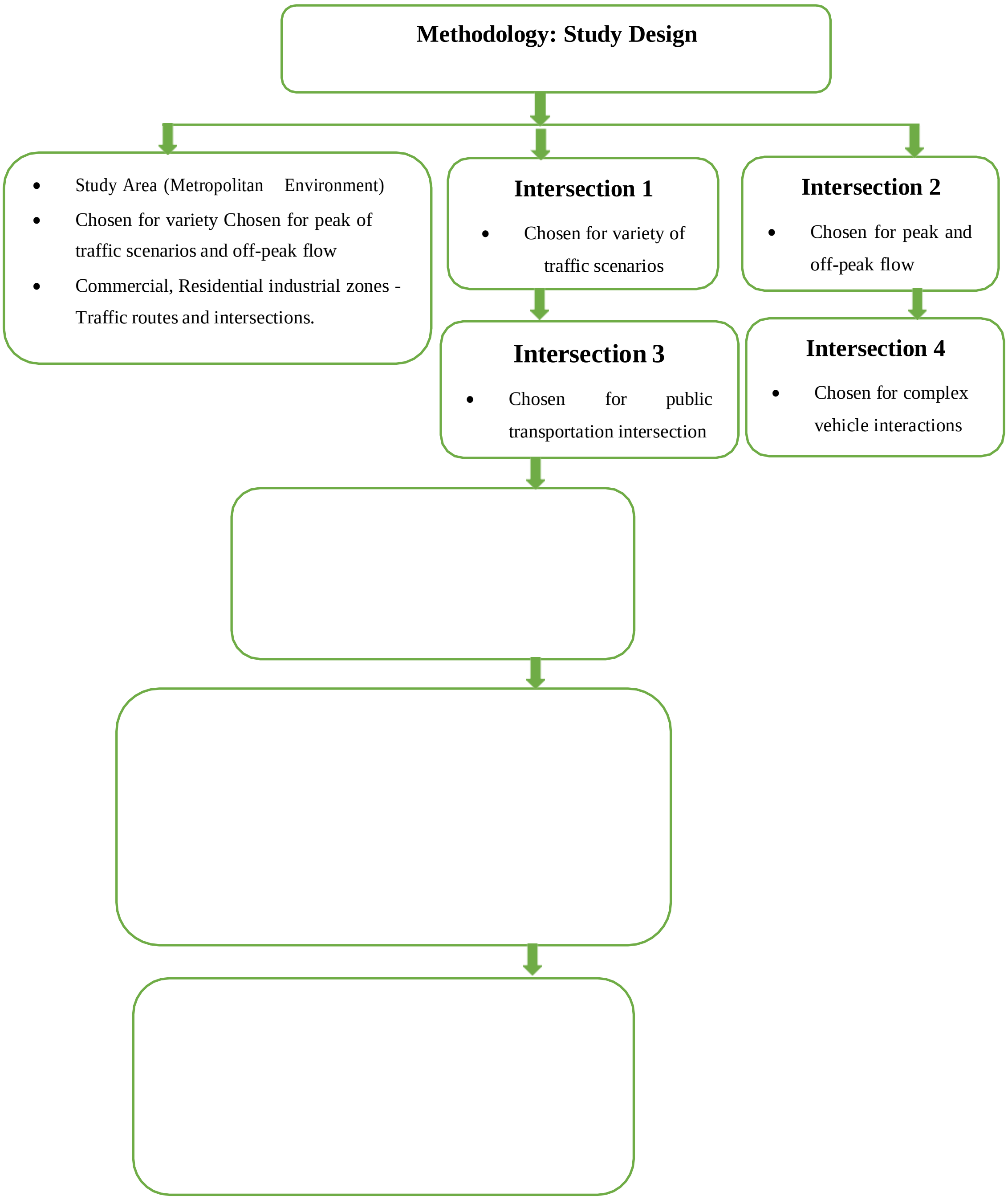
4. To examine the performance of motorised vehicles in terms of queue lengths and vehicle delays using VISSIM software and microsimulation models.

5. To provide recommendations for optimizing traffic management at signalised intersections with mixed traffic conditions.

6. The study purpose to contribute to the field of microsimulation by showcasing the application of the VISSIM software in analyzing complex traffic scenarios.

3. Methodology

The study design of methodology shows in below Figure 1.



Characteristics of Mixed Traffic

- Diverse Vehicle Types
- Varying Traffic Flows
- Interaction Scenarios

VISSIM Software

- Micro-simulation for Accurate Traffic Representation
- Realistic Traffic Dynamics and Vehicle Interactions
- Scenario Customization for What-If Analysis
- Visualization of Simulation Results
- Validation and Calibration for Realism

Analysis of Simulation Results

- Congestion Patterns
- Signal Strategies Effectiveness
- Vehicle Interaction Analysis
- Recommendations for Traffic Management

Figure 1: The study design of methodology

3.1 Study Area and Signalised Intersections

The study was conducted in a representative metropolitan area with a mix of commercial, residential, and industrial zones. Four signalised intersections were selected as the focus of analysis, chosen to encompass a range of traffic scenarios and vehicle interactions. These intersections were strategicallylocated at major arterial roads and represented varying levels of complexity in terms of traffic volume and vehicle composition.

According to Figure 2, the study is situated at the signalised intersection of Maharana Pratap (M.P. Nagar) Square in Bhopal by Google map, Madhya Pradesh, India. Figure 3 and Table 1, show intersection's division and the flow of traffic location and distribution of the M.P. Nagar Square signalised intersection, which is separated into four intersections with arrows indicating the eight direction of traffic flow.

Figure 2: The signalised intersection of Maharana Pratap (M.P. Nagar) Square in Bhopal

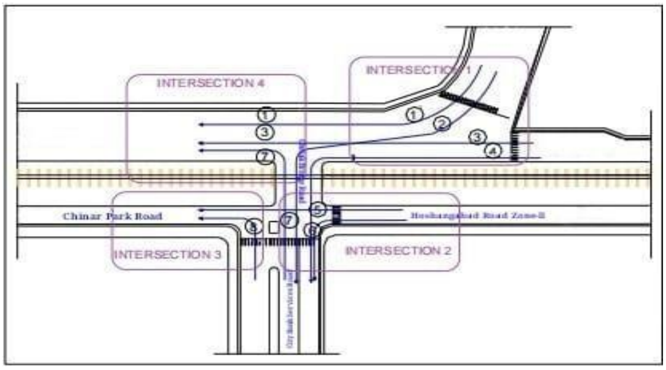


Figure 3: Show intersection's division and the flow of traffic location and distribution of the M.P. Nagar Square signalised intersection

Sr. No.	Intersection Name	Traffic Flow/Movement Direction(D)	Description
1.	Intersection 1	D-1	Traffic flow movement jyoti takiz in the west direction
2.		D-2	Traffic flow movement turn right, Chetak Bridge at west direction
3.	Intersection 2	D-3	Traffic flow movement City service Road in the east direction
4.		D-4	Traffic flow movement turn right, Vyapum Chouraha at east direction
5.	Intersection 3	D-5	Traffic flow movement Chinar Park Road in the south direction
6.		D-6	Traffic flow movement turn left, Jail Road at south direction
7.	Intersection 4	D-7	Traffic flow movement Hoshangabad Road in the south direction
8.		D-8	Traffic flow movement turn right, Zone-II at south direction

Table 1: Traffic Flow/Movement Direction of the signalised intersection M.P. Nagar Square

3.2 Characteristics of Mixed Traffic Conditions

Mixed traffic conditions were defined by the coexistence of different vehicle types, including private cars, buses, trucks, cyclists, and pedestrians. The study considered variations in traffic flow during peak and off-peak hours, as well as scenarios involving public transportation routes that intersected with general traffic lanes. This allowed for a comprehensive assessment of how various vehicle types interacted at signalised intersections under different conditions.

3.3 Micro-simulation Survey and Tools

Sr. No.	Different types of Survey	Location of Urban Area	Tools
1	Volume of Vehicle	Four Intersection and Eight Direction of M.P. Nagar square Road	Survey Form, Meter rollers, stationery, Handy Cam etc.
2	Volume of Vehicle Delay Time		
3	Queue Length of Vehicle		

Table 2: Micro-simulation Survey and Tools

3.4 VISSIM Software Selection and Aanalysis

The VISSIM, Traffic Simulation software was chosen as the primary tool for microsimulation-based analysis due to its well-established reputation and advanced capabilities. VISSIM offers several analyses in studying intersection performance:

- **Microscopic Accuracy:** VISSIM operates at the microscopic level, simulating individual vehicle movements and interactions. This granularity enables a detailed analysis of vehicle behavior, lane changes, and queuing patterns, which is crucial when dealing with mixed traffic scenarios.
- **Realistic Traffic Dynamics:** The software's ability to replicate real-world traffic dynamics ensures a high level of accuracy in capturing the complexities of traffic flow and intersections. This is especially important for assessing the performance of signalised intersections in dynamic urban environments.
- **Scenario Customization:** VISSIM allows for the creation of custom scenarios by adjusting parameters such as traffic volumes, signal timings, and vehicle types. This flexibility enables the simulation of various what-if scenarios, helping to identify optimal signal strategies.
- **Visualization:** VISSIM provides visual outputs, including animations and graphs, which facilitate the interpretation of simulation results. This visual representation enhances the communication of findings to both technical and non-technical stakeholders.
- **Analysis Validation and Calibration:** VISSIM can be validated and calibrated using real-world data to enhance its accuracy. This ensures that the simulated outcomes align closely with observed traffic behavior, providing confidence in the reliability of the simulation results.

Validation on Vissim is the process of comparing observations and simulation results to determine accuracy. Validation is focused with establishing whether the simulation model adequately represents the model conceptually Hellinga B and Hesham R et.al.,1996. The calibration and validation procedure are based on the amount of traffic flow and the length of the backlog. The Chi-square equation model and the statistical model developed by Geoffrey E. Havers (GEH) were utilised for validation. Equation 1, Hidayat A. et.al.,2014. Shows the general formula for Chi-square (x^2).

$$x^2 = \sum_{i=1}^{k} \left|\frac{o_i - E_i}{E_i}\right| \quad (1)$$

where: Ei = simulation data, Oi = observation data

The GEH equation model combines the variance of relative and absolute data to modify the Chi-square statistical formula. When the Chi-square value is determined using the Chi-square table with a significant level and the level of confidence in the Chi-square test is 95% or = 0.05, the test requirements are approved. Equation 2 is the GEH equation and it satisfies the criteria for the resultant error value as given in Table 3, Putri N H dan Irawan M Z et.al., 2015.

$$GEH = \sqrt{\frac{(q_{\text{simulated}} - q_{\text{observed}})^2}{0,5 \times (q_{\text{simulated}} + q_{\text{observed}}}} \quad (2)$$

where: q = traffic flow volume (vehicles/hour)

Value of GEH	**Description**
GEH < 5,0	Accepted
5,0 ≤ GEH ≤ 10,0	warning: possible model error or bad data
GEH > 10,0	Rejected

Table 3: Geoffrey E. Havers (GEH) Statistical Equation Model

By analysis VISSIM's, the software's ability to simulate intricate interactions and dynamics contributes to more informed decision-making in urban planning and traffic management.

4. Result and Discussion

4.1 Number of Vehicles at the Intersection

Table 4 show the different kinds of vehicles crossing at the intersection reveals the amount of overall traffic flow at each movement. At D-3 and D-1 at intersection 1, the unbelievable volumes are 4,564 and 4,502 cars per hour, respectively, while at D-7 and D-4 at intersection 2, they are 3,190 and 1,779, respectively. 71% of the vehicles in this category are motorcycles.

Vehicle Movement Direction	Motorcycle	Big Motorcycle	City Car	Sedan Car	MPV	SUV	Truck	Box Car	Small Bus	Big Bus	1 Axel Truck	2 Axel Truck	TOTAL (Veh. /hour)
D-1	3,005	255	297	72	569	181	63	45	7	6	1	1	4,502
D-2	461	60	46	13	103	43	13	20	4	1	1	1	766
D-3	3,229	247	230	55	548	133	78	33	1	6	1	3	4,564
D-4	996	102	118	30	427	78	10	14	1	1	1	1	1,779
D-5	526	34	51	2	80	24	4	2	1	2	1	1	728
D-6	305	22	16	4	25	6	3	3	1	1	1	1	388
D-7	2,004	715	208	3	201	19	19	16	1	1	2	1	3,190
D-8	662	3	33	6	299	86	13	11	1	1	1	1	1,117

Table 4: Volume Per Vehicle Type Peak Hour Period (vehicle/hour)

4.2 Micro-simulation of intersection traffic

Table 5 show the calibration values and results for the nine selected vissim parameters.

Sr No.	Simulation parameter	Before Calibration (m)	After Calibration (m)
1	Average Standstill Distance	2	0.06
2	Additive Part of Safety Distance	2	0.06
3	Multiplicative Part of Safety Distance	3	1
4	Minimum Headway	0.5	0.5
5	Desired Position at Free Flow	middle	any
6	Overtake at Same Lane (left)	off	on/yes
7	Overtake at Same Lane (right)	off	on/yes
8	Minimum Lateral Distance (driving)	1	0.3
9	Minimum Lateral Distance (standing)	1	0.5

Tabel 5: Calibration values of nine vissim parameters at the intersection

Table 5 show the nine vissim parameters that were chosen together with calibration values for actual traffic patterns during the busiest observation period. The calibration results show parameter values that vary between default and calibrated values.

4.3 Validating the output of the microsimulation model

Table 6 show the data for the Geoffrey E. Havers (GEH) test and micro-simulation model calibration for each movement at the four crossings during peak hours. Figures 4 and 5 provide graphic representations of the data.

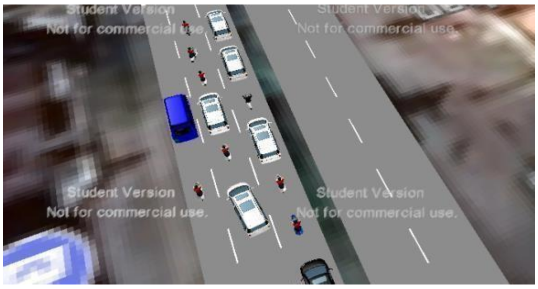


Figure 4: Visualization of the micro-simulation model After calibration

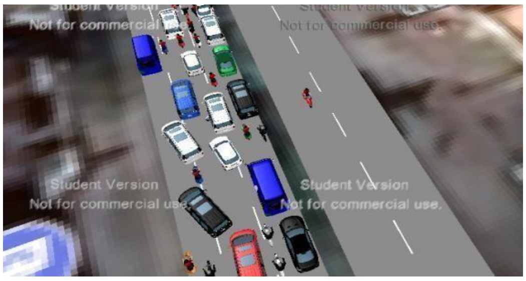


Figure 5: Visualization of the micro- simulation model Before calibration

Intersection	Traffic Movement	Observation	Simulation Model	*GEH Test*	Result
1	D-1	35	28	1.25	Accepted
	D-2	543	503	1.75	Accepted
	D-3	1932	1763	3.93	Accepted
	D-4	552	654	4.15	Accepted
	Total	3080	2948	2.40	Accepted
2	D-4	1101	1143	1.25	Accepted
	D-5	321	320	0.06	Accepted
	D-6	124	158	2.86	Accepted
	D-7	1328	1459	3.51	Accepted
	Total	2874	3080	3.78	Accepted
3	D-7	351	320	1.69	Accepted
	D-8	754	806	1.86	Accepted
	Total	1105	1126	0.63	Accepted
4	D-1	1698	1770	1.73	Accepted
	D-2	1093	1156	1.88	Accepted
	D-7	1340	1437	2.6	Accepted
	Total	4131	4363	3.56	Accepted

Table 6: Traffic flow volume as a result of observation, model calibration, and GEH test

Table 6 show that the traffic flow volume obtained from observation and micro-simulation using the Geoffrey E. Havers test at the signalised intersection of Maharana Pratap (M.P. Nagar) Square in Bhopal, road has been accurately calibrated for the four intersections in the eight directions of traffic flow movement. For all motions, both in the eight directions of movement and in the total volume at the four crossings, the simulation findings with the GEH test may be accepted. GEH score less than 5.00 or between 0.63 and 4.15. Figures 4 and 5 show changes in the volume of traffic flow and vehicle situation as a consequence of the simulation model being calibrated by altering the value of the driving behaviour parameter in accordance with the nine parameter values listed in Table 5. There is a line of extremely regular cars in each lane of the traffic flow volume before it has been calibrated. While the relevance of traffic flow and vehicle circumstances started to change once the simulation model was calibrated, the space between vehicles remained close together and some vehicles were not in the lanes. This signal indicates how traffic is behaving at the signalised intersection of Bhopal's Maharana Pratap (M.P. Nagar) Square.

Movement	Qlen-Min (m)	Qlen-Max (m)	Veh-Delay (det)	LOS
D-1	146.93	161.28	138.97	F
D-3	140.18	161.25	152.95	F
Total	143.56	161.28	173.51	F

Table 7: Queue length and vehicle delays and LOS at intersection 1

Movement	Qlen-Min (m)	Qlen-Max (m)	Veh-Delay (det)	LOS
D-6	124.45	161.22	878.94	F
D-7	142.84	161.23	164.83	F
D-2, D-4 and D-5)	80.21	100.80	1.63	A
Total	86.92	161.23	216.44	F

Table 8: Queue length and vehicle delays and LOS at intersection 2

Movement	Qlen-Min (m)	Qlen-Max (m)	Veh-Delay (det)	LOS
D-8	132.04	161.25	0.58	A
Total	66.18	161.25	1.01	A

Table 9: Queue length and vehicle delays and LOS at intersection 3

Movement	Qlen-Min (m)	Qlen-Max (m)	Veh-Delay (det)	LOS
P7	137.81	160.85	9.71	A
Total	140.76	161.30	19.56	C

Table 10: Queue length and vehicle delays and LOS at intersection 4

The microsimulation's results on the performance and behaviour of motorised vehicles reveal that the signalised intersection of Bhopal's Maharana Pratap (M.P. Nagar) Square Road is already in LOS F, with heavy traffic, slow speeds, lengthy lines, and significant barriers or delays. The longest line is at D-1 intersection 1, measuring 161.28 metres, while the shortest is at intersection 3, measuring 66.18 metres. D-6, intersection 2 had the highest vehicle delay rating of 14.65 vehicle minutes. The Maharana Pratap (M.P. Nagar) Square signalised crossroads in Bhopal should be a non-level intersection using the flyover paradigm to deliver the best quality of service. As a result, the geometric model at the signalised intersection of Bhopal's Maharana Pratap (M.P. Nagar) Square will be compared to the Flyover model in this study.

5. Conclusions

1. The signalised intersection of Maharana Pratap (M.P. Nagar) Square in Bhopal is analysed using four intersections, eight movement directions, and one merged traffic flow movement.

2. Microsimulation of traffic volume is performed by adjusting the nine values of the driver behaviour parameters based on actual intersection conditions.

3. The microsimulation model's traffic volume is validated with the Geoffrey E. Havers test and acknowledged as the actual traffic volume.

4. During the peak hour observation period, the longest queues and longest vehicle delays are recorded at intersections 1 in the north and 2 on the Traffic flow movement City service Road in the east.

5. The performance of the signalised intersection at Maharana Pratap (M.P. Nagar) Square in Bhopal is already at LOS F, where there is heavy congestion, low speed, lengthy lines, and significant obstacles or delays.

6. This paper analyses the geometric model of the Maharana Pratap (M.P. Nagar) Square Road signalled intersection into a non-planar intersection with the Flyover model.

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