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Multi- Leg Intersection Analysis & Optimization Using VISSIM

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Abstract: *PTV VISSIM is a microscopic traffic simulation tool, use to analyse urban traffic congestion at multi-leg intersections and optimize traffic flow. Panchavati Square at Amravati is one of the complex multi-legintersection. The research involves traffic data collection, including vehicle volumes, turning movements, signal timings at peak hours. The study evaluates the existing intersection performance by assessing key parameters such as average vehicle delay, vehicle travel time, queue lengths, queue counters, level of service (LOS), and emissions. Various optimization strategies are tested, including signal timing adjustments, lane reconfigurations, and adaptive traffic control systems. Simulation results indicate that optimized signal phasing and geometric improvements significantly reduce delays and improve intersection efficiency. The findings highlight the effectiveness of VISSIM-based simulation in enhancing intersection performance, reducing congestion, and improving urban mobility.*

This study investigates traffic performance at the 124 Conflict Area, focusing on critical parameters such as queue length, vehicle delay, and travel time. Data were collected through field surveys and simulation modelling, capturing operational characteristics during peak traffic periods. Analysis of queue dynamics revealed significant accumulation at key intersection approaches, often exceeding acceptable thresholds and indicating poor traffic discharge efficiency. Delay measurements showed prolonged intersection wait times, particularly during high-volume intervals, underscoring inefficiencies in signal timing and intersection geometry. Vehicle travel time data further reflected these inefficiencies, with notable variations indicative of stop-and-go traffic and intermittent congestion. The findings emphasize the need for operational enhancements, including signal optimization and potential geometric reconfiguration. The study provides empirical insights to inform targeted mitigation strategies, contributing to improved safety and flow efficiency in urban conflict-prone intersections.

Keywords: Geometric reconfiguration, multi-leg intersection, queue dynamics signal optimization, traffic simulation, urban mobility, vehicle travel time VISSIM

I. INTRODUCTION

Multi-leg intersections, where three or more roads converge, present unique challenges in traffic management due to the complexity of vehicle movements and the potential for increased conflicts. Efficiently managing these intersections is critical to minimizing delays, reducing congestion, and ensuring safety for all road users. VISSIM, a microscopic traffic simulation software developed by PTV Group, is an essential tool for analysing and optimizing traffic flow atcomplex junctions such as Panchavati Square, Amravati. VISSIM provides a detailed, simulation-based approach to understanding the intricacies of multi-leg intersections. By modelling the behaviour of individual vehicles, it allows engineers and planners to assess the impact of various traffic control measures, such as signal timing adjustments, lane configurations, and the implementation of roundabouts or other traffic calming strategies.

One of VISSIM's key strengths is its ability to simulate various traffic scenarios under different conditions, including peak hour congestion, incidents, and the introduction of new traffic control devices. The software's robust traffic signal modelling capabilities are particularly valuable for multi-leg intersections, where efficient signal phasing and timing are crucial to managing the complex movements and minimizing delays. Urbanization and rapid population growth have significantly increased traffic congestion, especially at busy intersections. Multileg intersections, characterized by three or more roadways converging at a single junction, pose unique challenges in terms of traffic flow, safety, and management. Panchavati Square in Amravati is one such critical intersection requiring detailed traffic analysis and optimization for efficient operation. This study employs VISSIM, a microscopic traffic simulation software, to analyse and optimize traffic flow at Panchavati Square with vehicle input, vehicle routes, conflict area, links etc.

VISSIM is a widely used software for microscopic traffic simulation, offering robust tools for analysing and optimizing traffic systems. It allows for: Detailed modelling of traffic flows and behaviours. Assessment of various traffic management strategies, including signal timings and lane allocations. Visualization of traffic conditions for better decision-making. Integration with real-world data for reliable simulation outcomes.

Data:

- Study Area: Panchavati Square, Amravati
- Panchavati Square is a prominent multileg intersection in Amravati, characterized by:
- High traffic volumes during peak hours.
- Mixed traffic conditionsincluding cars, buses, two-wheelers etc.
- Challenges such as irregular geometry, signal timing inefficiencies, and frequent congestion.

Scope:

- Ongoing Monitoring and Adjustment
- Expansion of VISSIM Analysis
- Integration with Smart City Initiatives

Objectives of the Study:

- Analyze the existing traffic conditions at Panchavati Square.
- Identify bottlenecks and factors contributing to congestion.
- Optimize signal timings and lane configurations to improve traffic flow and reduce delays.

II. RESEARCH METHODOLOGY

One of VISSIM's most powerful features is its ability to simulate the interactions between various modes of transportation. By analyzing interactions at Panchawati Square, VISSIM helps to identify potential conflicts and design solutions that accommodate all users.

- Data Collection
- Traffic Volume Data: Manual or automated vehicle counts during peak and off-peak hours.
- Geometric Data: Intersection layout, number of lanes (total 26 links)
- Signal Timings: Existing signal phases and cycle lengths.
- Model Development in VISSIM
- Input traffic volume, vehicle route and signal timing data.
- Calibrate the model using real-world observations to ensure accuracy
- Simulation and Analysis
- Run baseline simulations to evaluate current performance metrics such as queue lengths, delays, and Level of Service (LOS).
- Identify problem areas (e.g., high delays, congestion hotspots.
- Optimization Scenarios.
- Signal timing adjustments.
- Evaluate the performance of each scenario based on key metrics like average delay, queue length and emissions.
- Result Interpretation

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Manual Data collection of traffic volume:

Vehicle input:Vehicle inputs were defined at five key entry points in the network. The composition of vehicle classes included private cars, autos (three-wheelers), buses, and trucks. The input rates were based on field data collected.

Entry Point	Vehicle Volume(0-MAX)	Vehicle Composition
1. irw to nag	4141.0	Car, LGV, HGV (50 km/h)
2. gad inw	1930.0	Car, LGV, HGV (50 km/h)
3. nag to irw	1567.0	Car, LGV, HGV (50 km/h)
4. kantainw	192.0	Car, LGV, HGV (50 km/h)
5. rtoinw	976.0	Car, LGV, HGV (50 km/h) (Stochastic)

Vehicle route:The simulation network consists of multiple bidirectional and unidirectional links designed to replicate urban traffic behavior. The vehicle routes were defined to reflect actual origin-destination (OD) patterns within the selected network

	From Irwin road	**Towards Gadge nagar road**	**TowardsNagpur road**	**Towards Kanta nagar road**	**Towards RTO road**
	Vehicle Input	**2666**	**1314**	**68**	**93**
2)	From Gadge nagar road	TowardsNagpur road	Towards Kanta nagar road	Towards RTO road	TowardsIrwin road
	Vehicle Input	**438**	**82**	**554**	**856**
3)	From Nagpur road	Towards Kanta nagar road	Towards RTO road	TowardsIrwin road	Towards Gadge nagar road
	Vehicle Input	**125**	**100**	**995**	**347**
4)	From kantanagar	Towards RTO road	Towards Irwin road	Towards Gadge nagar	Towards Nagpur road
	Vehicle Input	**08**	**59**	**91**	**34**
5)	From RTO road	TowardsIrwin road	Towards Gadge nagar road	Towards Nagpur road	Towards Kanta nagar road
	Vehicle Input	**178**	**693**	**94**	**11**

Geometric characteristics of simulation links:

The study area was modelled using PTV VISSIM 2025, incorporating 26 links representing various directional movements in the network. Each link was defined with appropriate geometric parameters including link length, number of lanes, and behaviour type, as summarized in table.

Link No.	Name	Link Behaviour Type	Display Type	Level	No. of Lanes	Length (m)
1	irw to nag	Urban (motorized)	Road gray	Base	2	230.95
2	irw to nag	Urban (motorized)	Road gray	Base	2	230.95

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3	gad away	Urban (motorized)	Road gray	Base	2	105.77
4	gad inw	Urban (motorized)	Road gray	Base	2	105.77
5	kanta away	Urban (motorized)	Road gray	Base	1	88.72
6	kantainw	Urban (motorized)	Road gray	Base	1	88.72
7	rto away	Urban (motorized)	Road gray	Base	1	114.67
8	rtoinw	Urban (motorized)	Road gray	Base	1	114.67
9	nag to gad	Urban (motorized)	Road gray	Base	2	30.91
10	gad to irw	Urban (motorized)	Road gray	Base	2	33.3
11	kanta to rto	Urban (motorized)	Road gray	Base	2	24.24
12	rto to kanta	Urban (motorized)	Road gray	Base	2	34.0
13	rto to irw	Urban (motorized)	Road gray	Base	2	30.74
14	irw to rto	Urban (motorized)	Road gray	Base	2	28.1
15	gad to kanta	Urban (motorized)	Road gray	Base	2	59.55
16	kanta to gad	Urban (motorized)	Road gray	Base	2	59.55
17	kanta to irw	Urban (motorized)	Road gray	Base	2	74.34
18	irw to kanta	Urban (motorized)	Road gray	Base	2	75.77
19	nag to gad	Urban (motorized)	Road gray	Base	2	34.27
20	nag to rto	Urban (motorized)	Road gray	Base	2	38.1
21	Kantto nag	Urban (motorized)	Road gray	Base	2	56.3
22	rto to gad	Urban (motorized)	Road gray	Base	2	74.55
23	gad to rto	Urban (motorized)	Road gray	Base	2	72.91
24	rto to nag	Urban (motorized)	Road gray	Base	2	56.4
25	nag to irw	Urban (motorized)	Road gray	Base	2	55.22
26	Rtoto kanta	Urban (motorized)	Road gray	Base	2	38.55

Signal timing:

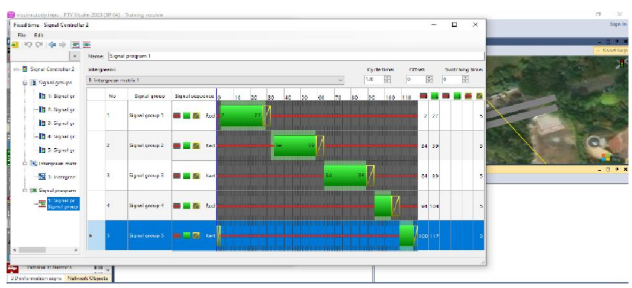

Fig. 1 signal time

Signal Group	Phase Start Time (sec)	Phase End Time (sec)	Green Duration (sec)	Cycle Time (sec)
Signal Group 1	02	27	25	120
Signal Group 2	34	59	25	120
Signal Group 3	64	89	25	120
Signal Group 4	94	104	10	120
Signal Group 5	109	117	8	120

Conflict points:

The intersection geometry included 124 conflict points, comprising merging and diverging conflicts due to multilane channelization. Crossing conflicts from multiple legs and turning movements.This high number of conflicts indicates a

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significant potential for operational inefficiencies and safety risks. The visual inspection of vehicle paths (green connectors) suggests areas of high interaction density, particularly at the core of the intersection where all approaches converge.

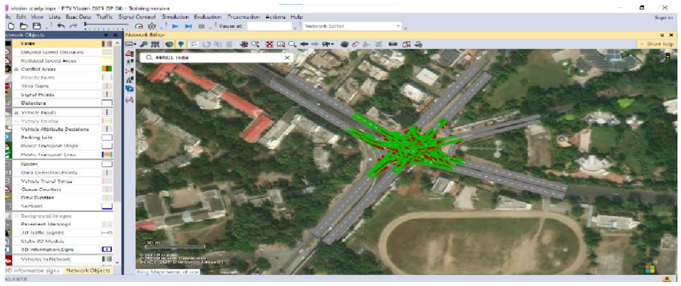

Fig. 2 Conflict area

Simulation and Analysis:

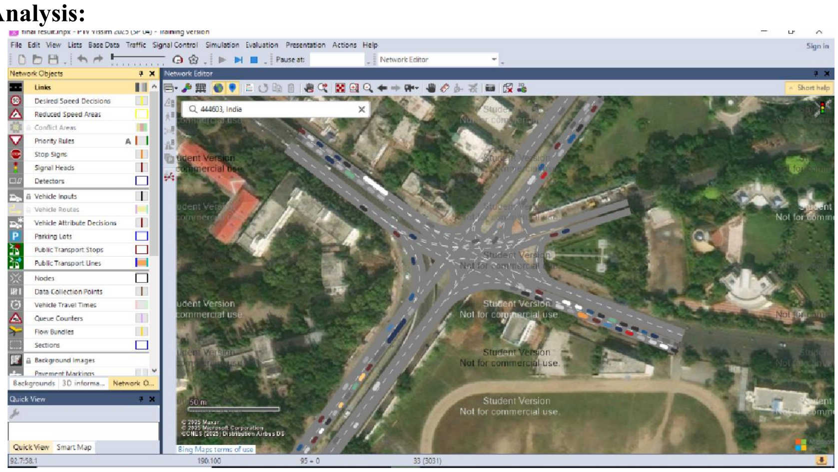

Fig. 3 Simulation

Queue result:

Number	Time interval	Queue counter	Queue length	Queue length max.	No. of stop
39	0-3600	1	76.26072	89.11327	277
39	0-3600	2	64.64415	85.93195	354
39	0-3600	3	67.39366	82.31051	331
39	0-3600	4	12.48831	33.59781	23
39	0-3600	5	69.9613	108.9259	268
40	0-3600	1	72.98806	89.0615	162
40	0-3600	2	57.42962	85.93195	226
40	0-3600	3	62.17527	82.31051	215
40	0-3600	4	11.8442	33.59781	13
40	0-3600	5	54.41853	104.6793	164
41	0-3600	1	76.26072	89.11327	277
41	0-3600	2	64.64415	85.93195	354
41	0-3600	3	67.39366	82.31051	331
41	0-3600	4	12.48831	33.59781	23

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41	0-3600	5	69.9613	108.9259	268
42	0-3600	1	76.26072	89.11327	277
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42	0-3600	3	67.39366	82.31051	331
42	0-3600	4	12.48831	33.59781	23
42	0-3600	5	69.9613	108.9259	268
43	0-3600	1	76.26072	89.11327	277
43	0-3600	2	64.64415	85.93195	354
43	0-3600	3	67.39366	82.31051	331
43	0-3600	4	12.48831	33.59781	23
43	0-3600	5	69.9613	108.9259	268
Average	0-3600	1	75.60619	89.10292	254
Average	0-3600	2	63.20124	85.93195	328
Average	0-3600	3	66.34998	82.31051	308
Average	0-3600	4	12.35949	33.59781	21
Average	0-3600	5	66.85274	108.0766	247
Standard deviation	0-3600	1	1.463576	0.023153	51
Standard deviation	0-3600	2	3.226436	0	57
Standard deviation	0-3600	3	2.333734	0	52
Standard deviation	0-3600	4	0.288055	0	4
Standard deviation	0-3600	5	6.950937	1.899126	47
Minimum	0-3600	1	72.98806	89.0615	162
Minimum	0-3600	2	57.42962	85.93195	226
Minimum	0-3600	3	62.17527	82.31051	215
Minimum	0-3600	4	11.8442	33.59781	13
Minimum	0-3600	5	54.41853	104.6793	164
Maximum	0-3600	1	76.26072	89.11327	277
Maximum	0-3600	2	64.64415	85.93195	354
Maximum	0-3600	3	67.39366	82.31051	331
Maximum	0-3600	4	12.48831	33.59781	23
Maximum	0-3600	5	69.9613	108.9259	268

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Data collection result:

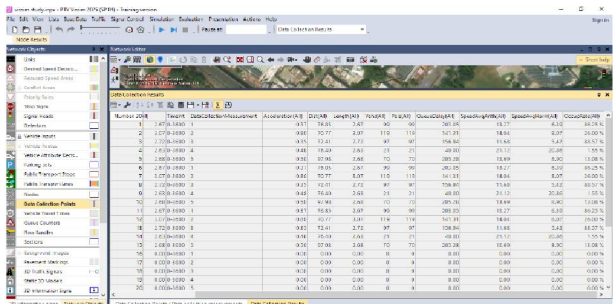

Fig. 4 Data collection result

Queue delay:

Point	Average Queue Delay (s)	Std Dev	Min	Max
1	75.03	0.024	75.02	75.07
2	71.65	6.22	60.53	74.43
3	107.04	6.85	94.80	110.10
4	49.54	0.92	47.89	49.95
5	148.90	17.85	116.97	156.88

Travel time:

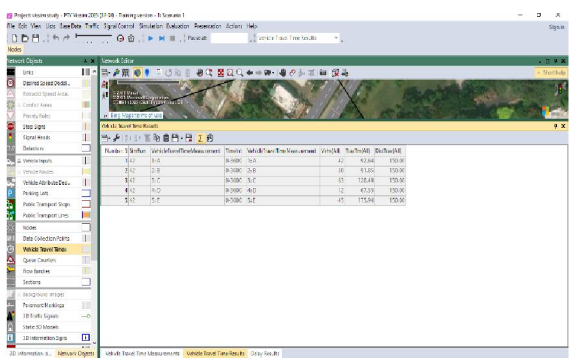

Fig. 5 Travel time

III. RESULT INTERPITATION

Queue Counters:The three queue counter charts from VISSIM simulation scenarios reveal distinct trends in queue length and stop behaviour across five traffic legs, allowing to draw conclusions about intersection performance and optimization effectiveness.

Sr. No.	Source	Key Insight	Citations
1	Scenario 1 Queue Chart	Highest queue lengths and stops indicative of congestion and poor optimization.	-
2	Scenario 2 Queue Chart	Moderate performance reduction in congestion but still not optimal.	-
3	Scenario 3 Queue Chart	Best performancelowest queue metrics across all counters.	-

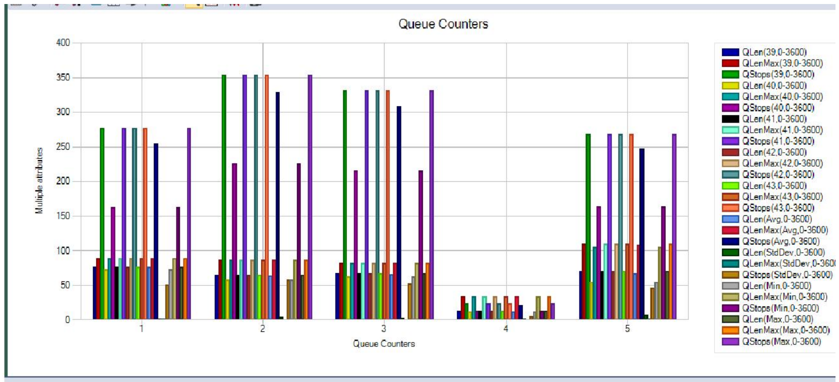

Fig. 6 queue counter for scenario 1

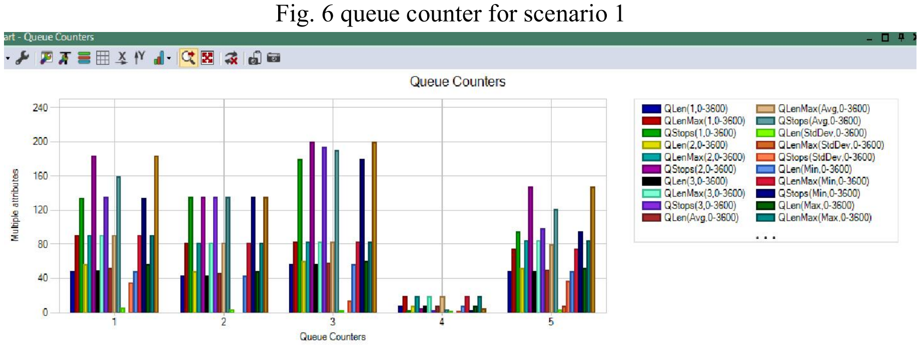

Fig. 7 queue counter for scenario 2

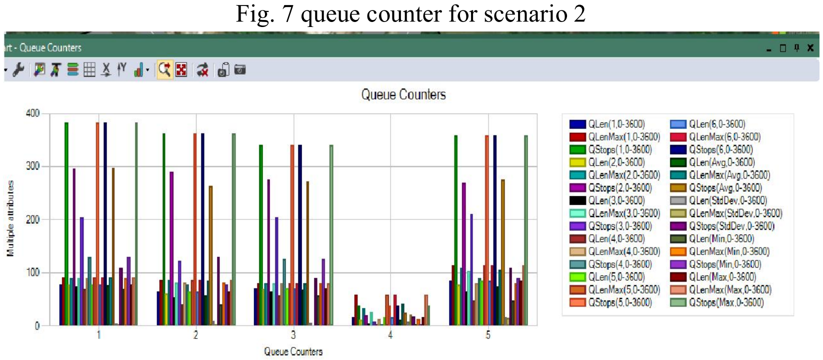

Fig. 8 queue counter for scenario 3

Delay measurement: Based on the visual analysis of the delay and queue counter charts across the three scenarios, it is evident that different phases and configurations significantly impact stop delays, vehicle delays, pedestrian delays, and the number of stops.

Sr. No.	**Source**	**Key Insight**	**Citations**
1	Scenario 1 Delay measurement	High peak delays in stop and vehicle metrics suggest inefficiencies under initial settings	-
2	Scenario 2Delay measurement	Reduced peak delays indicate improved signal coordination	-
3	Scenario 3Delay measurement	Lowest overall delays and stops show optimized signal and traffic management	-

Vehicle travel time:

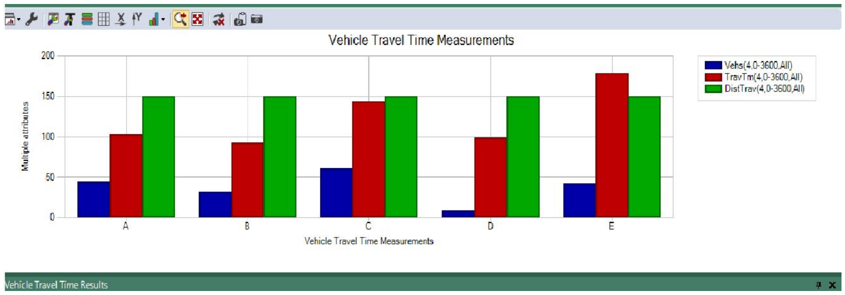

Fig. 9 vehicle travel time scenario 1

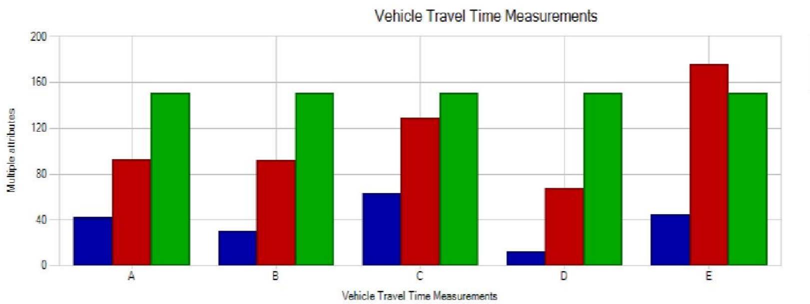

Fig. 10 vehicle travel time scenario 2

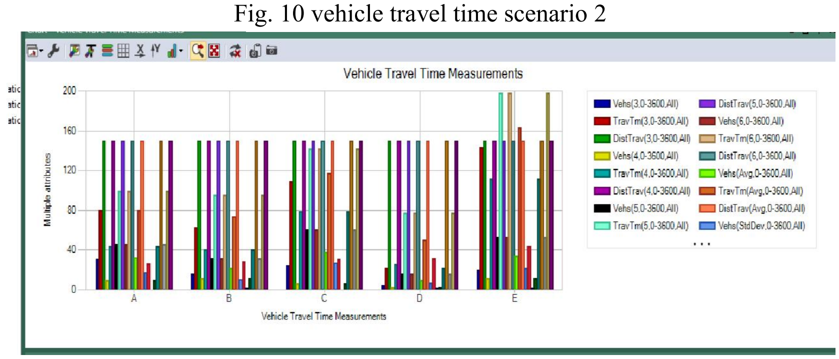

Fig. 11 vehicle travel time scenario 3

IV. FUTURE SCOPE

To build upon the findings and improvements observed in different Scenarios, several future-oriented recommendations can be made for further optimizing traffic flow and minimizing delays at Panchawati Square. A key future scope lies in integrating Artificial Intelligence (AI)-based adaptive signal control systems, which can continuously learn and respond to real-time traffic conditions using machine learning algorithms. This would enhance responsiveness to fluctuating traffic volumes, particularly during special events or unplanned congestion. The deployment of Internet of Things (IoT) sensors and connected vehicle infrastructure could facilitate more granular data collection on vehicle speed, queue lengths, and pedestrian movement, allowing for predictive traffic modelling and proactive management. Additionally, incorporating multi-modal transport prioritization, including dedicated signal phases for public transport and non-motorized users (pedestrians, cyclists), can promote sustainable mobility and reduce conflicts. Simulation-based planning using software like VISSIM or Synchro should be continuously used to test different configurations under various demand scenarios before field implementation. On the infrastructure side, integrating smart signage and real-time traffic information systems would enhance driver awareness and route choice, further smoothing flow. Future studies should also explore the impact of seasonal and weather variations on traffic performance and model scenarios accordingly. Finally, public engagement and behaviour studies could identify user compliance trends, supporting tailored awareness campaigns and enforcement strategies. These advances will ensure Panchawati Square evolves into a resilient, data-driven, and user-centric urban mobility node.

V. CONCLUSION

It is a powerful tool for analysing traffic flow, optimizing signal timings, and improving overall intersection performance by simulating different traffic scenariosVISSIM helps identify conflict points, no. of links, vehicle input, vehicle routes which gives queue length, density, delay result, vehicle travel time etc. for particularly Panchawati square. Based on the comprehensive evaluation of traffic performance at Panchawati Square across the three scenarios, it is evident that Scenario 3 delivers the most efficient outcome in terms of minimizing delays and improving vehicle travel time. The delay measurement graphs indicate that Scenario 3 consistently reduces stop delays, vehicle delays, and pedestrian wait times across all observed time intervals compared to Scenario 1 and 2.These results collectively indicate that Scenario 3's design possibly incorporating coordinated signals, reduced cycle lengths, and better lane discipline significantly enhances intersection performance. The findings highlight the critical importance of data-driven signal optimization and holistic planning in managing urban intersections like Panchawati Square, ultimately suggesting that Scenario 3 should be implemented or further refined as the preferred design moving forward.

Ultimately, VISSIM supports informed decision-making for infrastructure planning, offering insights into improving traffic management, reducing emissions, and enhancing safety at complex intersections like Panchawati Square.

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