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Comparative Analysis of Traffic Simulation Parameters Using SUMO and TraCI API

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Abstract: Traffic simulation plays a vital role in evaluating and optimizing urban mobility systems. This study presents a comparative analysis of key traffic simulation parameters using the Simulation of Urban Mobility (SUMO) along with its Traffic Control Interface (TraCI) API. By adjusting parameters such as vehicle speed, acceleration, lane-changing behavior, and traffic signal timing, the research examines their impact on traffic performance of vehicles, specifically overall travel time, queue length, and vehicular throughput. The study leverages TraCI to dynamically control and monitor simulation components in real time, enabling a more detailed understanding of how individual parameters influence system behavior. Multiple traffic scenarios are tested using both static and adaptive control strategies to provide a comprehensive comparison. Results were compared to identify which parameters have the most significant effect on traffic flow. Fine-tuning these parameters how them can lead to more efficient and realistic simulations.

Keywords: Traffic Violations, Data Analytics, Over speeding, Signal Jumping, Jaywalking

I. INTRODUCTION

Urban transportation systems are facing increasing pressure due to rapid urbanization, population growth, and the rising number of vehicles on the road. These changes have led to challenges such as traffic congestion, increased travel times, air pollution, and inefficient use of road infrastructure. Addressing these issues requires effective planning and management strategies, which in turn depend on accurate modeling and simulation of traffic systems. Traffic simulation provides a cost- effective, risk-free, and efficient method for analyzing various traffic scenarios and testing new infrastructure or policies before real-world implementation.

Simulation of Urban Mobility (SUMO) is a powerful, open-source traffic simulation suite developed by the Institute of Transportation Systems at the German Aerospace Center (DLR). It has been actively developed since 2001 and is widely recognized for its flexibility, scalability, and modular design. SUMO supports simulations at various levels of detail—including microscopic, mesoscopic, and macroscopic modeling—making it suitable for both small-scale intersection studies and large-scale urban network simulations. One of the key strengths of SUMO is its ability to simulate individual vehicle behavior, including car-following, lane-changing, and traffic light interaction, using customizable parameters. It also supports multi-modal traffic, allowing users to model pedestrians, bicycles, public transport, and freight vehicles within the same environment. Additionally, SUMO includes tools for traffic demand modeling, network generation, route assignment, and emission calculation. It can import real-world road networks from sources such as OpenStreetMap (OSM), which significantly reduces the time and effort required to create realistic scenarios.

Another significant feature is SUMO's Traffic Control Interface (TraCI)—a Python-based API that enables live control and communication with a running simulation. TraCI allows for dynamic interaction with traffic elements such as vehicles, traffic lights, and sensors, making SUMO highly suitable for integration with intelligent transportation systems (ITS), machine learning models, and autonomous vehicle research. This real-time control capability opens the door for simulating adaptive traffic signal control, connected vehicle systems, and V2X communication. The growing need for smart city development, sustainable transportation, and data-driven decision-making has made SUMO an essential tool for urban mobility research. Its open-source nature encourages transparency, collaboration, and the development of custom extensions, allowing researchers to tailor the simulation environment to their specific use cases.

This research paper focuses on the use of SUMO for simulating real-world traffic conditions, highlighting its application in network modeling, traffic signal optimization, and performance analysis. A detailed methodology is presented for building a complete simulation scenario—from road network creation using OpenStreetMap, to traffic data integration,

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simulation execution, and result analysis. Furthermore, the paper explores how SUMO's output can be combined with external tools such as MongoDB, Python, and data analytics platforms to extract valuable insights and support urban transport planning.

By using SUMO, urban planners, engineers, and researchers can explore various traffic management strategies, evaluate their effectiveness under different conditions, and contribute to the design of smarter, more efficient, and more sustainable urban mobility systems.

II. LITERATURE REVIEW

Intersection analysis using computer vision techniques with SUMO

Shirazi et al. (2023) This paper uses computer vision and the SUMO traffic simulator to study intersections. A deep learning-based tracking system is built using YOLO for object detection and a correlation filter to track vehicles and pedestrians. From the tracking data, traffic details like speed and turn counts are measured. A method is also introduced to add turning movement counts (TMC) into SUMO to create realistic traffic simulations. Tests show that YOLOv5 works best for traffic camera footage, especially after fine-tuning with a pedestrian dataset from the University of Nevada, Las Vegas. The system was used to track traffic at three downtown Las Vegas intersections during peak hours, recording turn counts every 15 minutes. These results were used to adjust SUMO for accurate simulation, helping to analyze travel times, lane usage, and signal performance. The study found that the rate of left turns has a big impact on travel time at intersections.

Citypulse: Proof-of-Concept for Real-Time Traffic Data Analytics and Congestion Prediction

Teledjieu et al. (2025) have developed the tool named as Citypulse, to analyse and study the urbn traffic. CityPulse is a prototype system designed to analyze urban traffic in real time using big data tools—without needing expensive physical sensors on the ground. It works by simulating over 11 million traffic-related records, including things like vehicle congestion, GPS locations, and weather conditions. Using Citypulse, the cleaned and organized data is then passed to a simple machine learning module and displayed through a web interface built with Flask (backend) and React (frontend). Performance tests show that CityPulse can handle over 300,000 records per minute, with only a small delay (about 10%) even under heavy use. Because it uses Docker containers for all parts of the system, it's easy to deploy, manage, and scale—making it a practical, low-cost solution for monitoring traffic congestion, especially in developing countries like Cameroon. However, it's important to note that CityPulse uses simulated data, not real-world sensor data. So, while it shows what's possible, its results depend on how realistic the fake data is, and may not fully capture the complexities of real urban environments.

Calibration of SUMO Microscopic Simulation for Heterogeneous Traffic Condition: The Case of the City of Khulna, Bangladesh

Chowdhury et al (2024). Modeled the city traffic in Bangladesh using SuMO tool. The level of heterogeneity in traffic in more in Bangladesh, hence modeling traffic accurately is difficult, especially in busy urban areas. This study uses the SUMO traffic simulator to model and improve traffic conditions in Khulna City. The study was performed at the Powerhouse intersection which is a busy area linking the central business district (CBD) and the railway station. Field data on traffic flow, queue length, and travel time were collected and compared with simulation results to calibrate the SUMO model. The calibration minimized errors in queue length and travel time, resulting in optimized simulation settings, there by considering the standard values of the simulation parameters such as sigma (σ) = 0.3 and tau (T) = 1.4. Further to this, there were two scenarios which were considered for this study with different set of considerations through the developed simulation model. One was in terms of roadway geometric changes & the other one with the optimization of traffic flow, management of traffic lights with effective and time saving solution. The results show that a well-calibrated SUMO model can reflect real traffic conditions and help plan effective traffic solutions. However, field data is essential for accurate and reliable simulations.

Sumonity: Bridging SUMO and Unity for Enhanced Traffic Simulation Experiences

Pechinger & Lindner (2024). This paper introduces "Sumonity", a tool that connects the SUMO traffic simulator with the Unity game engine. It combines SUMO's accurate traffic modeling with Unity's realistic graphics and physics to create more lifelike traffic simulations. Sumonity uses a pure pursuit control method to better simulate how individual vehicles move, making it suitable for both regular and autonomous vehicles. The paper also highlights how this tool can support future research in realistic traffic simulation.

TRAFFIC SIMULATION & INTEGRATION USING SUMO SIMULATOR

Kumar Singh et al. (2019) Studied This study models the road network of Madhubani city in SUMO using data from OpenStreetMap. Managing road networks is key to a city's growth. Since traffic flow is complex and unpredictable,

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simulations are commonly used for planning. Traffic data, including road layouts and vehicle flow, was input into the simulation. The study also explores improved traffic signal planning based on the simulation results. However, it was found that large-scale transport integration is limited, as the city lacks a multimodal transport system.

The Open Source Traffic Simulation Package SUMO

Krajzewicz et al. (2024) This paper Since 2000, the Institute of Transportation Research (IVF) at the German Aerospace Centre (DLR) has been developing SUMO, an open-source microscopic traffic simulation tool. It serves as a common platform for testing traffic algorithms and models. Since 2003, IVF has also worked on virtual traffic management systems and has led several major projects, including INVENT and the real-time traffic simulation for World Youth Day 2005 in Cologne. This paper briefly presents SUMO and these projects to demonstrate how it can simulate large-scale traffic scenarios and be used as a testbed for traffic management algorithms with minimal additional development.

Building a real-world traffic micro-simulation scenario from scratch with SUMO

Maria Laura Clemente (2022) Studied the tool "Simulation of Urban Mobility" (SUMO), and observed that it is a very flexible traffic simulation tool that supports various scales. From detailed (sub-microscopic) to broad (macroscopic) models. With the right input data, users can create many configurations by adjusting routing methods, car-following models, and other parameters. Building a basic SUMO scenario involves several steps: creating the road network, defining traffic, choosing a routing algorithm, and running the simulation. This study presents a real-world case to demonstrate the full process, starting with road network preparation from OpenStreetMap. It also explains how to use MongoDB to store and manage important data from SUMO's output.

Data Collection & Processing:

The traffic data for the study intersection was collected for the peak hour traffic of the morning and evening times of the day. The broad level traffic data in the junction is presented in the following table:

Table 1 Traffic Data Collection- AM & PM Peak- broad summary- totals

MODE	Morning peak Hr	Evening peak Hr
Four-Wheeler	2377	2933
Two-wheeler	5298	5872
Auto rickshaw	1246	1505
Mini Bus	557	405
Bus	618	810
LCV	1558	1382
Two-Axle truck	508	455
Multi-Axle truck	46	46
Cycle	29	32
Total	12237	13439

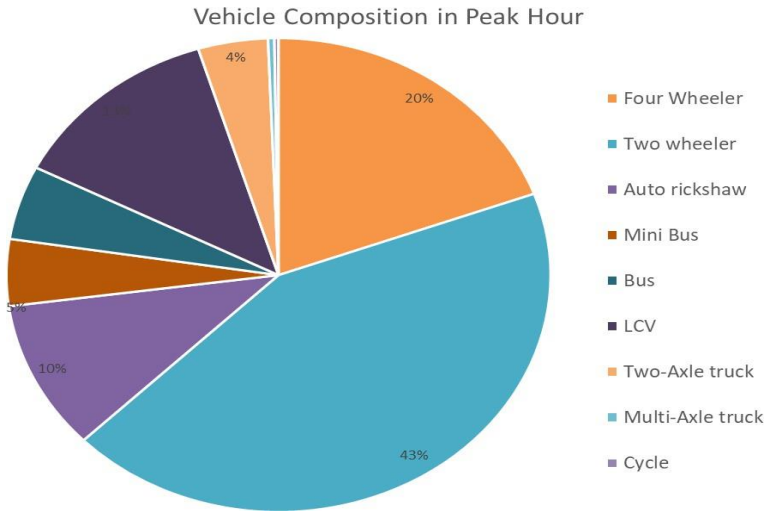

Figure 1 Vehicle compositions from Traffic Data of Junction

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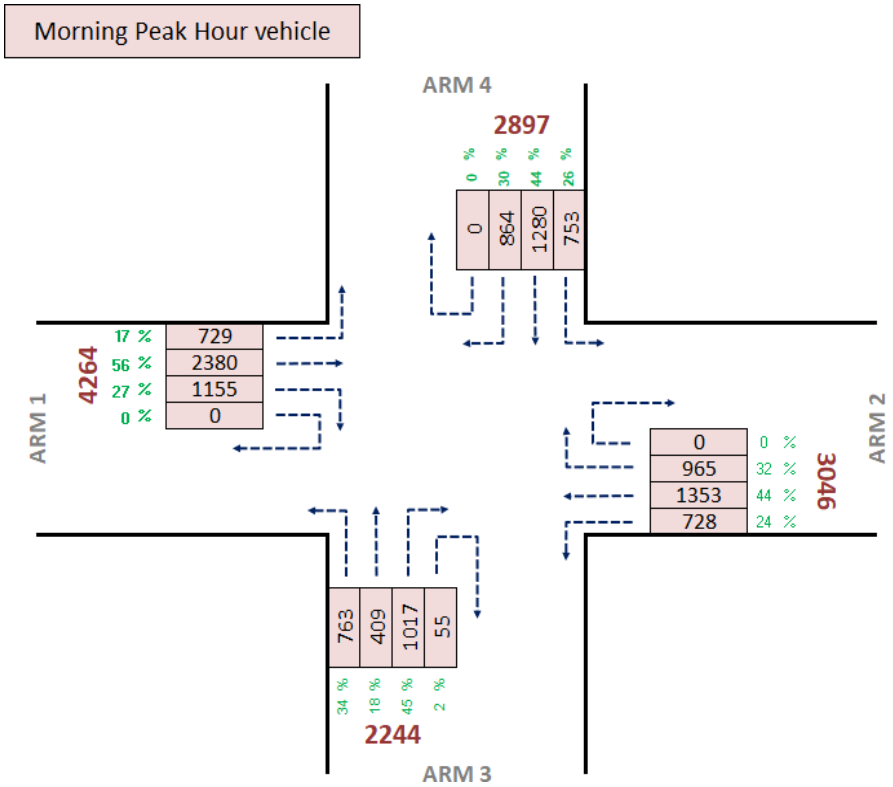

Figure 2 - AM Peak- Traffic Data Collection for the study intersection (Warje Chowk)

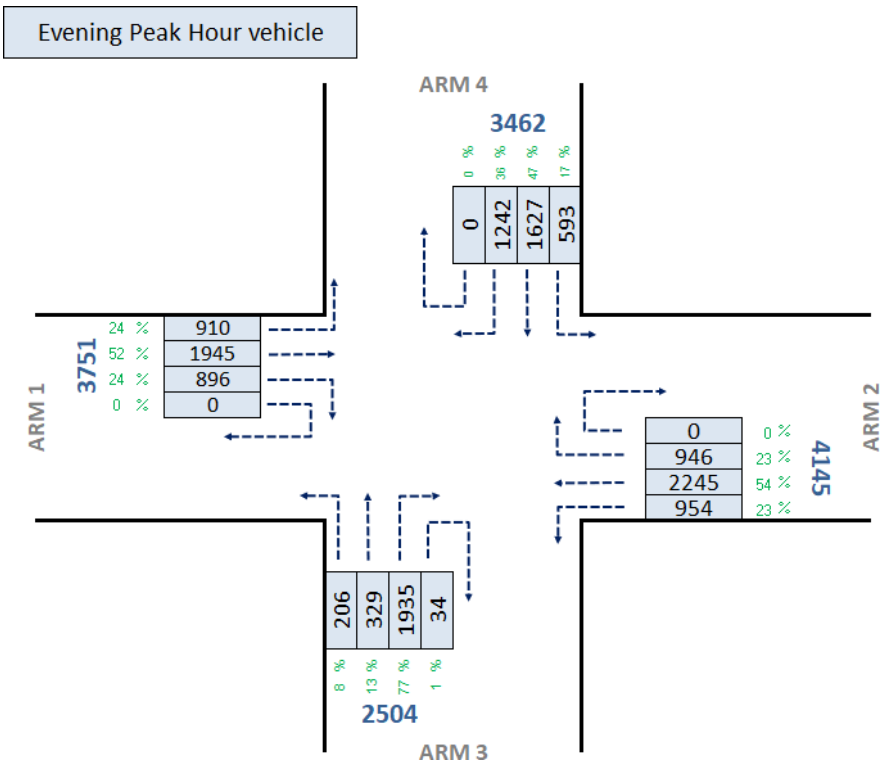

Figure 3 - PM Peak- Traffic Data Collection for the study intersection (Warje Chowk)

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III. METHODOLOGY

Based on the turning volume summary, the volume inputs were given to the junction model. The following section presents the methodology to code an intersection in SuMO. Intersection coding as per the existing roadway conditions, and the traffic parameters such as speed decisions and the turning volume per hour was coded as per the traffic data available.

Junction Coding:

In SUMO (Simulation of Urban MObility), a "junction" is the network element representing an intersection, defined in XML files with tags like <junction> and various attributes including id, type, x, y, incLanes, intLanes, and shape. You can create and modify junctions using the netedit tool, which provides a graphical interface for designing road networks, or by manually editing the XML files. Junctions can be plain, act as traffic lights, or have other specific functions like merging, and their type determines the right-of-way rules at the intersection.

The code is as follows:

```
<junction id="<ID>" type="<JUNCTION_TYPE>" x="<X-POSITION>" y="<Y-POSITION>" incLanes="<INCOMING_LANES>" intLanes="<INTERNAL_LANES>" shape="<SHAPE>">
  <!-- requests -->
</junction>
```

The code terminologies which have been used from the TraCI library of the python are as follows:

- id: A unique identifier for the junction.
- type: Specifies the kind of intersection, such as priority (default), traffic_light, zipper (for late merging)
- x, y: The Cartesian coordinates of the junction's center.
- incLanes: A list of incoming lane identifiers that connect to this junction.
- intLanes: A list of internal lane identifiers within the junction itself.
- shape: Defines the geometric shape of the junction, which can be important for detailed modeling

In SuMO.gui interface, there are two ways of creating the junction. Creating and Editing Junctions has two possible ways as mentioned below:

- **Using <u>netedit</u>:**

The graphical tool netedit allows you to visually construct and edit road networks. You can add junctions, adjust their positions, and set their types, which is often easier than manual XML editing.

Using the netedit tool directly looks like this, as mentioned in the following table, where we can add or subtract the road network as per the requirement:

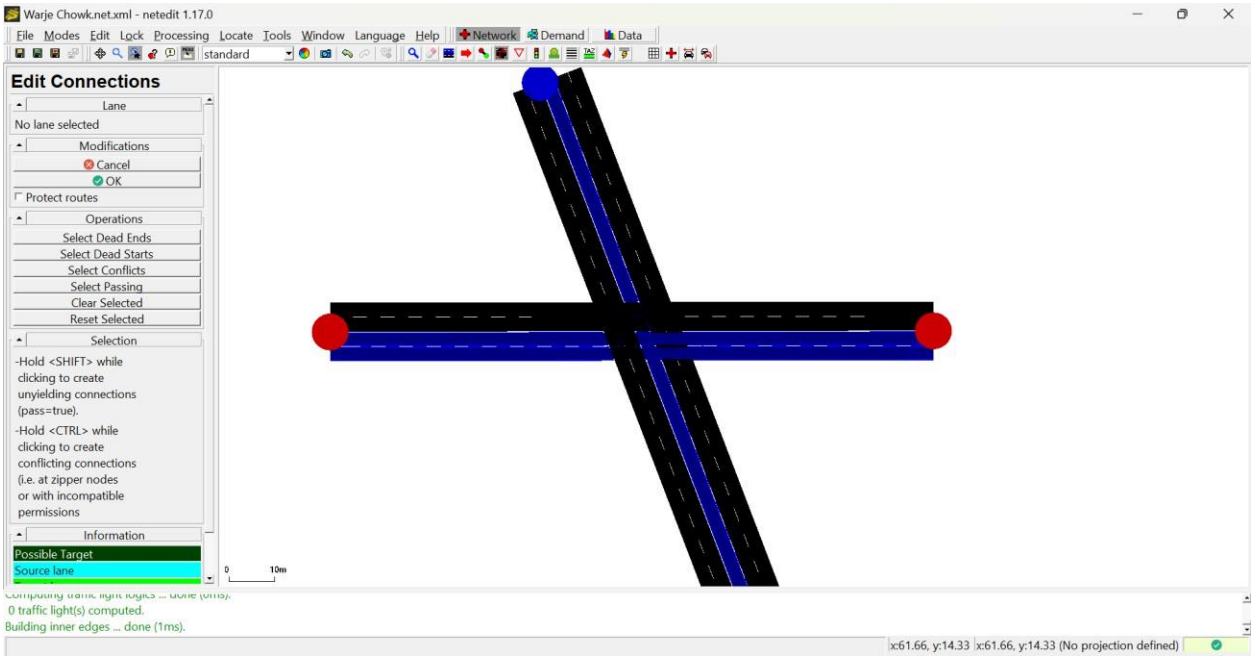

Figure 4 Network Layout from netedit tool window

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- **Manual XML Editing:**

You can directly edit the .net.xml file in a text editor to define junctions, their properties, and their connections to other road elements like edges and lanes.

Generally, road networks in sumo are represented as graphs in SUMO. An intersection ("node") consists of incoming and outgoing edges, where an "edge" represents a road with one or more lanes. Each lane has a unique id which is derived from the edge id and the numerical index. However, the finally processed junction will look like this in sumo:

Outputs and Results- Comparisons

AM Peak:

Movement Performance - Vehicles

Mov ID	Turn	Demand Flows Total veh/h	Demand Flows HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance m	Prop. Queued	Effective Stop Rate	Aver. No. Cycles	Average Speed km/h
SouthEast: Towards Navale Bridge Rd_NB												
21a	L1	811	0.0	0.323	27.0	LOS C	29.8	208.5	0.70	0.76	0.70	41.1
22	T1	457	0.0	0.323	39.0	LOS D	29.8	208.5	0.87	0.73	0.87	36.6
23b	R3	1158	0.0	0.990	73.3	LOS E	79.8	558.9	1.00	0.99	1.23	27.2
Approach		2425	0.0	0.990	51.4	LOS D	79.8	558.9	0.87	0.86	0.99	32.4
East: Towards Kothrud Rd_WB												
4b	L3	748	0.0	0.998	77.4	LOS E	74.9	526.9	1.00	1.02	1.26	26.6
5	T1	1448	2.0	0.998	71.5	LOS E	74.9	526.9	1.00	1.07	1.26	27.4
6a	R1	949	0.0	0.998	75.7	LOS E	72.2	506.0	1.00	1.03	1.26	26.9
Approach		3146	0.9	0.998	74.2	LOS E	74.9	526.9	1.00	1.04	1.26	27.1
NorthWest: Towards Chandani Chowk Rd_SB												
27a	L1	802	0.0	0.919	57.5	LOS E	66.3	463.9	1.00	0.93	1.09	30.9
28	T1	1285	0.0	0.919	55.2	LOS E	66.3	463.9	1.00	0.95	1.10	31.3
29b	R3	860	0.0	0.969	72.6	LOS E	57.4	401.8	1.00	0.96	1.23	27.3
Approach		2947	0.0	0.969	60.9	LOS E	66.3	463.9	1.00	0.95	1.13	29.9
West: Towards Shivane Rd_EB												
10b	L3	757	0.0	0.988	69.0	LOS E	94.5	666.5	1.00	1.02	1.20	28.6
11	T1	2411	2.0	0.988	62.4	LOS E	97.3	683.4	1.00	1.03	1.19	29.4
12a	R1	1128	0.0	0.988	66.5	LOS E	97.3	683.4	1.00	1.01	1.19	29.0
Approach		4296	1.1	0.988	64.7	LOS E	97.3	690.7	1.00	1.02	1.19	29.1
All Vehicles		12815	0.6	0.998	63.6	LOS E	97.3	690.7	0.98	0.98	1.16	29.3

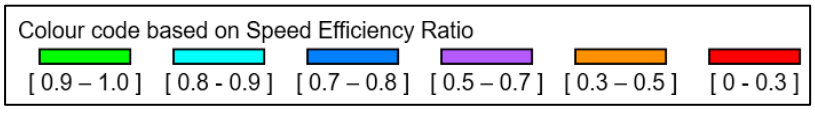
PM Peak:

Movement Performance - Vehicles

Mov ID	Turn	Demand Flows Total veh/h	Demand Flows HV %	Deg. Satn v/c	Average Delay sec	Level of Service	95% Back of Queue Vehicles veh	95% Back of Queue Distance m	Prop. Queued	Effective Stop Rate	Aver. No. Cycles	Average Speed km/h
SouthEast: Towards Navale Bridge Rd_NB												
21a	L1	213	0.0	0.119	41.7	LOS D	13.9	97.0	0.77	0.71	0.77	35.6
22	T1	363	0.0	0.119	38.5	LOS D	13.9	97.5	0.78	0.65	0.78	36.5
23b	R3	1861	0.0	0.933	57.7	LOS E	119.7	838.1	1.00	0.91	1.00	30.7
Approach		2437	0.0	0.933	53.4	LOS D	119.7	838.1	0.95	0.85	0.95	31.8
East: Towards Kothrud Rd_WB												
4b	L3	1105	0.0	0.198	10.6	LOS B	18.8	131.5	0.28	0.69	0.28	50.3
5	T1	2293	2.0	1.093	100.8	LOS F	205.6	1463.7	1.00	1.19	1.36	22.0
6a	R1	978	0.0	0.465	50.3	LOS D	54.5	381.8	0.91	0.83	0.91	33.0
Approach		4376	1.0	1.093	66.7	LOS E	205.6	1463.7	0.80	0.99	0.99	28.1
NorthWest: Towards Chandani Chowk Rd_SB												
27a	L1	644	0.0	0.658	57.4	LOS E	68.1	476.6	0.98	0.86	0.98	31.1
28	T1	1569	0.0	0.658	53.9	LOS D	68.1	476.6	0.99	0.86	0.99	31.6
29b	R3	1271	0.0	0.920	66.5	LOS E	85.0	594.7	1.00	0.89	1.03	28.6
Approach		3484	0.0	0.920	59.2	LOS E	85.0	594.7	0.99	0.87	1.00	30.4
West: Towards Shivane Rd_EB												
10b	L3	911	0.0	0.920	66.6	LOS E	83.9	590.0	1.00	0.90	1.04	28.9
11	T1	1980	2.0	0.920	61.6	LOS E	84.9	597.0	1.00	0.90	1.03	29.6
12a	R1	901	0.0	0.920	66.0	LOS E	84.9	597.0	1.00	0.89	1.03	29.2
Approach		3792	1.0	0.920	63.8	LOS E	84.9	602.7	1.00	0.90	1.03	29.3
All Vehicles		14088	0.6	1.093	61.8	LOS E	205.6	1463.7	0.93	0.91	1.00	29.6

The movement results from the analysis of the junction are as follows:

Travel Speed at Junction- Quality Thresholds



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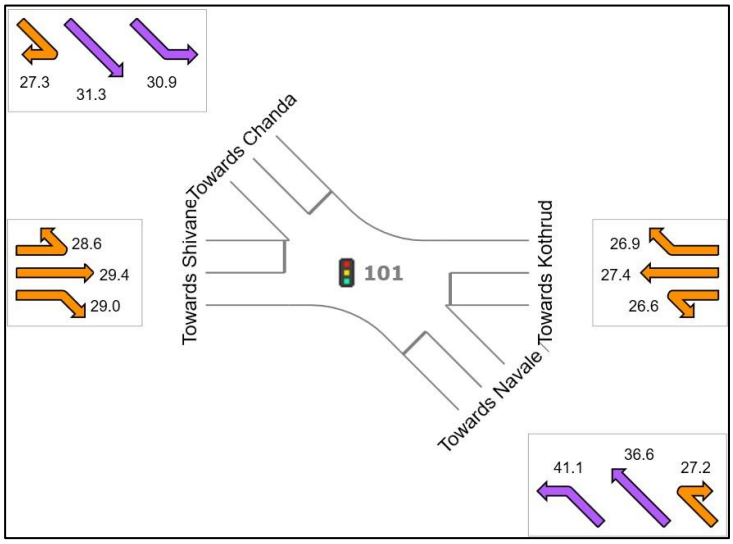
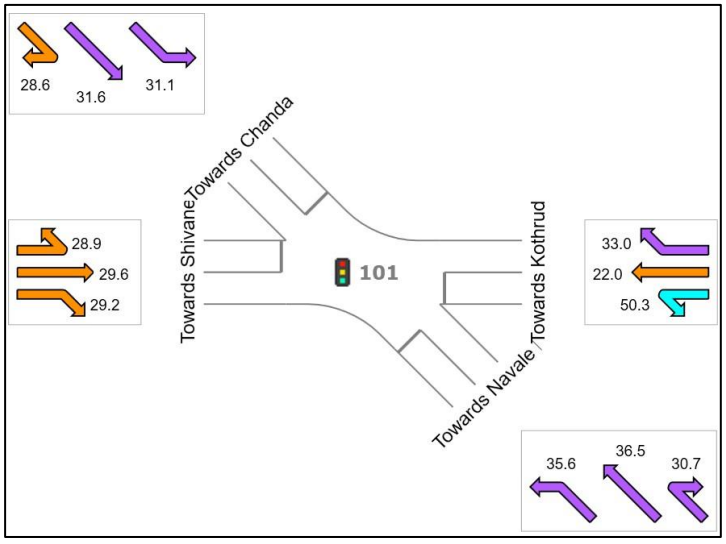
Travel Speed: AM Peak

	Approaches				Intersection
	Southeast	East	Northwest	West	
Travel Speed	32.4	27.1	29.9	29.1	29.3

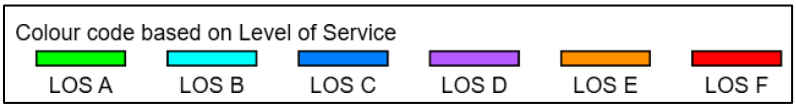


Travel Speed: PM Peak

	Approaches				Intersection
	Southeast	East	Northwest	West	
Travel Speed	31.8	28.1	30.4	29.3	29.6



Average Control Delay at Junction- Quality Thresholds



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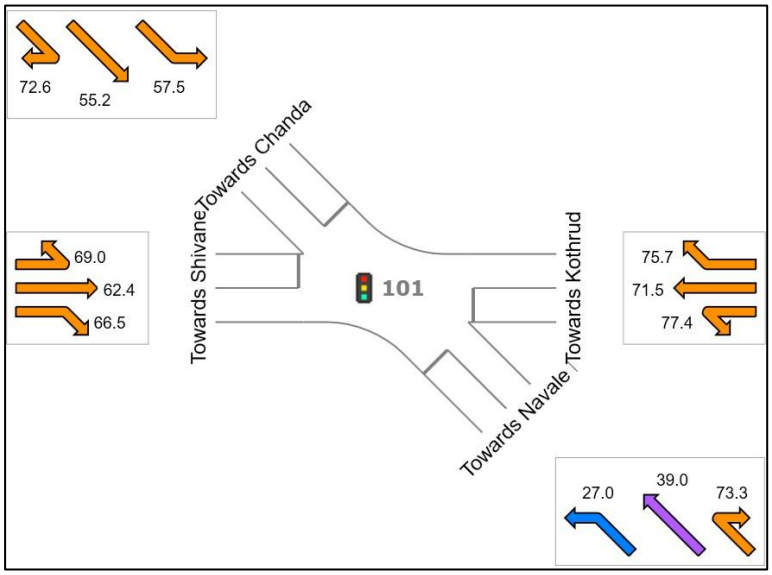
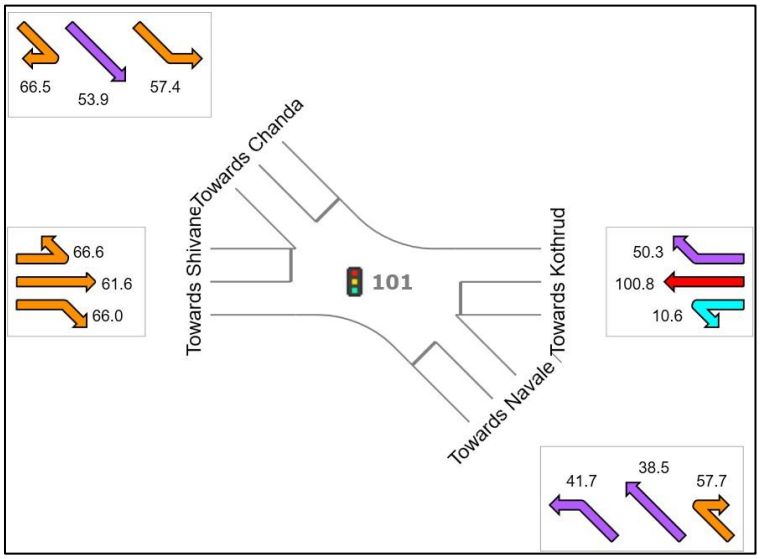
Average Control Delay: AM Peak

	Approaches				Intersection
	Southeast	East	Northwest	West	
Delay (Control)	51.4	74.2	60.9	64.7	63.6
LOS	D	E	E	E	E



Average Control Delay: PM Peak

	Approaches				Intersection
	Southeast	East	Northwest	West	
Delay (Control)	53.4	66.7	59.2	63.8	61.8
LOS	D	E	E	E	E



Comparative Analysis: CO2 levels at morning & evening peak hour timeframes CO2 Levels- AM Peak

	Approaches				Intersection
	Southeast	East	Northwest	West	
CO2 (Total)	575.3	835.6	724.5	1112.9	3248.4

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CO2 Levels- PM Peak

	Approaches				Intersection
	Southeast	East	Northwest	West	
CO2 (Total)	582.8	1150.7	843.3	964.4	3541.2

IV. CONCLUSION

This paper presents a comprehensive intersection analysis system that combines computer vision techniques with traffic micro-simulation. An intersections site from Warje, Pune- India was considered to monitor the movement of vehicles. The intersection was coded using Netedit extension of the tool. The traffic data required for the traffic demand at the AM & PM Peak hours of the days was collected.

Further to the well-developed junction in sumo, the comparison between the morning and evening peak hour was performed using the traffic parameters such as control delay, queue length, CO2 levels, etc. A detailed table illustrating the approach wise data outputs for the junction is also extracted for individual peak. Experimental results demonstrate that the junction performs well for AM Peak, instead of PM peak. The PM peak has the exceeded or over-riden outputs as compared to AM Peak. However, further detailed investigation can be done with strategic inputs and target outputs for the desired parameters.

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