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MEZOSIMULATION ANALYSIS OF TRAFFIC FLOW AT CLOSELY SPACED PRIORITY-CONTROLLED INTERSECTIONS [15]

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Abstract: *This study describes a mezosimulation investigation of traffic flow at three closely spaced priority-controlled crossings using PTV VISSIM software. Along a main metropolitan roadway of a “T & Y” crossing and one standard intersection are modeled, with priority control applied to each. The goal is to assess network performance using important traffic parameters such as Level of Service (LOS), delays, queue lengths, and volume-to-capacity ratios in idealized conditions. The simulation runs various traffic scenarios to determine how closely spaced intersections affect traffic flow and congestion. The findings indicate that the spacing and type of crossings significantly affect traffic delays and queue lengths, with closely spaced intersections causing cascading delays due to upstream congestion influencing downstream traffic flow. These findings shed light on how to optimize priority-controlled crossings for better traffic management and network performance in urban contexts.*

Keywords: *Traffic, Modelling, Simulation, Mezosimulation, Traffic Flow Analysis, Priority-Controlled Intersections, PTV VISSIM, Level of Service (LOS), Intersection Delays, Queue Lengths, Volume-to-Capacity Ratio (v/c), "T" Intersections, Urban Traffic Management, Intersection Spacing, Traffic Efficiency, Network Performance, Congestion Analysis.*

INTRODUCTION

This study investigates the traffic flow performance at three closely spaced priority-controlled intersections using PTV VISSIM mezosimulation software, due to its proven effectiveness in modeling of traffic flows as highlighted by Fellendorf and Vortisch (2010). The modeled roadway includes one "T", one "Y" and one standard intersection, all situated along a standard two-lane collector street in an idealized urban environment. By examining key traffic parameters such as Level of Service (LOS), delays, queue lengths, and volume-to-capacity ratios, this research aims to provide valuable insights into how intersection design and spacing influence overall network efficiency.

The study seeks to demonstrate the substantial benefits of employing traffic simulation technologies to pinpoint critical management triggers that might aid transportation authorities in enhancing the efficiency of road networks. The research offers actionable insights through the modeling and analysis of diverse traffic situations, facilitating evidence-based decision-making, optimizing traffic management tactics, and ultimately enhancing the efficiency and capacity of urban transportation systems. The results will provide a basis for formulating proactive strategies to mitigate traffic congestion, reduce delays, and facilitate a more efficient vehicular flow under varying situations.

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EXPOSITION

Urban traffic management is a critical challenge that cities worldwide are confronted with, as the pressure on road networks increases due to the expanding populations and vehicle use. The design and spacing of intersections, particularly in high-traffic metropolitan areas, are among the primary factors that influence traffic flow efficacy (Milevich et al., 2016). Priority-controlled intersections provide a cost-effective solution for traffic management by prioritizing specified traffic streams over signal-based control. Nevertheless, in order to comprehend the dynamics of congestion, delays, and queue formation, a comprehensive analysis of the interaction between closely spaced intersections and their collective impact on network performance is necessary (Łach & Svyetlichnyy, 2024).

Understanding street capacities is crucial for traffic simulations. In Bulgaria there are many old towns and due to their unique urban structures, many of the streets are substandard in comparison to the contemporary street designs. Many traditional Bulgarian cities have small, winding streets, confined spaces, and limited growth potential, making traffic flow and management difficult. But also, in the big cities there is often a need to adjust the capacity of the streets during the modeling process due to some of the following circumstances:

- Adjusting to Historical Street Dimensions – cities like Plovdiv, Veliko Tanovo and others have many collector roads that are intercepted by historical narrower streets, which naturally are limiting vehicle throughput and capacity. These lowered capacities must be accurately defined in a simulation to match true traffic restrictions. But it is also important to understand how those natural bottlenecks are affecting the efficiency of the main streets and this can be easily implemented with accurate traffic flow simulations.
- Seasonal Traffic Peak Management – during the tourism season, traffic in Bulgarian old towns increases significantly. To estimate how more vehicles would affect intersections and road networks, particularly on narrow, priority-controlled roads, street capacity must be known. Simulations can assist authorities in estimating peak congestion periods, allocating resources, and implementing temporary traffic management measures to alleviate seasonal traffic needs by using accurate capacity data.
- Simulating Close-Quarters Intersections – traditionally the Bulgarian towns have tightly spaced crossroads with distinct street shapes and capacity constraints, which exacerbates traffic. Effective modeling capacity enables accurate simulation of intersection interaction effects, which is critical in areas where preservation restrictions prohibit street layout alterations. Simulations based on reliable capacity data can uncover congestion concerns and offer operational improvements such as adaptive priority control for managing traffic inside ancient urban structures.

This simulation was conducted in an idealized urban area, free of pedestrians walking across the streets, devoid of motorbikes and bicycles, with no structures obscuring vehicles' vision at intersections. The simulated roads (fig.1) comprise of five distinctive two-lane streets (fig.2) – a collector street connected with three priority-controlled intersections (conventional four-way, a ‘T’ and a ‘Y’ crossroads).

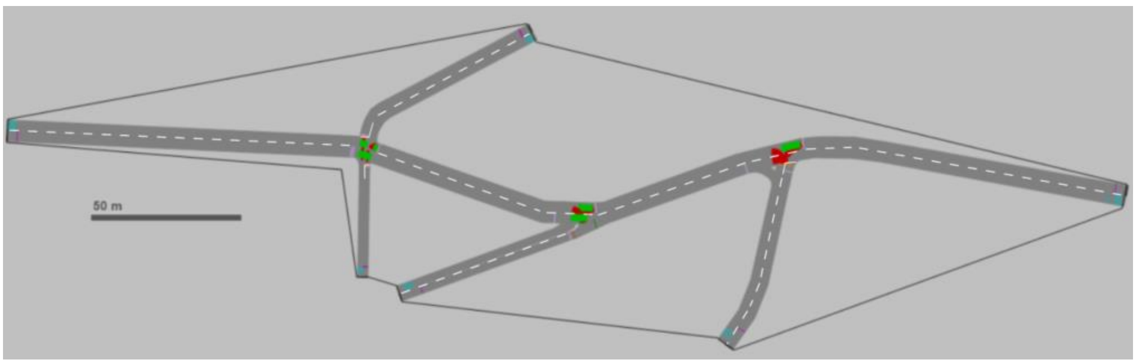

Fig.1 Model overview

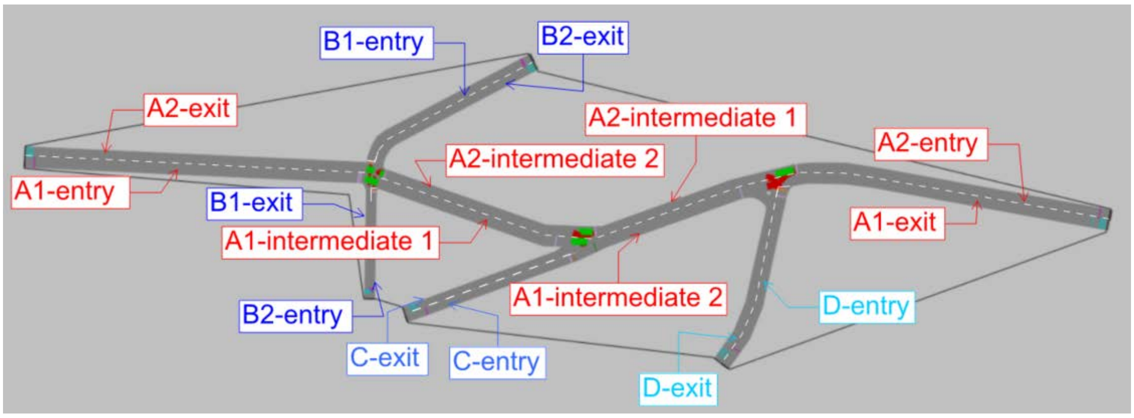

Fig.2 Cartographic representation of streets

The lane width of each of the streets is defined as:

- 3.75m for ‘A1’ and ‘A2’ entry, intermediate and exit sections;
- 1.75m for ‘B1-exit’ and ‘B2-entry’ sections;
- 2.85m for ‘B1-entry’ and ‘B2-exit’ sections;
- 2.50m for ‘C-entry and exit’ sections;
- 3.00m for ‘D-entry and exit’ sections.

The geometrical characteristics of the modeled intersections and the spacing between them is depicted on fig.3. Each intersection is intentionally positioned to impact the dynamics of the

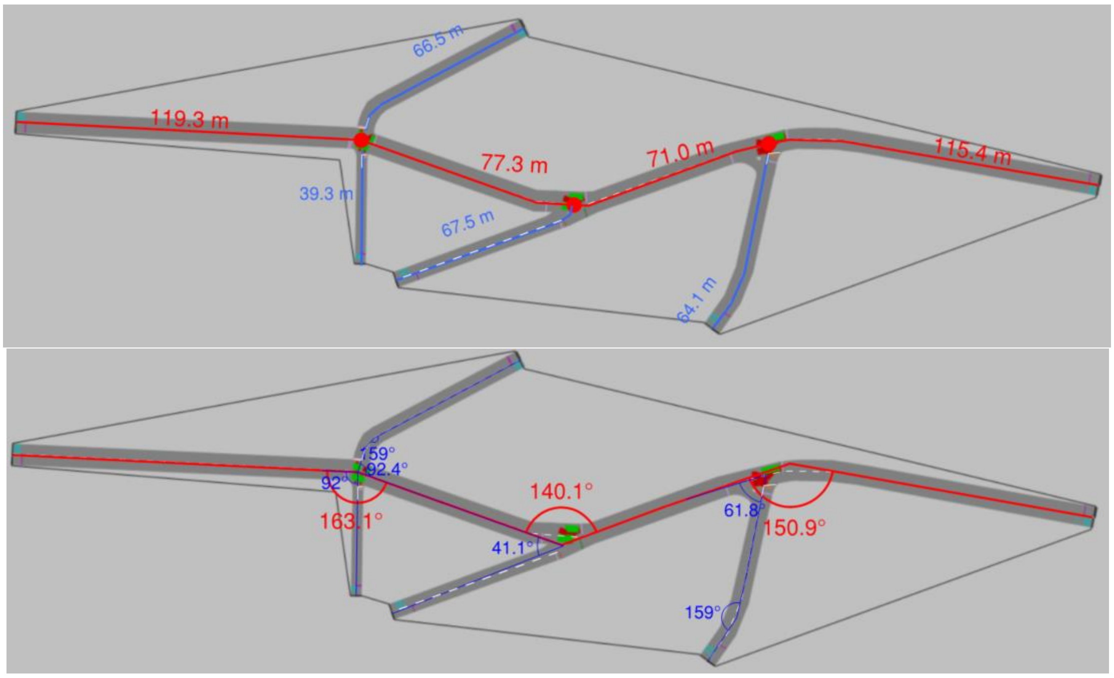

Fig.3 Intersections spacing and angular approaches

traffic flow and it is establishing a distinct interaction zone where queues from one intersection can affect the behavior of the drivers at the subsequent one. This study employs the following precise measurements for intersection spacing:

- 1st Intersection (roads ‘A&B’ is a conventional 4-way crossroad positioned 119.3m from the starting location of the model. This intersection is the principal entrance point for cross-traffic into the main roadway and sets the baseline for traffic flow analysis at future intersections, and it is controlled with a “STOP” sign.
- 2nd Intersection is type ‘Y’ (roads ‘A&C’), controlled with “GIVE WAY” sign and it is located 77.3 meters downstream from the 4-way crossroad, has a distinctive traffic flow pattern due to its geometry, which usually makes merging smoother but may cause delays

when vehicle volumes increase. Under high traffic loads, queue spillover from the 4-way intersection is increased by the short distance to this intersection.

- 3rd Intersection is type ‘T’ (roads ‘A&D’) controlled with a “STOP” sign, and it is prioritizing the main route over the intersecting road 71 meters after the "Y" intersection further restricts traffic flow. In peak traffic, delays from the "T" intersection can propagate backward to the "Y" junction due to its proximity.

The roadway extends 115.4 meters beyond the "T" intersection, where the end of the model is located, which is allowing lines to dissipate and traffic flow to recover as vehicles approach the end of the simulation area. Hence, the total modeled roadway is 620.4 m where 38% of it is secondary roadways.

The Highway Capacity Manual (HCM) offers standardized methods for assessing the capacity of roadways. The general formula for calculating the Base Capacity (C_{base}) of a lane on an urban street segment is as follows:

$$C_{base} = V_s * f_w \quad (1)$$

Where:

- V_s is the standard volume (also known as ‘base flow’ or ‘base flow rate’), i.e. the number of vehicles per unit time passing a given point on a road under ideal conditions, often given as 1,900 to 2,000 vehicles per hour per lane (v/h/l) for urban streets.
- f_w is an adjustment factor for lane width (addresses lanes that are either larger or smaller than the standard width).

The HCM standards recommend a standard lane width of 3.5 meters for urban streets to ensure optimal vehicle flow and driver comfort. It is widely considered that highways with this lane width allow for the best vehicle throughput, a s drivers may move comfortably without feeling constrained. This breadth also provides for the smooth movement of passenger automobiles and light trucks. As the lane widths of the model differ from this standard, the capacity needs to be adjusted to reflect the practical impact of narrower and wider lanes on vehicle throughput. Therefore, the narrower lanes on the secondary roads will have reduced capacity because drivers are more cautious, often driving at lower speeds and allowing more space between vehicles to avoid collisions. Where slightly wider lanes on the collector street can enhance capacity, as drivers feel more at ease and can maintain consistent speeds with less lateral displacement.

Based on HCM concepts and practical traffic engineering research, the adjustment factor requires refinement for each 0.5-meter deviation from the standard 3.5 meters lane width “W” with 5% reduction, or increase as needed:

$$f_w = 1 - 0.05 * (3.5 - W) \quad (2)$$

The idealized lane capacities based on width variations for this model are shown in table-1.

Table-1. Base capacity for each lane of the model

Lane	**Width** (m)	**Standard Volume** (v/h/l)	**Adjustment Factor**	**Base Capacity** (v/h/l)
A1 and A2	3.75	2000	1.013	2025
B1-exit, B2-entry	1.75	2000	0.913	1825
B1-entry, B2-exit	2.85	2000	0.968	1935
C-entry and exit	2.50	2000	0.950	1900
D-entry and exit	3.00	2000	0.975	1950

In the simulation, there are four different scenarios (table-2), each with a different proportion of Light Vehicles (LVs), Large Goods Vehicles (LGVs ≤ 3500 kg), and Heavy Goods Vehicles (HGVs > 3500 kg). Additionally, the simulation makes use of the modeled infrastructure at a gradient distance of 0%. The most important entry points in the simulation model are A1, A2, and B1. They are significant for monitoring capacity and congestion because they handle more traffic. The secondary entry points (B2, C, & D) service lower volumes, contributing to flow with less intensity than primary entries.

Table-2. Simulation traffic composition

Simulation No.	Entry		Percentage of Vehicles		
	Primary	Secondary	LV	LGV	HGV
1	A1, A2 & B1	B2, C & D	93%	5%	2%
2	A1, A2 & B1	B2, C & D	80%	10%	10%
3	A1, A2 & B1	B2, C & D	70%	20%	10%
4	A1, A2 & B1	B2, C & D	70%	10%	20%

Simulation No.1 represents light business traffic scenario, with most vehicles being passenger cars. Cars cause less traffic congestion than big vehicles, hence the v/c ratio is likely lower. The lower LGV and HGV numbers indicate fewer flow disturbances and higher capacity utilization. In
The scenario in simulation No.2 is more balanced, but the LGVs and HGVs are more prevalent. This combination may indicate an urban region with moderate commercial vehicle activity. Simulation No.3 indicates a commercial area with increased medium-sized delivery vehicles, where simulation No.4 analyzes the impact of a high proportion of HGVs in the traffic mix.

Each simulation examines traffic flow under diverse demand scenarios, i.e. test models (TM) (table-3) to assess the network's resiliency, pinpoint out potential congestion areas, and provide methods for efficient traffic management across varied loads. This is especially advantageous for urban traffic management and can guide decisions about infrastructure planning and capacity management.

Table-3. Testing scenarios for the high and low demand street entries

Entry	Simulated Vehicles Volume (v/h/l)						
	TM-1	TM-2	TM-3	TM-4	TM-5	TM-6	TM-7
A1	50	100	200	400	600	800	1000
A2	50	100	200	400	600	800	1000
B1	50	100	200	400	600	800	1000
B2	50	50	50	50	50	50	50
C	50	50	50	50	50	50	50
D	50	50	50	50	50	50	50

The simulated volume of vehicles in table-3 encompasses LVs, LGVs, and HGVs. Consequently, it is essential to ascertain the proper Passenger Car Equivalent (PCE) for the purpose of the study and to determine the volume-to-capacity ratio (table-4). According to the HCM for urban roadways with a 0% gradient, typical PCE values are: 1.5 – 2.0 for LGVs, and 2.0 – 3.0 for HGVs.

Table-4. Volume-to-capacity (V/C) ratio for each individual street

Entry	Max Volume	Base Capacity	Simulation-1		Simulation-2		Simulation-3		Simulation-4	
	(v/h/l)	(v/h/l)	PCE	V/C ratio	PCE	V/C ratio	PCE	V/C ratio	PCE	V/C ratio
A1	1000	2025	1067.5	0.527	1225	0.605	1300	0.642	1375	0.679
A2	1000	2025	1067.5	0.527	1225	0.605	1300	0.642	1375	0.679
B1	1000	1935	1067.5	0.552	1225	0.633	1300	0.672	1375	0.711
B2	50	1825	53.4	0.029	61.3	0.034	65.0	0.036	68.8	0.038
C	50	1900	53.4	0.028	61.3	0.032	65.0	0.034	68.8	0.036
D	50	1950	53.4	0.027	61.3	0.031	65.0	0.033	68.8	0.035

These values assume average conditions without the effect of hills, typical lane widths, and standard urban traffic patterns. Because of the differences in lane widths, this study used the midpoint values for PCE conversion factors, i.e. 1.75 for LGVs and 2.5 for HGVs.

The literature has limited information regarding the derivation of LOS thresholds based on the v/c ratio (Othayoth & Rao, 2019). Numerous researchers have attempted to establish particular V/C ratio ranges to delineate each LOS type (fig.4); however, this process is not straightforward and can frequently be inaccurate. The main reason is the unpredictable characteristics of the traffic.

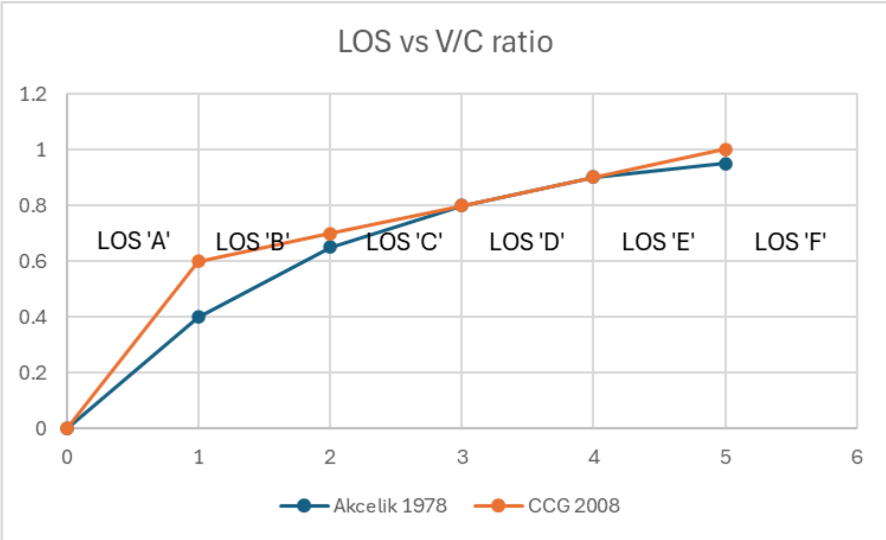

Fig.4 Example of suggested relationships between V/C ratio ranges and LOS

It is alluring to utilize the computed V/C ratios from Table 4 and designate LOS 'C' for entry B1 in Simulation 4, where V/C_{max} is approximately 0.7 and conclude that in this scenario the road users will be experiencing partial constraint flow (table-5). This action will be highly subjective, as noted by Akcelik (1978), since the definition of Level of Service (LOS) is partially a question of judgment rather than an exact science. The primary cause is that the delays do not align precisely with LOS grades, complicating the assignment of exact values (Zheng & Zuylen, 2010).

Table-5 Raham & Nakamura (2005) mixed traffic flow LOS categorization criterion

Level of service	Road user's understanding	Opportunity for passing-overtaking	Average speed of passenger cars (km/h)
LOS A	Smooth flow (LOS I)	No restriction to P/O	> 60
LOS B		Slight restriction to P/O	55 – 60
LOS C	Partial-constraint flow (LOS II)	More marked restriction to P/O	45 – 55
LOS D		Little freedom to P/O	35 – 45
LOS E	Constraint flow (LOS III)	Very little freedom to P/O	25 – 35
LOS F	Congested flow (LOS IV)	No opportunity to P/O	< 25

The computed v/c ratios, vehicle composition, and lane capacity modifications enable traffic simulations to reflect real-world intricacies, particularly in environments with heterogeneous traffic such as urban locales or historic towns with diverse road conditions, thereby preventing oversimplified and misleading performance assessments.

The simulated results of the PTV VISSIM mezosimulation software reveal how different traffic volumes impact performance across multiple movements (fig. 5 & fig.6). The outcomes for high-demand entry A1, A2, and B1 indicate a gradual reduction in LOS (from A to F) as vehicle traffic escalates, particularly in scenarios characterized by elevated proportions of LGVs and HGVs (e.g., the 70/10/20 vehicle composition). Secondary entries (B2, C, D) generally maintain a high Level of Service (often LOS A) under lower demand scenarios.

Movement	1 - 2: A1-Entry@0.1 - 1: D-Exit@55.5						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_C	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 2: A1-Entry@0.1 - 6: A1-Exit@110.3						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_B	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_C	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 2: A1-Entry@0.1 - 8: C-Exit@57.1						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_D	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 2: A1-Entry@0.1 - 12: B2-Exit@55.5						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 2: A1-Entry@0.1 - 14: B1-Exit@37.3						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 13: B1-Entry@0.6 - 1: D-Exit@55.5						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_D	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_D	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_D	LOS_C	LOS_B	LOS_B	LOS_A	LOS_A	LOS_A
70/10/20	LOS_E	LOS_D	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A

Movement	1 - 13: B1-Entry@0.6 - 6: A1-Exit@110.3						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_C	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_D	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_C	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_D	LOS_D	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 13: B1-Entry@0.6 - 8: C-Exit@57.1						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_C	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_C	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_C	LOS_D	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_D	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 13: B1-Entry@0.6 - 14: B1-Exit@37.3						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_F	LOS_C	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_E	LOS_D	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A
70/20/10	LOS_E	LOS_E	LOS_C	LOS_C	LOS_A	LOS_A	LOS_A
70/10/20	LOS_F	LOS_E	LOS_C	LOS_C	LOS_A	LOS_A	LOS_A

Movement	1 - 13: B1-Entry@0.6 - 16: A2-Exit@117.4						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_D	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 3: A2-Entry@0.6 - 1: D-Exit@55.5						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 3: A2-Entry@0.6 - 8: C-Exit@57.1						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 3: A2-Entry@0.6 - 12: B2-Exit@55.5						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 3: A2-Entry@0.6 - 14: B1-Exit@37.3						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 3: A2-Entry@0.6 - 16: A2-Exit@117.4						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 11: B2-Entry@0.1 - 1: D-Exit@55.5						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 11: B2-Entry@0.1 - 6: A1-Exit@110.3						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_E	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_B	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_B	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 11: B2-Entry@0.1 - 8: C-Exit@57.1						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 11: B2-Entry@0.1 - 12: B2-Exit@55.5						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 11: B2-Entry@0.1 - 16: A2-Exit@117.4						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Fig.5 Simulation results for entries ‘A’ and ‘B’

Movement	1 - 7: C-Entry@0.2 - 1: D-Exit@55.5						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_F	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 4: D-Entry@0.3 - 6: A1-Exit@110.3						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 7: C-Entry@0.2 - 6: A1-Exit@110.3						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_D	LOS_D	LOS_B	LOS_A	LOS_B	LOS_B	LOS_A
80/10/10	LOS_C	LOS_E	LOS_B	LOS_A	LOS_B	LOS_B	LOS_A
70/20/10	LOS_B	LOS_E	LOS_B	LOS_A	LOS_B	LOS_B	LOS_A
70/10/20	LOS_C	LOS_B	LOS_C	LOS_B	LOS_B	LOS_B	LOS_B

Movement	1 - 4: D-Entry@0.3 - 8: C-Exit@57.1						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 7: C-Entry@0.2 - 12: B2-Exit@55.5						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 4: D-Entry@0.3 - 12: B2-Exit@55.5						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 7: C-Entry@0.2 - 14: B1-Exit@37.3						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 4: D-Entry@0.3 - 14: B1-Exit@37.3						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_D	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_C	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_B	LOS_B	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_C	LOS_A	LOS_A	LOS_B	LOS_A	LOS_A	LOS_A

Movement	1 - 7: C-Entry@0.2 - 16: A2-Exit@117.4						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_F	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_C	LOS_E	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_D	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_C	LOS_D	LOS_C	LOS_A	LOS_A	LOS_A	LOS_A

Movement	1 - 4: D-Entry@0.3 - 16: A2-Exit@117.4						
Scenario	Main RD [Veh/hr]						
	1000	800	600	400	200	100	50
93/05/02	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
80/10/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/20/10	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A
70/10/20	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A	LOS_A

Fig.6 Simulation results for entries ‘C’ and ‘D’

In high-demand scenarios or with a substantial presence of LGVs and HGVs, these entry may see a decline in Level of Service to B or C. This suggests that secondary entry in the model can facilitate the primary flow with reduced congestion, but only at relatively low volume-to-capacity (V/C) ratios for particular streets, typically when volumes are below 40% of their inherent capacities. However, they are impacted by elevated traffic volumes and the presence of larger vehicles inside the network. Therefore, an intrinsic limitation of this study is that the simulations are restricted to low constant traffic levels from secondary entrants. Although calibration can enhance model accuracy, it would be difficult to achieve a precise real-world representation as it would be case-specific (Rrecaj & Bombol, 2015), whereas this paper takes a more generic theoretical problem-solving approach.

The validation of VISSIM in various situations (Fellendorf & Vortisch, 2001) improves the dependability of our simulation results, giving us confidence in the analysis of traffic flow and delay patterns observed in this study. The simulation results offer vital insights into urban traffic management. The intersection spacing and type have a considerable influence on network efficiency:

(1) Closely spaced intersections will result in cascading delays at higher traffic volumes, as upstream congestion impacts downstream traffic flow, leading to extended queues and diminished Level of Service (LOS) at numerous intersections.

(2) Intersection types (e.g., "T" intersections versus regular four-way) have an impact on overall flow, with "T" intersections generally performing better in terms of LOS, particularly in moderate traffic numbers. This is generally correct, because they involve fewer conflict points than four-way intersections, which often results in fewer delays and shorter queues.

(3) Standard four-way junctions with priority control exhibit greater delays, particularly under elevated demand and diverse traffic compositions. This is apparent in situations when primary movements (such as B1 to D-Exit) often attain Level of Service D or lower, underscoring the challenges these crossings face with heightened traffic volumes.

These findings emphasize the necessity for strategic planning in intersection design and spacing to successfully control urban traffic flow. Modifying intersection spacing or implementing "T" intersections in designated places may alleviate delays and enhance overall network efficiency, particularly in high-traffic metropolitan corridors. Additionally, the comprehensive analysis of Level of Service (LOS) for each movement and scenario establishes a basis for informed infrastructure decisions aimed at optimizing urban road network efficiency and mitigating congestion effects.

CONCLUSION

This research conducted a mezosimulation examination of traffic flow at closely situated, priority-controlled crossings utilizing VISSIM software. The results indicate the importance of intersection spacing and type on traffic delays, queue lengths, and Level of Service (LOS). The findings indicate that closely situated crossings are prone to exacerbating delays, as upstream congestion frequently affects downstream intersections. The simulations demonstrate that "T" crossings typically provide more efficient traffic flow compared to conventional four-way intersections under analogous situations. This is due to the diminished conflict spots in “T” crossings, which assist in alleviating delays and preserving a superior Level of Service (LOS). In situations characterized by a substantial presence of heavy goods trucks (HGVs), the level of service (LOS) deteriorated markedly, particularly at key access points such as A1, A2, and B1. Secondary entry, including B2, C, and D, exhibited greater LOS stability but were influenced by traffic loads on the primary roadway. These fluctuations highlight the significance of street and lane capacities in precisely forecasting congestion hotspots within metropolitan networks. The volume-to-capacity (V/C) ratio was crucial in determining thresholds at which Level of Service (LOS) begins to decline due to heightened traffic volumes. Seasonal traffic surges, especially in regions with historic and narrow thoroughfares, could be more efficiently regulated by modifying priority rules at junctions. This research provides significant insights for enhancing traffic flow in metropolitan areas with restricted growth capabilities. The investigation illustrates the efficacy of PCE adjustments for heterogeneous traffic compositions, enhancing the realism of simulation outcomes.

The findings indicate that urban planners ought to prioritize adaptive traffic management at crossroads characterized by a significant number of commercial vehicles. The study emphasizes the advantage of use simulation techniques to anticipate congestion and proactively regulate traffic volumes. Subsequent study may augment these findings by incorporating pedestrian flows, cycling traffic, and seasonal fluctuations to improve the model's applicability. The validation of VISSIM modeling methodologies substantiates the reliability of the simulations in accurately depicting real-world traffic patterns. This research endorses data-driven solutions to enhance urban mobility and alleviate congestion at vital crossings in contemporary and historical contexts.

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