

Enhancing the pedestrian crossing modeling with priority regulations in Vissim traffic simulation software

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Abstract — This study investigates the performance of the traffic simulation software Vissim in the context of pedestrian crossings. The primary aim was to analyze the functioning principles and limitations of priority regulation methods, compare their performance, and propose potential improvement options. Vissim provides two core methods for managing priority—conflict zones and priority rules. However, these approaches do not fully address real-world factors, such as noncompliance with priority rules and pedestrian's crossing decisions based on vehicle proximity. To overcome these limitations, we introduced an innovative methodology utilizing loop detectors placed at 10-meter intervals to monitor vehicle positions. This was combined with signal logic to simulate pedestrians' distance-dependent crossing decisions. The integration of real-world pedestrian decision-making processes into the simulation was validated through modifications to the software, and their impacts on key performance indicators - such as execution time and accuracy - were evaluated. The proposed approach provides a more realistic representation of pedestrian-vehicle interactions, significantly improving the accuracy and reliability of traffic simulations.

Index Terms — Traffic Simulation, Pedestrian Crossing, Crossing Decision Modeling, Control Logic, Priority Regulation

I. INTRODUCTION

PEDESTRIAN traffic is the most prevalent mode of transportation, functioning independently or as part of multimodal mobility chains. Pedestrian crossings are one of the most critical road infrastructures; ensuring safety and facilitating efficient traffic flow at the same time is challenging. However, they inherently involve safety risks. During road infrastructure planning, careful planning is necessary; not only considering safety issues but the impact of a pedestrian crossing on traffic flows. The usually applied tool is a traffic simulation software to determine the impacts. In order to achieve realistic simulation results, understanding the dynamics of pedestrians' crossing habits and the interactions between pedestrians and drivers is essential. In this study, the environment of a pedestrian crossing on a two-lane road was analyzed. The

primary objective was to model pedestrian crossing decisions according to reality, based on vehicle proximity, providing insights into pedestrian behavior under varying traffic conditions. As a limitation, the investigated environment was a simple unsignalized pedestrian crossing on a 2x1 lanes road.

Input data for the simulation was derived from a previous video-based survey conducted at a pedestrian crossing in Budapest (District 3, 80 Szőlő Street) [1]. The survey provided one-hour interval traffic data, disaggregated by direction, including pedestrian and vehicle counts. Driver yielding rates were recorded at 69%, aligning with a similar study from the Czech Republic (64%) under comparable traffic patterns [2]. Pedestrian demographic characteristics were categorized by gender (male, female) and age group (young, middle-aged, elderly). The crossing decision (cross or stop) was only influenced by traffic conditions.

The simulation model was developed using the collected data to evaluate the availability and suitability of priority regulation methods in traffic simulation software for modeling pedestrian crossings based on vehicle proximity. The Vissim software was selected as one of the most known and used traffic simulation tool. Moreover, Vissim is considered as a better tool for pedestrian modelling [3]. The novelty of the paper is the development of an alternative mechanism to model the vehicle distance-based crossing decisions of pedestrians, which are lacking in the current software. We implemented loop detectors on the road and signal-controlled pedestrian crossing, based on detector occupancy, utilizing the Vissim VisVAP module. This setup allowed for modeling the distance of approaching vehicles and the crossing decisions of different pedestrian groups. Autonomous vehicle technology is growing, and according to the expectations, fully autonomous vehicles will be on the road. This way their different driving characteristics should be modeled to explore their effect on traffic flow; particularly due to their rule-following behavior (unconditional yielding, adherence to speed limits). Accordingly, we considered autonomous vehicles besides human-driven vehicles. As precise distance measurements were unavailable,

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10-meter distance intervals were used to classify the nearest vehicle's distance at the moment of crossing decision. Five intervals were considered: 20-30 m, 30-40 m, 40-50 m, 50-60 m, and 60-70m, while the 0-20 m range was excluded since no pedestrian crossed when a vehicle approached within this distance.

Accordingly, a novel, vehicle distance-based pedestrian decision-making mechanism is introduced, enhancing the accuracy of crossing behavior simulations.

The structure of the paper is as follows: Section 2 summarizes the key findings from previous research and related literature. Section 3 presents the default settings for priority regulation in Vissim. In Section 4, we discuss the challenges encountered in modeling pedestrian crossing decisions and the solutions we applied to address them. In Section 5, we evaluate the model through a series of simulation runs and compare the key performance indicators. Finally, the concluding section summarizes our main contributions and findings.

II. LITERATURE REVIEW

Pedestrian crossings involve complex interactions influenced by various factors. Pedestrian behavior and risk-taking depend on demographics like age, gender [4], and whether they cross alone or in groups [5]. Driver behavior is similarly affected by factors like vehicle speed, which shows an inverse correlation with yielding tendencies [6][7], while drivers in vehicle platoons demonstrate a reduced likelihood to yield to pedestrians [8].

In crossing decisions, pedestrians evaluate vehicle time gaps or physical distances. The accepted time gaps identified by researchers are ranged from 5.2 to 9.4 [9][10][11]. However, research suggests pedestrians rely more on estimating vehicle distance than time gaps [12][13]. Therefore, in this study, we model the vehicle distance parameter.

Besides the actual crossing behavior, its traffic simulation modeling represents a key research focus. Studies distinguish crossing types: unsignalized crossings without refuge islands [14], unsignalized crossings with refuge islands [15], and signal-controlled crossings [16]. In Vissim software, crossing control is primarily implemented through conflict zones and priority rules. Dahlberg and Segernäs [17] provide an overview of these settings and their differences.

The VisVAP module of Vissim enables flexible definition of traffic signal control logics. It has been widely utilized in various studies for calibration of modeling tasks [18][19][20]. In our research, the VisVAP module was employed to regulate pedestrian crossing behavior.

III. DEFAULT PEDESTRIAN CROSSING CONTROL METHODS

Vissim provides two main methods to control priority at unsignalized pedestrian crossings: *conflict areas* and *priority rules*. Priority rules allow greater parameterization and improved simulation of pedestrian crossing decisions, also accounting for drivers' compliance rates. While conflict areas are the default recommendation, priority rules require more expertise and careful configuration.

A. Application of conflict areas

In the conflict area approach, one of the two intersecting directions is designated to have priority over the other. This method is easier to manage and more accurately reflects road user's behavior compared to priority rules. Vehicles from the subordinate direction calculate at each simulation step whether they can pass before the pedestrian arrives. If so, the vehicle continues its path, potentially accelerating. If not, it slows down and yields to the pedestrian. Braking is also applied if there is not enough space to clear the conflict area, such as in cases of congestion.

The yielding vehicle monitors the pedestrian's presence and calculates based on its speed and the pedestrian's speed whether there is sufficient time to cross within the default 3-meter detection area prior to the conflict zone (beginning of the pedestrian crossing) (Fig. 1). The program also ensures that the minimum time gaps are met (i) between the departing pedestrian and the front of the approaching vehicle ('front gap'), or (ii) between the rear of the departing vehicle and the approaching pedestrian ('rear gap'). By default, both gaps are set to 0.5 seconds.

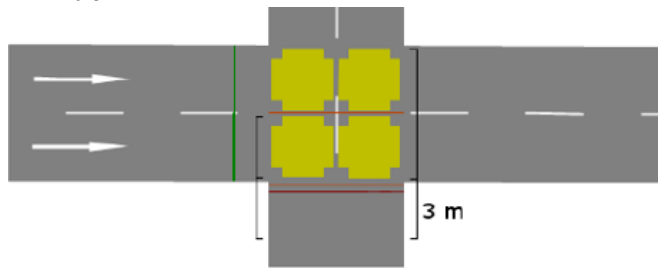


Fig. 1. Conflict area and its 3-meter detection zone (source: Vissim 2020 guide available in the software)

B. Application of priority rules

A more complex, yet more customizable alternative for regulating priority relationships is the setup of priority rules. To establish a priority rule, two markers must be placed within the model:

- Red marker (stop line): Vehicles from the subordinate direction must stop behind the stop line if a vehicle (pedestrian) from the primary direction is present in the clearance zone or if the minimum required crossing time is not met.
- Green marker (conflict marker): One or more conflict markers can be assigned with a stop line. The key parameters include the *clearance* and the *gap time*.

Fig. 3 illustrates the configuration of the priority rule. In this example, a 10-meter clearance is defined. If a vehicle in the primary direction is within this zone, vehicles from the subordinate direction must wait at the stop line. The minimum time gap is set to 3 seconds, allowing subordinate vehicles to proceed only if the primary vehicle takes longer than this to reach the conflict marker. A vehicle approaching from the primary direction, traveling at 50 km/h (14 m/s) and positioned 49 meters from the conflict marker, will reach it in 3.5 seconds, surpassing the 3-second threshold. Consequently, the subordinate vehicle is allowed to proceed, provided that by both the clearance and the time gap requirements are satisfied.

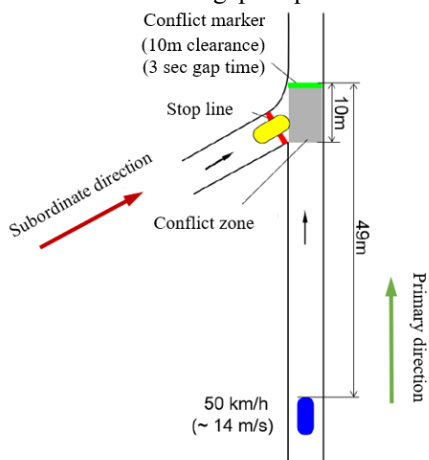


Fig. 3. Example illustrating the parameters for configuring priority rules (based on Vissim 2020 guide available in the software, edited by the authors)

During the model development, several challenges were encountered, as neither the conflict area setup nor the priority rules accounted for pedestrians' crossing decisions based on vehicle distance. Therefore, it was necessary to introduce an alternative regulatory logic that considers crossing decision mechanisms influenced by various pedestrian characteristics, such as gender and age group.

IV. METHODOLOGY: NEW MECHANISM FOR VEHICLE DISTANCE-BASED CROSSING DECISIONS AND PRIORITY RULES

A. Modifications in conflict area and priority rule configuration

The following challenges encountered when applying conflict zones:

- Configuring vehicle yield compliance rate is not supported.
- Pedestrians are unable to consider vehicle distance when making crossing decisions.

The application of priority rules enabled the configuration of vehicle yield compliance rates, allowing certain vehicles to adhere to or ignore the yielding obligation. Accordingly, a new vehicle type was set to represent non-yielding vehicles, and the priority rule was configured to apply to all vehicles except those classified as non-yielding.

When applying priority rules, the clearance was the primary parameter adjusted. The minimum time gap parameter was not considered, as the low speed of pedestrians often resulted in time gaps exceeding the minimum required by a vehicle. The

clearance was designed to reflect real-world conditions, extending beyond the road to account for approaching pedestrians (Fig. 2, left). Additionally, vehicles were allowed to accelerate when pedestrians reached the midpoint of the crossing from the near side (Fig. 2., right).

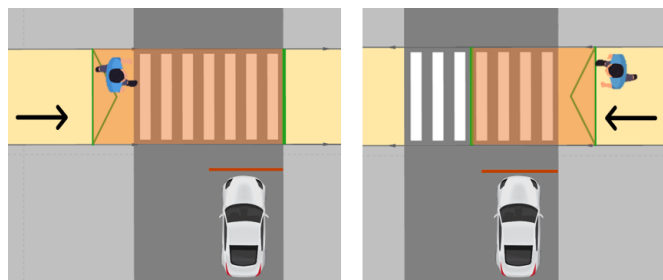


Fig. 2. Setting priority rule for yielding drivers

For non-yielding drivers, a new priority rule was implemented for safety reasons, requiring braking if a pedestrian has already stepped on the road. However, the clearance was not extended beyond the road.

Moreover, priority rules were also implemented for pedestrians, similarly to vehicles. Vehicle distances were modeled using segmentation: first, a 0-20 meter segment closest to the crossing, followed by 10-meter segments up to a distance of 70 meters from the crossing. The 0-20 meter segment was specifically excluded based on the road-side measurements used, as no pedestrian began crossing when a non-yielding vehicle was within 20 meters. In contrast, for vehicles approaching from distances greater than 70 meters, all pedestrians had already chosen to cross. Priority rules were applied to each segment, with the clearance set to 10 meters, in line with the segmentation. If a vehicle was present in a given segment, pedestrians were required to yield and stop at the edge of the crossing.

If the vehicle was at a specific distance from the crossing, some pedestrians chose to cross, while others stopped. Therefore, for each segment, we defined two distinct pedestrian types: those who adhered to the priority rule (stopped) and those who did not (crossed). This was applied for each pedestrian age group and gender. An additional assumption was made that pedestrians who crossed at a specific vehicle distance would exhibit the same behaviour at greater vehicle distances.

The simultaneous application of priority rules for both pedestrians and drivers revealed a new issue: pedestrians granted priority by nearby vehicles sometimes hesitated to cross due to distant vehicles (distance-based crossing decisions). This led to both the pedestrian and the vehicle remaining stationary, causing traffic congestion and terminating the simulation with errors. Consequently, priority rules were abandoned for modeling pedestrians' distance-based crossing behavior.

B. Integration of loop detectors and traffic signal control logic

To solve this issue, -as a novel approach, we utilized the Vissim VisVAP module to implement a traffic signal control logic based on loop detector sensing. The VisVAP module provides a graphical interface that allows for the definition of signal control logic using flowcharts. Signal control can be

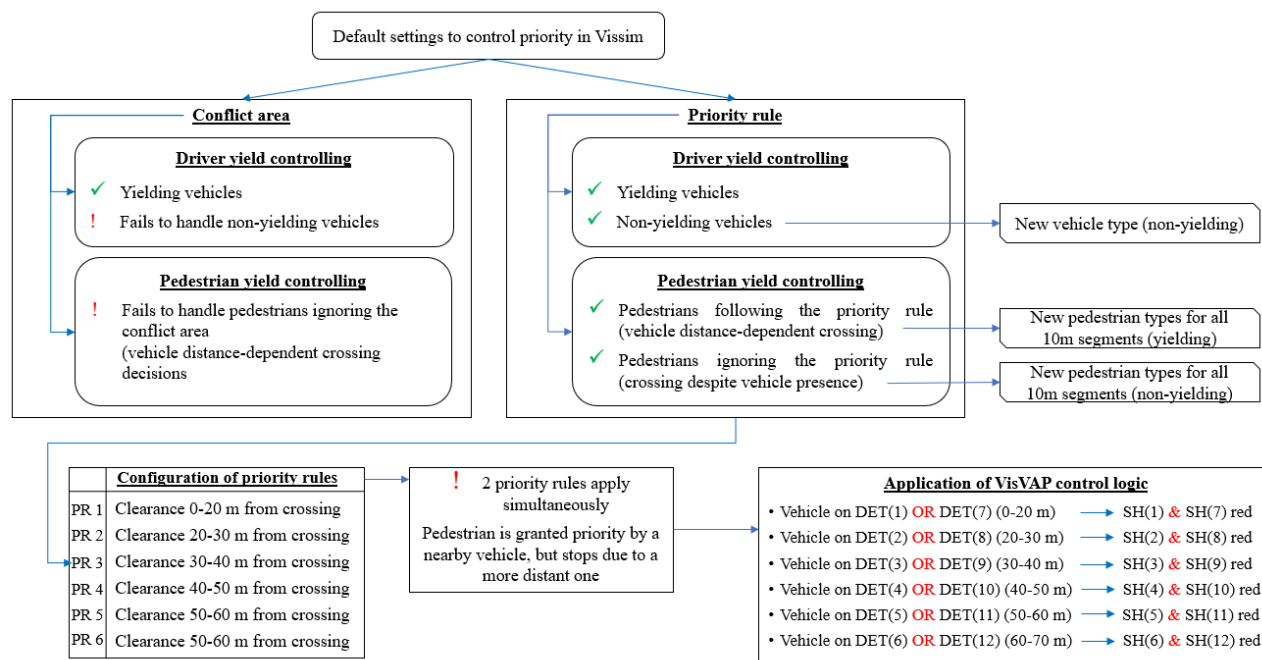


Fig. 4. Vissim calibration process for modeling pedestrian crossing decisions based on vehicle distance.

based on data provided by loop detectors placed within Vissim. The control logic created in VisVAP can be stored in a “.vap” file, which can then be directly imported into Vissim.

This method accounted for the distance of approaching vehicles and modeled pedestrian behavior. The loop detectors were positioned on the road following the segmentation described before. The primary priority control methods of Vissim, the identified challenges, and the key components of our enhanced priority control logic are summarized in Fig. 4.

In the vicinity of the pedestrian crossing, a total of 12 signal heads (6-6 on each side of the crossing) and 12 loop detectors (6-6 per directions) were installed in the physical model. Since the placement of the loop detectors and signal heads is symmetric on both sides of the crossing, the control of opposing signal heads in pairs was managed by a shared signal group. As a result, the 12 signal heads were controlled by 6 signal groups. For example, based on the occupancy of the 1st and 7th detectors, located 20 meters from the crossing, the 1st signal group controls the 1st and 7th signal heads at the two ends of the crossing. The 2nd and 8th detectors, located 20-30 meters away, monitor the area and trigger the 2nd signal group to control the 2nd and 8th signal heads. The remaining detectors and pedestrian signal heads function in a similar manner as the distance from the crossing increases. The distribution of the loop detectors, signal heads, and signal groups is shown in Fig. 5.

The control of signal groups was based on the vehicle detection (occupied/free) from the associated loop detectors. The occupancy state was checked in all simulation time steps, and the signal heads controlling pedestrians were adjusted accordingly.

For detectors 1 and 7, which monitor the 0-20 meter section closest to the crossing, both occupancy and vehicle speeds were considered. Vehicles entering this segment at speeds below 5

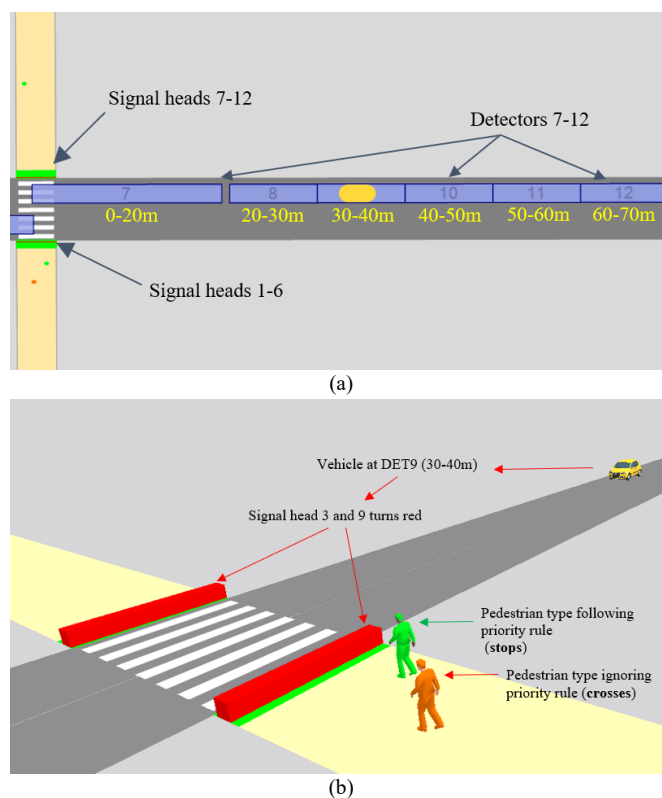


Fig. 5. Placement of loop detectors and signal heads (a). An example of the logic for a vehicle between 30-40 meters.

m/s were always assumed as yielding vehicles. In such cases, the pedestrian signal heads turned green. If yielding vehicles were present in the 0–20 meter segment from both directions, all signal heads switched to green. With this solution, we eliminated the issue of pedestrians waiting at the crossing despite receiving priority, due to a more distant vehicle's signal (previous priority rule issue). On the other hand, if a vehicle exceeds 5 m/s speed within the 0–20 meter segment, it was

classified as a non-yielding vehicle.

simulation. Based on pedestrian counts, we calculated crossing

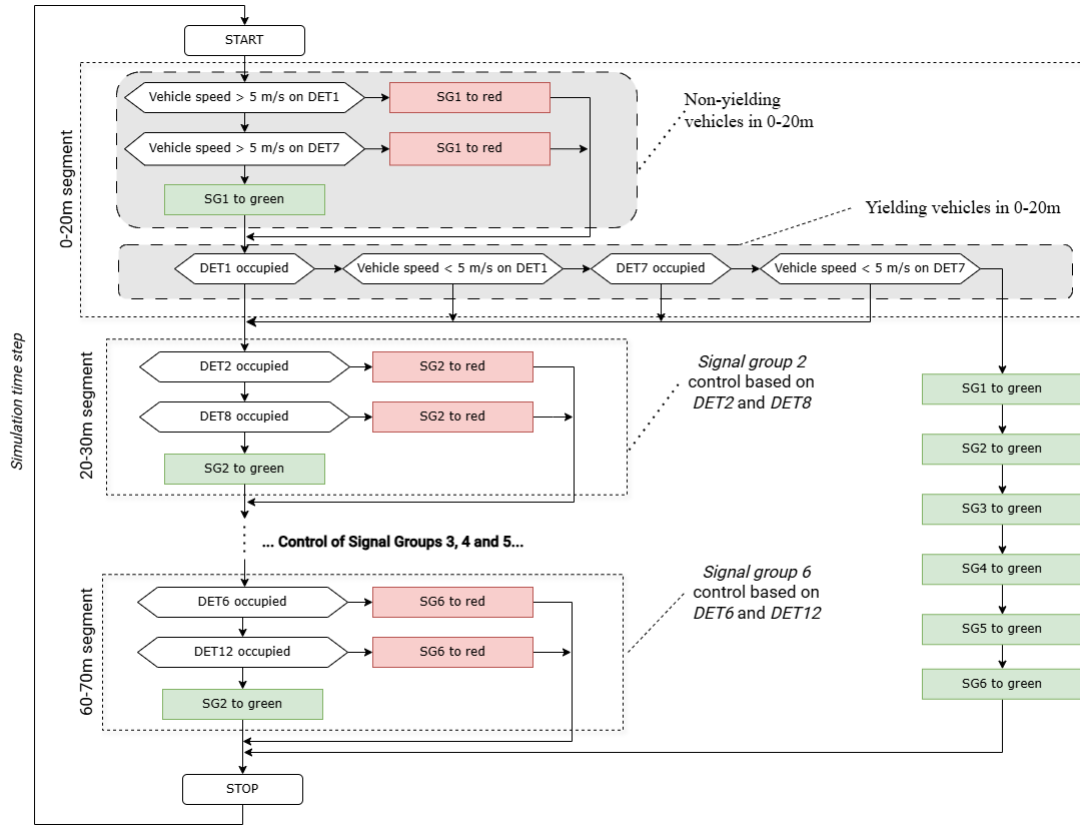


Fig. 6. Vehicle distance-dependent crossing control for pedestrians using VisVAP logic.

In such cases, signal group 1, associated with the 0–20 meter detectors, activated and switched signal heads 1 and 7 to red.

For detectors beyond 20 meters, only the presence of vehicles was assessed, and the control was applied accordingly. If a vehicle was detected on the respective detector from either direction (interpreted pairwise), the corresponding signal group was activated, and the two associated signal heads turned red. A pedestrian accepting a 40-meter vehicle distance, for example, would cross when encountering a vehicle in the 40-50 meter segment (detectors 4 and 10, by direction), but would receive a red signal and stop when encountering a vehicle in the 30-40 meter segment (detectors 3 and 9, by direction). The vehicle distance-based crossing logic for pedestrians built in VisVAP is illustrated in Fig. 6.

Autonomous vehicles were classified into three different vehicle classes, based on following distances of 50, 60, or 70 meters the kept. These gaps were considered sufficient for pedestrians to begin crossing between vehicles. The traffic was composed of either fully human-driven vehicles, fully autonomous vehicles, or a mixed traffic. In the mixed traffic scenarios, the proportion of autonomous vehicles was set to 25%, 50%, and 75%.

V. MODEL TESTING AND RESULTS

Following the development of the control logic, the model was evaluated through trial simulations. From the collected data [1], the discrete number of pedestrians was calculated for each demographic group and vehicle distance interval. This required the formulation of 60 distinct pedestrian classes in the

probabilities for each vehicle distance interval. For vehicles at 30-40 meters, 38-48% of pedestrians crossed, while at 60-70 meters, the crossing rate reached 90%.

The traffic distribution was approximated using a stochastic model. A total of 13 scenarios were considered, 1 baseline scenario with only human-driven vehicles and 12 scenarios with varying autonomous vehicle traffic rates (25%, 50%, 75%, and 100%). Each scenario was executed four times. Results showed that while higher autonomous vehicle traffic shares reduced pedestrian stops and delays (up to 29.24%-43.72%), on the vehicle side, travel times and stops increased gradually (up to 19.55%-20.95%).

The duration of the runs was 1 hour, with a 0.1 second time-step. The random seed parameter was set to 3 initially, with a step size of 2. The model parameters, including the speed thresholds used to classify yielding and non-yielding vehicles, were determined through a series of iterative simulation runs. During this process, speed values that led to unrealistic pedestrian behavior or conflicts between pedestrians and vehicles were excluded. It is important to note that these parameters were relevant within a 20-meter range from the crossing; beyond this, up to 70 meters, the data from the more distant loop detectors were used for control decisions.

We also examined the differences in runtime between the conflict zone, the priority rule, and our developed control logic (Table I). Simulations were run on a workstation with an Intel Core i5-6300 HQ CPU and 8 GB RAM. In the base model without scenarios, no runtime difference was observed between VISSIM default priority control methods, with both completing in 37 seconds. Running the scenarios showed a similar result,

with runtimes exceeding 8 minutes. With our control logic developed in the VisVAP module, the base version ran in 72 seconds, while the variations took 16 minutes. This is nearly double the runtime of the basic settings, but it resulted in a more realistic model.

TABLE I
SIMULATION RUNTIME REQUIREMENTS WITH DIFFERENT PRIORITY CONTROL METHODS

Priority control methods	Baseline case runtime [min:sec]	Runtime of 12 scenarios [min:sec]
Conflict zone	0:37	8:28
Priority rule	0:37	8:16
Control logic (VisVAP)	1:12	16:02

VI. CONCLUSION

In this study we introduced a novel mechanism to model the vehicle distance-based crossing decisions of pedestrians and priority rules at an unsignalized pedestrian crossing in the Vissim traffic simulation software. Two priority control methods available in the default settings were examined: conflict zones and priority rules. Our analysis revealed that the conflict zone method did not account for drivers' willingness to yield, and pedestrians could not factor in vehicle distance when making crossing decisions. The priority rule method allowed pedestrians to consider vehicle distance by adjusting the clearance parameter, but in some cases, conflicts between priority rules for vehicles and pedestrians caused the simulation to fail.

To address these limitations, we introduced an innovative approach using the VisVAP module, which incorporated loop detectors and signal control logic to model vehicle distance and pedestrian decisions. After the testing of the method developed, we found that the running time is doubled between Vissim's default priority control methods and the developed control logic. However, this new model, based on distance-based pedestrian decision-making, provides a more accurate representation of reality. Although the perceptual reliability of distance versus time gap remains debated, prior studies [12][13] suggest pedestrians rely more on vehicle distance. Based on these findings and our field observations, we chose distance as the key parameter. While this approach may involve some subjectivity, it allows for intuitive and practical modeling. The model also captures variations across pedestrian groups influenced by demographic factors.

We found, as lessons learned, that the applied parameters may be changed based on the local traffic habits. Accordingly, local surveys measuring the drivers' and pedestrians' decisions are needed. While validation was based primarily on visual consistency with field behavior, which is sufficient for engineering applications, future research should incorporate quantitative validation methods to enhance scientific generalizability. The proposed solution offers a more reliable framework for traffic simulation professionals, enabling more precise modeling results. The proposed method could be the basis for creating a new pedestrian module.

This work enhances the accuracy of traffic simulations and provides a robust tool for further research in pedestrian-vehicle interactions and signal control strategies. Future research aims to examine pedestrian decision-making across diverse crossing

types, to enhance model adaptability. Computational optimizations (e.g., parallel processing, control by external code) will also be explored to improve simulation run efficiency.

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