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Article

Development of micromodels for improvements in driving safety using as a case study a university campus in Panama

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Abstract: This research focuses on addressing critical driving safety issues on university campuses, particularly vehicular congestion, inadequate parking, and hazards arising from the interaction between vehicles and pedestrians. These challenges are common across campuses and demand effective solutions to ensure safe and efficient mobility. To address these issues, the study developed detailed microsimulation models tailored to the Victor Levi Sasso campus of the Technological University of Panama. The primary function of these models is to evaluate the effectiveness of various safety interventions, such as speed reducers and parking reorganization, by simulating their impact on traffic flow and accident risk. The models provide calculations of traffic parameters, including speed and travel time, under different safety scenarios, allowing for a comprehensive assessment of potential improvements. The results demonstrate that the proposed measures significantly enhance safety and traffic efficiency, proving the model's effectiveness in optimizing campus mobility. Although the model is designed to tackle specific safety concerns, it also offers broader applicability for addressing general driving safety issues on university campuses. This versatility makes it a valuable tool for campus planners and administrators seeking to create safer and more efficient traffic environments. Future research could expand the model's application to include a wider range of safety concerns, further enhancing its utility in promoting safer campus mobility.

Keywords: driving safety; simulation models; traffic micromodels; traffic flow; speed tables; road safety; university campus

1. Introduction

Globally, urban mobility (Ceder, 2021; Miskolczi et al., 2021) has become a central issue in urban planning (Koszowski et al., 2019; Ortiz Sánchez et al., 2020)and sustainable development agendas (Abduljabbar et al., 2021; Holden et al., 2019) . In this context, university campuses represent urban environments that require specific solutions to ensure efficient and safe mobility (Chavez et al., 2019; Mugion et al., 2018). Many studies have addressed mobility in university environments (Edilberto Rincón Romero et al., 2023; Fernandes et al., 2019; Gutiérrez-Gallego and Pérez-

Pintor, 2019), highlighting the importance of comprehensive strategies that address both vehicular and pedestrian transport (Menini et al., 2021; Sgarra et al., 2022).

Early studies laid the groundwork for understanding the relationship between campus planning and mobility (Dober, 1996; Turner, 1984). These studies highlighted the importance of considering accessibility and connectivity in the physical design of campuses, as well as the need for transportation policies that encourage sustainable modes of mobility providing a valuable frame of reference for understanding this phenomenon (Sultan et al., 2021).

Among the most studied topics are transport planning (Kaplan, 2015), traffic management (Fujdiak et al., 2016), road and pedestrian infrastructure design (Coutts et al., 2019; Nesoff et al., 2018; Serrone et al., 2023; Zambare and Liu, 2024) and promotion of sustainable transport modes (Pucher and Buehler, 2017; Shah et al., 2021; Spadaro and Pirlone, 2021). In terms of transport planning, mathematical and simulation models have been proposed to predict traffic flow (Bowman and Miller, 2016; Dorokhin et al., 2020; Xue et al., 2019) and assess the impact of specific interventions (Baptista Neto and Barbosa, 2016). Traffic management includes measures such as speed regulation (De Pauw et al., 2014), traffic light control (Ghazal et al., 2016) and the implementation of parking policies (Yan et al., 2019). In terms of infrastructure design, solutions such as the creation of dedicated bicycle lanes (Grigoropoulos et al., 2021; Schaefer et al., 2020) and the installation of pedestrian signage have been explored (Zhang et al., 2015).

The promotion of sustainable modes of transport has been a growing area of interest, with initiatives that seek to reduce reliance on personal vehicles and promote more environmentally friendly alternatives (Gao and Zhang, 2020; Lyons, 2018; Pojani and Stead, 2015; Sultana et al., 2019). These approaches include promoting the use of bicycles (Agarwal et al., 2020; Lin et al., 2018), improvements in public transportation (Saif et al., 2018), and the implementation of car-sharing programs (Mattia et al., 2019; Tirachini et al., 2020).

Several approaches have been implemented globally to address such issues, including reorganizing parking, installing speed tables, and implementing smart traffic management systems. These solutions aim to improve safety by reducing vehicle speeds and organizing traffic flow more effectively (dell'Olio et al., 2019; Mirheli and Hajibabai, 2020). Despite these efforts, challenges remain. For instance, while speed tables can effectively reduce vehicle speeds, they may also contribute to increased congestion during peak hours (Agerholm, et al., 2020; Ullah et al., 2016). Similarly, reorganization of parking spaces can alleviate some issues but often fails to address the root cause of congestion, such as high vehicle-to-space ratios and inadequate alternative transportation options (Parmar et al., 2020; Yan et al., 2019). In terms of pedestrian connectivity, the importance of adequate infrastructure to ensure the safety and comfort of users has been highlighted in studies that emphasize the need for well-connected and accessible pedestrian spaces (Arellana et al., 2021; Jabbari et al., 2021; Schnarre et al., 2022).

This scenario is where simulation approaches come in, which have emerged as fundamental pillars for the analysis and prediction of traffic behavior in urban environments (Asaithambi et al., 2018; Kessels, 2019; Wen and Bai, 2017), but also in university campuses environments (Bustillos et al., 2011; Hamad, 2020; Suthanaya and Upadiana, 2019). Macrosimulation, which models vehicular flow at the network level, has allowed traffic planners and managers to assess the impact of new infrastructure, such as roads and parking lots, on overall circulation within the campus and surrounding areas (Arliansyah et al., 2017; Chalfen and Kamińska, 2018; Thonhofer et al., 2018).

Meanwhile, microsimulation focuses on the individual behavior of vehicles, pedestrians and cyclists, providing detailed insight into real-time interactions in specific environments (Huang et al., 2012; Imai et al., 2024). Recent studies have applied microsimulation models to analyze the effectiveness of traffic management measures, such as smart traffic lights and access restrictions, in optimizing vehicular flow and pedestrian safety in areas with high traffic density and pedestrian activity (Galatioto et al., 2012; Imai et al., 2024; Li et al., 2017; Ziemska-Osuch and Osuch, 2022).

The aim of this research is the development of microsimulation models to improve driving safety using as a case of study the Victor Levi Sasso (VLS) campus, the main campus of the Universidad Tecnológica de Panamá (UTP), that is strategically located in Panama City. The Universidad Tecnológica de Panamá, like many other university campuses around the world, faces unique challenges in terms of mobility of vehicular and pedestrian traffic, specifically road safety problems caused by parallel parking of cars within the campus. The implementation of measures to improve this problematic is modeled and the effects that these interventions would have on vehicular flow are evaluated. Through this analysis, it is intended to propose effective strategies that optimize both pedestrian safety and traffic efficiency within the campus.

2. Case of study

In order to study the current mobility demand within the UTP VLS Campus, a pedestrian and vehicular count was carried out at key points to describe the behavior of internal mobility. The methodology applied in this gauging sought to obtain an accurate representation of people and vehicles flow, which is essential for the analysis of possible alternatives for improvement and future planning.

The central campus is located in Panama City, as shown in **Figure 1**, the campus is surrounded by a forest area that provides a natural and green environment. It has two main internal circulation roads, as well as a central roundabout for the traffic flow. In addition, it has a network of sidewalks that connect the main buildings and areas of the campus, making it easy to get around on foot. The growing student population and the increase in the diversity of transportation modes have generated additional pressure on the existing infrastructure. Vehicular congestion, lack of adequate parking and pedestrian safety are some of the main concerns that require immediate attention.

To introduce the current demand situation, it is important to show the enrollment status in the UTP VLS Campus. During the year 2023 there was an enrollment of 17,082 and 15,437 students during the first and second semester, respectively. **Figure 2** shows the enrollment growth trend over the last 20 years for the UTP VLS Campus.

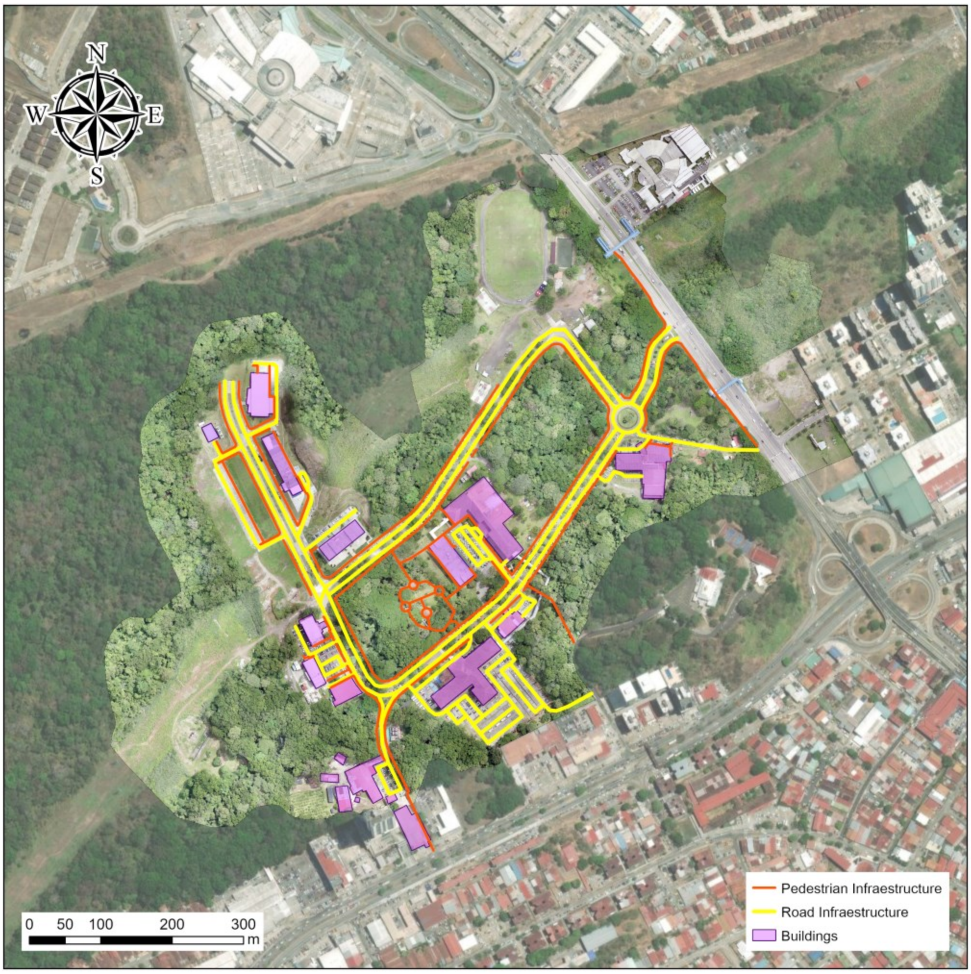

Figure 1. Road and pedestrian configuration of the Victor Levi Saso Campus of the Technological University of Panama.

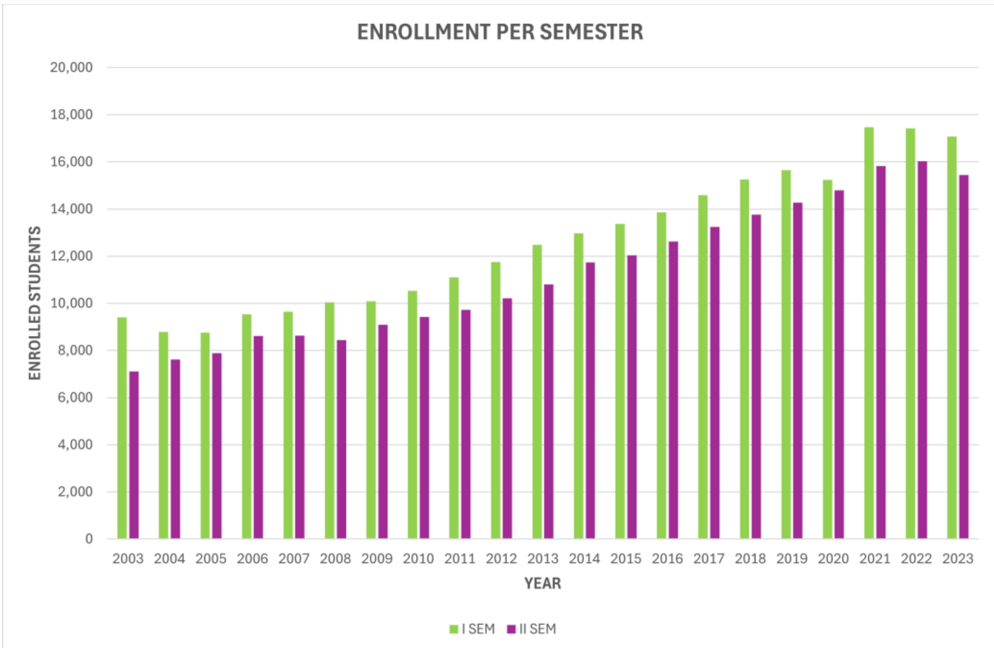

Figure 2. UTP VLS Campus student enrollment by 2023.

The existing road configuration on the campus presents unconventional characteristics since it is organized through two roads that share the same direction, as shown in **Figure 3**, which is a peculiarity within the internal mobility planning. This design, although it facilitates orderly circulation, can generate congestion, especially when considering the limitation to one lane per roadway in certain areas due to the parallel parking along the edge of the road that occurs in these areas.

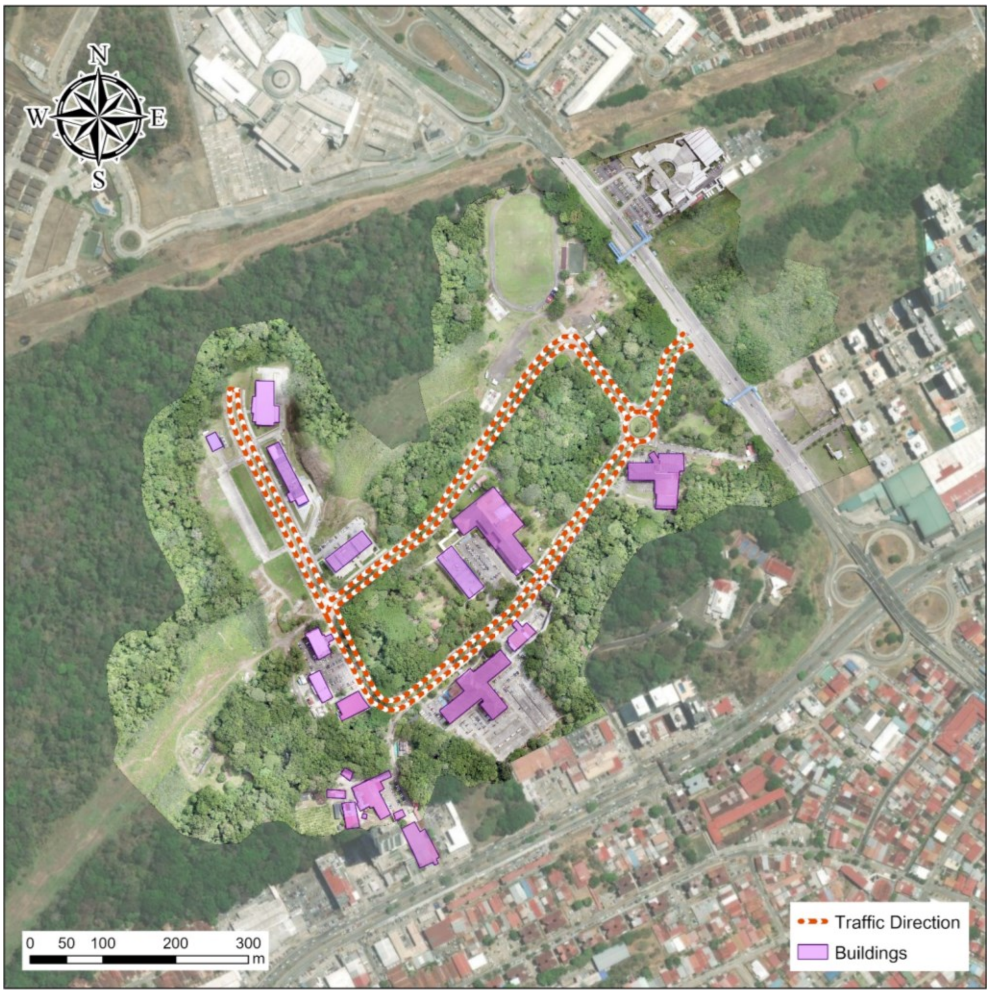

Figure 3. Direction of traffic flow in the UTP VLS Campus.

Figure 4 illustrates the parking dynamic of the UTP VLS Campus, the presence of parallel parked vehicles along the edges of the roadway effectively reduces these roadways to a single lane of vehicular circulation. The internal road structure of the campus is characterized by 8.21 m wide roadways, vehicles parked on both sides of the roadway occupy an average of 2.20 m on each side, leaving the central lane of circulation of ap-proximately 3.80 m. The UTP VLS Campus has a total of 1699 parking spaces, distributed between 753 spaces considered informal located along the edges of the roads and 946 spaces formally assigned within parking lots.

These informal parking spaces located on the edges of internal roads represents a major challenge for the management of vehicular mobility on campus. The lack of regulation in these parking spaces generates several problems, such as the disorderly distribution of vehicles and vehicular congestion, which obstructs the flow of traffic and reduces the capacity of the roadways. This situation is especially problematic in critical areas such as curves, where the presence of vehicles parked on both sides considerably reduces the space available for circulation, which can complicate emergency situations by restricting the access of emergency vehicles, such as fire trucks, which require a wide turning radius in curves.

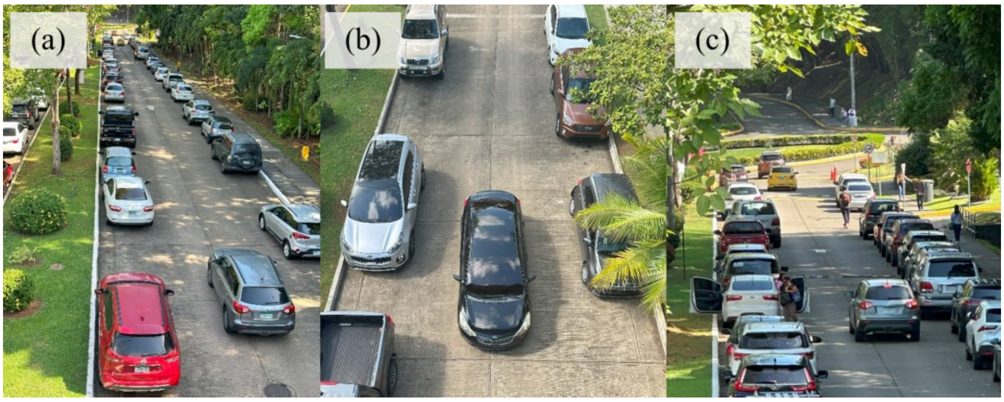

Figure 4. (a) View of the reduction of roadways to travel lane on the UTP VLS Campus; **(b)** aerial view of the travel space within each roadway; **(c)** view of how vehicles and pedestrians interact on the campus roadways.

3. Methodology

The alternatives were evaluated by means of a micro simulation model using the PTV Vissim program, a traffic micro simulation software that allows detailed and accurate modeling of traffic flows. It can simulate multiple modes of transportation, including vehicles and pedestrians, in a shared environment, including their interaction. This software digitally reproduces traffic patterns, which positions it as a helpful tool for transportation planners and mobility studies. In the context of a university campus simulation, PTV Vissim is used to evaluate how existing campus infrastructure can handle different traffic volumes and what modifications might be needed to improve flow and safety.

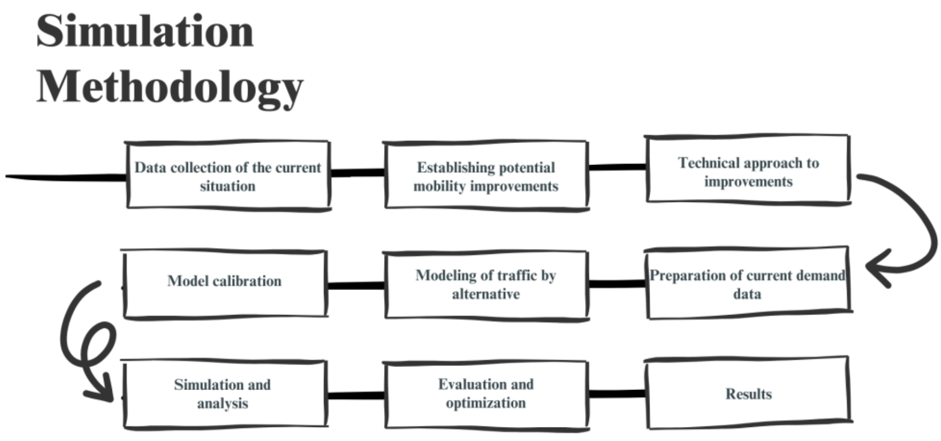

Figure 5. Methodology implemented for the simulation.

For this, several traffic scenarios were developed representing the different proposed alternatives, including the improvements associated with each one and the flow volumes obtained during the study, in order to analyze how each phase would impact overall traffic. **Figure 5** shows the methodology for the modeling of measures to improve driving safety within the UTP VLS campus.

Data collection of the current situation: First, the current conditions of internal mobility in the UTP VLS Campus were modeled, with the help of the data obtained through the previously mentioned gauging (see **Table 1**). Necessary data were collected, such as the campus road and sidewalk network, existing parking lots, pedestrian and vehicle mobility patterns through the aforementioned gauging, and traffic speeds within the campus. This also included traffic demand data, which determined how many road users needed to move from a specific origin to a specific destination, both pedestrians and vehicles.

Table 1. Proposed alternatives and the improvement measures considered in each of them.

Measurements	**Existing Model**	**Alternative**			
		1	**2**	**3**	**4**
Reorganization of traffic flow	No	Yes	Yes	Yes	Yes
Redesign of parking lots	No	Yes	Yes	Yes	Yes
Speed table	No	Yes	Yes	Yes	Yes
Mountable roundabouts 1	No	Yes	Yes	Yes	Yes
Mountable roundabouts 2	No	Yes	Yes	Yes	Yes
Mountable roundabouts 3	No	No	Yes	Yes	Yes
New road	No	No	No	Yes	Yes
New accesses	No	No	No	No	Yes

Establishing potential mobility improvements: The issues and possible improvements in the internal mobility of the campus were recognized through working groups. In these sessions, improvement objectives were established for the plan, based on the data obtained.

Technical approach to improvements: Based on the information research, a set of improvements were proposed for the previously established problematic situations. To develop these improvement measures, technical design guides, national regulations and relevant research were consulted in order to adequately evaluate this set of improvements.

Preparation of current demand data: Using the data previously collected during the surveys, the two proposed peak hours were taken, one for the morning shift and the other for the afternoon shift and were complemented with transportation planning analyses where the routes and demand for each alternative studied were proposed, and a series of considerations were considered. The demand for trips to the most crowded buildings on campus was estimated on the basis of the number of classrooms in each building.

Modeling of traffic by alternative: The existing model of the mobility environment in the UTP VLS Campus shows a basic infrastructure with no recent improvements in traffic management, road safety and pedestrian connectivity. This research establishes a series of alternatives for the implementation of improvements:

- Reorganization of traffic flow: Modelling of a two-way circulation system on internal campus roads to facilitate more flexible traffic management.
- Reorganization of parking lots: Modelling of a 30° herringbone parking system, optimizing space, and facilitating vehicle access and egress, which contributes to smoother and safer traffic flow.
- Speed table: Modelling of safe pedestrian crosswalks that provide a continuous crossing for pedestrians and act as speed reducers for vehicles.
- Mountable roundabouts: Modelling of mountable roundabouts with aprons of distinctive materials such as cobblestones, allowing safe maneuvering for large vehicles and improving traffic flow and safety.
- New road: Modelling of the road that directly connects "Avenue A" with "Avenue B", providing new internal transit routes.
- New accesses: Modelling of additional accesses to improve access to the campus.

As can be seen in **Table 1**, the initial strategy consists of adopting those improvements that require minimal modifications to the campus or budget. Subsequently, they will be implemented gradually.

Model calibration: The existing condition was mainly modeled with the proposed parameters in order to evaluate if the behavior was in line with the real situation.

Simulation and analysis: Once the calibration was performed, simulations of the models were carried out.

Evaluation and optimization: Average distance traveled (km), average circulation time (min), average speed (km/h) and average speed at speed tables (km/h) were obtained from the simulation of the models in order to analyze the behavior of the internal mobility of the campus.

4. Results

The gauging results reflect the typical behavior of an on-campus day in relation to class schedules, which begin at 7:50 a.m. for the morning shift, 12:50 p.m. for the afternoon shift, and 5:50 p.m. for the evening shift until 11:00 p.m. During the vehicular analysis, 7008 vehicles entered, and 6951 vehicles left the campus. It is noteworthy that 92% of these correspond to private vehicles, which underscores the predominance of this mode of transportation among the university community, 3.3% to cabs, 2.0% to motorcycles, 1.3% to institutional cars, 1.3% to service vehicles and a minority of 0.1% to buses and trucks. It was observed that between 7:00 a.m. and 8:00 a.m., there is a morning peak with 899 vehicles entering and 329 leaving the campus, while in the afternoon/evening hours, between 5 p.m. and 6 p.m., there are 912 vehicles entering and 587 leaving the campus. Regarding pedestrian flow, the study revealed that 7906 pedestrians entered, and 7244 pedestrians left the campus. The hours of greatest pedestrian flow coincide with the start and end of classes, with peaks observed between 7:00 a.m. and 8:00 a.m., and between 12:00 p.m. and 1:00 p.m., respectively.

The focus of the proposed alternatives addresses a phased improvement of driving safety on the UTP VLS campus. Each has been carefully designed to address specific aspects that will improve vehicular and pedestrian mobility within the campus. **Figure 6** shows the distribution of the improvement measures listed in **Table 1**. The analysis is intended to evaluate the desirability of implementing the changes in a comprehensive manner, as suggested by Alternative 3 and 4, versus taking a phased approach that introduces incremental improvements from Alternative 1 through Alternative 4.

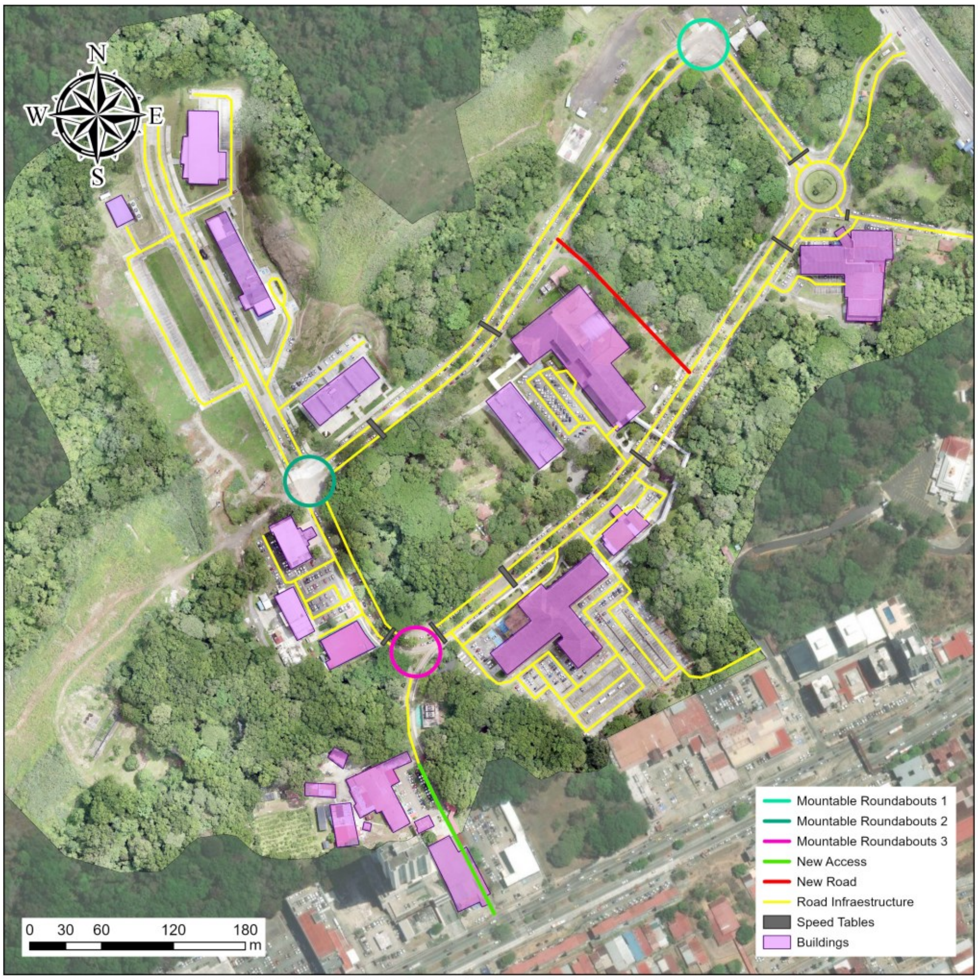

Figure 6. Location of the improvement simulated for driving safety within the UTP VLS Campus.

Figure 7 shows some examples of the simulations carried out in PTV to evaluate the specific alternatives for the driving safety within the UTP VLS campus. The examples illustrate various configurations and strategies, allowing a visual and quantitative comparison of their effectiveness in improving internal mobility and reducing congestion.

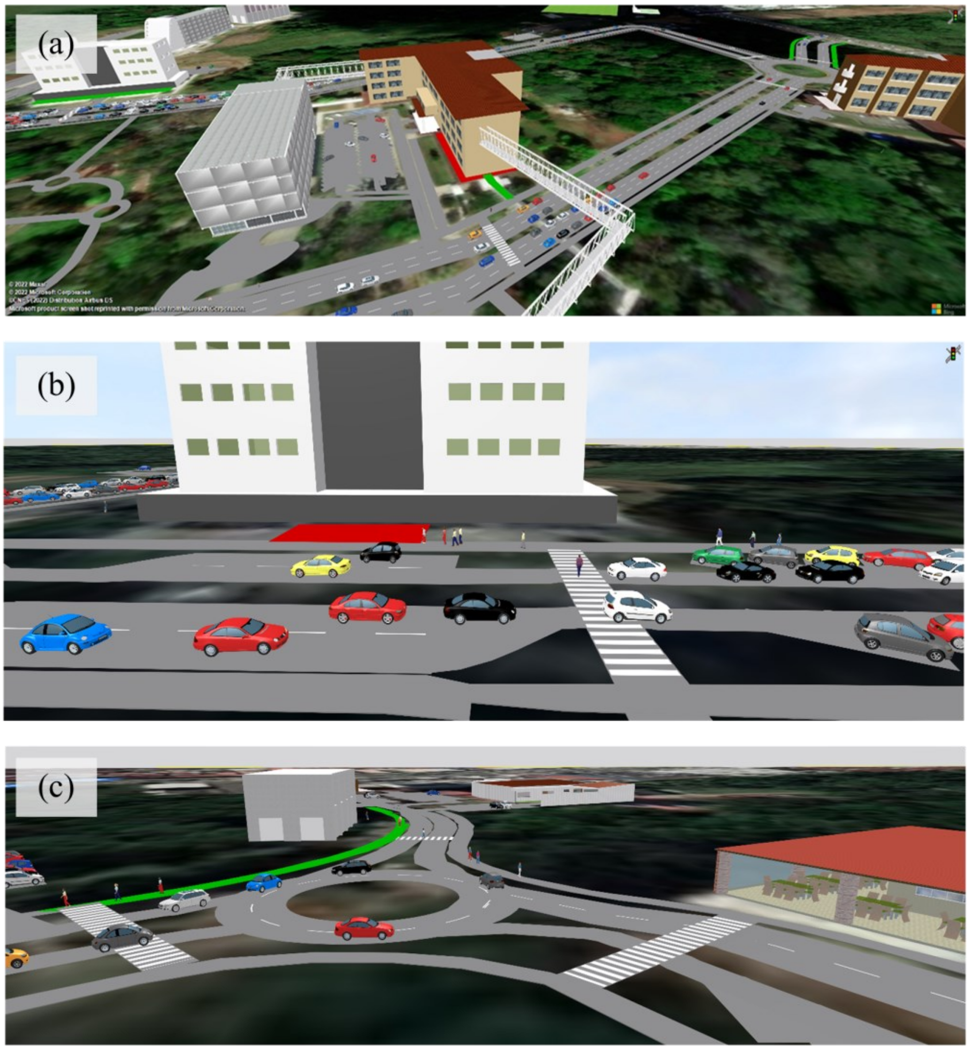

Figure 7. (a) Model of the current circulation system inside the UTP VLS Campus; **(b)** simulation of the UTP VLS Campus with speed tables and drop offs; **(c)** simulation of the UTP VLS Campus with mountable traffic roundabouts.

According to **Figure 8a**, that shows the average distance traveled by vehicles during the simulation, measured in kilometers, all alternatives demonstrate a decrease in average distance traveled compared to the existing model. Alternative 1 achieves a reduction in travel distance of 194 m and 45 m for the morning and afternoon shifts, respectively. Alternative 2, on the other hand, shows an improvement in travel distance of 253 m in the morning and 214 m in the afternoon. Alternative 3 shows a reduction of 273 m in the morning and 185 m in the afternoon. Although, it is important to mention that this last alternative increases the distance traveled in the afternoon shift with respect to Alternative 2. On the other hand, Alternative 4 has a reduction of 332 m of travel for the morning shift and 411 m for the afternoon shift; this alternative is the one that shows the best reduction in average distance traveled with respect to the current situation of all the alternatives proposed.

Figure 8b illustrates the average time that vehicles spend circulating in the traffic network during the simulation, in minutes. An average decrease of 5 min and 9 s in the morning shift and 3 min and 12 s in the afternoon/evening shift is recorded for

Alternative 1 compared to the existing model. Alternative 2 is notable for a savings of 5 min and 54 s in the morning and 3 min and 5 s savings in the afternoon compared to the existing condition. Alternative 3 shows a decrease of 7 min and 12 s in the morning and 5 min and 48 s in the afternoon compared to the initial alternative. Finally, Alternative 4 shows a decrease of 9 min and 18 s for the average circulation time in the morning and 6 min and 54 s in the afternoon, thus significantly optimizing traffic times on campus.

It is important to note that, as reported, Alternative 3 evidence an increase in the average distance traveled in the evening shift compared to Alternative 2, as shown in **Figure 8a**. However, this route is completed in a shorter circulation time, attributable to the reduction of queues in the internal route and fewer vehicle stops in the simulation (see **Figure 7**). The average circulation time for Alternative 3 translates into a 46.5% decrease with respect to the current time required to move within the UTP VLS Campus and Alternative 4 a 60% decrease of the existing average circulation time, thus improving the efficiency of the trips made.

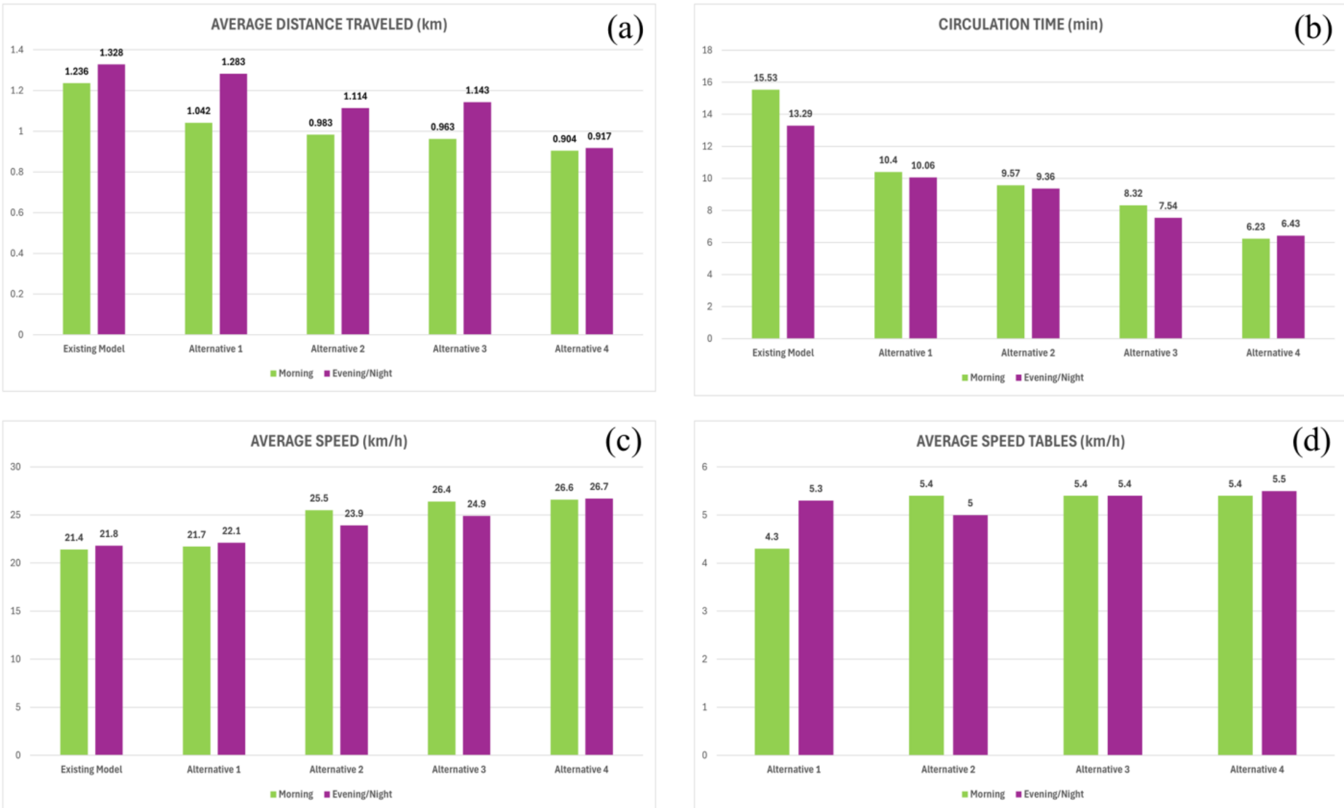

Figure 8. (a) Average distance traveled by vehicles during the simulation, measured in kilometers; **(b)** average time that vehicles spend circulating in the traffic network during the simulation, in minutes; **(c)** average speed at which vehicles travel on the simulated network, in kilometers per hour; **(d)** speed recorded in the speed tables in certain segments of the network.

The speed analysis shows that by reducing the average speed because of the implementation of speed tables, a significant decrease in the risk of accidents is reached, thus improving road safety in areas of increased interaction between vehicles and pedestrians. **Figure 8c** shows the average speed at which vehicles travel on the simulated network of the campus, in kilometers per hour, and **Figure 8d** shows the speed reduction at the speed tables. The proposed alternatives achieve a higher average speed compared to the current alternative, as a direct result of the optimization of the parking process, due to the reorganization of side parking to 30° angled parking (see **Figure 9**), as well as shorter trips and shorter average distance traveled.

In all models, pedestrian crosswalks on campus avoided conflict between motor vehicles and pedestrians, simulating that pedestrian crossed properly while vehicles stopped, according to the parameters allowed by PTV Vissim. This modification reduces congestion and obstructions in the traffic lanes, facilitate a more agile transit through the campus. These areas minimize the stops of vehicles that are only trying to drop off passengers, thus relieving obstructions on the roadways and improving traffic flow.

Figure 9 shows one of the measures to model which were the speed tables. A total of 9 of these were modeled and will cover the entire roadway, with a width of 4 m in the pedestrian traffic zone and vehicular ramps of 2 m in length, with a total dimension of 8 m. They are designed to force drivers to slow down, which reduces the likelihood of accidents and helps maintain a constant and safe speed along the route, reducing aggressive driving behaviors. It is important to note that according to **Figure 8d** although the average speed of traffic on the alternatives increases, the maximum speed achieved within the circulation is 26.7 km/h, a value that still is within the safety limits for pedestrians and other drivers, as the maximum speed for on-campus driving is 30 km/h. It is also important to note that in these "speed table" zones these average traffic speeds are reduced to 5.0–5.5 km/h. By slowing vehicle speeds, speed tables create a safer environment for pedestrians, fulfilling their function; especially in areas with heavy pedestrian traffic such as campuses.

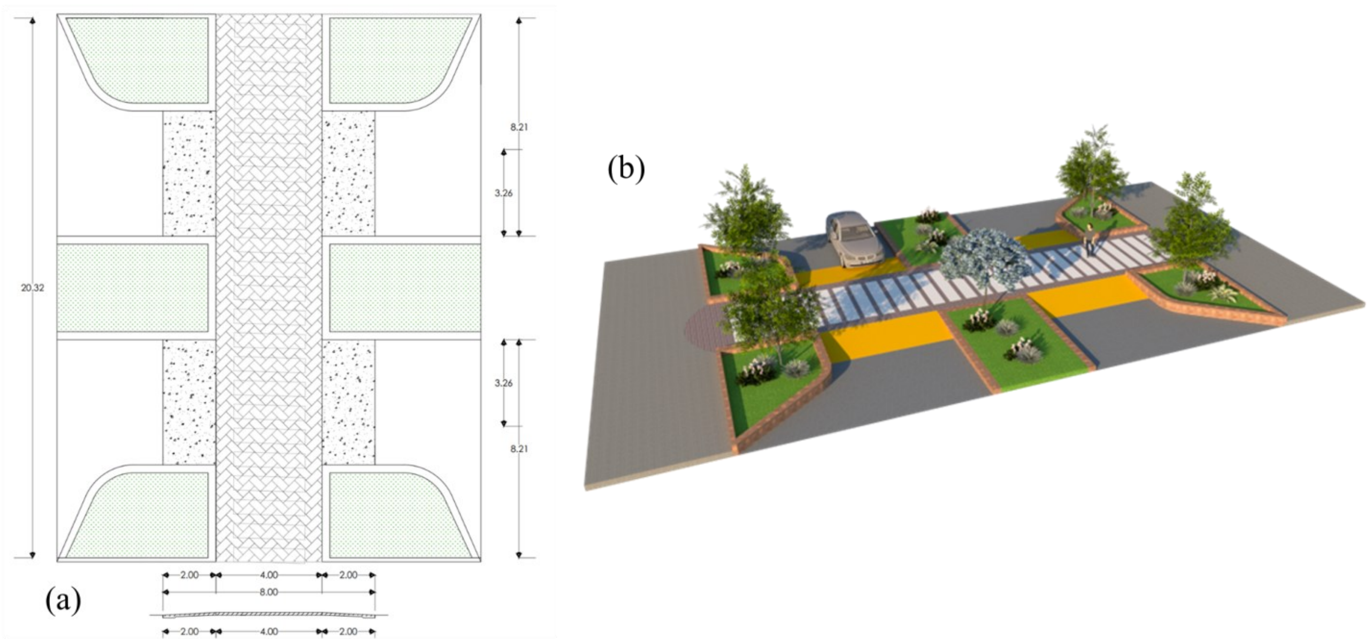

Figure 9. (a) Measures designed in meters for the speed tables in the modelling; **(b)** desired model of speed tables to be implemented.

5. Discussion and conclusion

The implementation of micro modeling has proven to be an effective tool for simulating proposed improvements to driving safety and mobility on campus. The micromodels allowed us to simulate traffic dynamics and pedestrian mobility on campus, providing a detailed and quantitative view of how improvement alternatives may influence vehicular and pedestrian flow. This approach is especially valuable in university environments where the interaction between pedestrians and vehicles is intense and requires integrated and specific solutions as is the case of the Victor Levi Sasso Campus of the Universidad Tecnológica de Panamá.

The presence of speed tables can change drivers behavior, making them more aware of their surroundings and the need to drive with caution, and pedestrians and bicyclists may also feel safer and more confident moving around campus, knowing that vehicles are required to slow down. The proposed alternatives achieve a higher average speed compared to the current alternative, as a direct result of the optimization of the parking process, due to the reorganization of side parking to 30° angled parking (see **Figure 10**), as well as shorter trips and shorter average distance traveled.

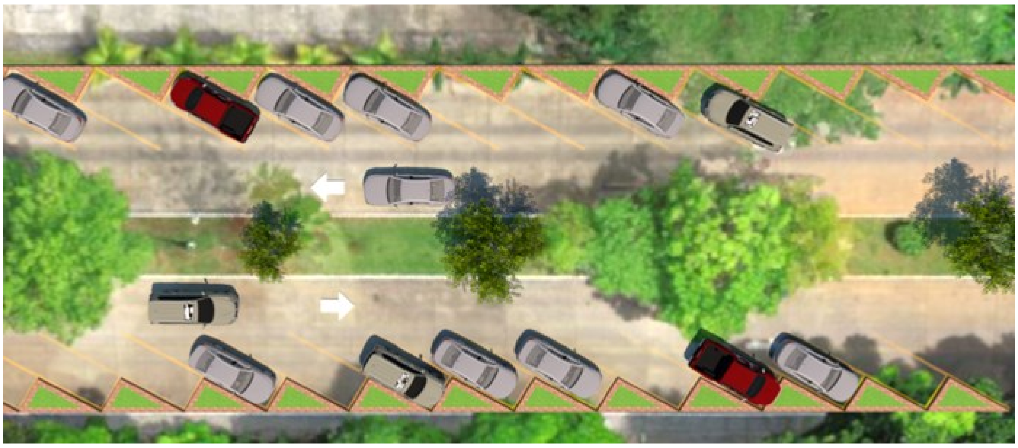

Figure 10. Plan-view showing the improvements included in the parking lot simulation at a 30-degree angle.

The full implementation of Alternative 4 offers a direct and complete response to the mobility challenges on the UTP VLS Campus. Comparatively, this strategy demonstrates remarkable efficiency by reducing travel distances and circulation times faster than a phased implementation, resulting in an immediate improvement in the mobility experience for campus users. Requires significant upfront investment and detailed planning to execute all improvements simultaneously. Risks associated with project management may be higher due to the complexity and scope of work involved. Temporary disruptions to campus users may be more extensive during the construction period.

The progressive implementation of Alternatives 1 through 4, allows for a phased approach to mobility improvement, facilitating budget and resource management over several phases. Each stage provides the opportunity to evaluate the impact of previous interventions and adjust before proceeding to the next phase. This flexibility can be advantageous in adapting to budget constraints or changes in campus needs. Full mobility improvements may take longer to realize, extending the period before the full proposed benefits are experienced. Intermediate phases may present temporary challenges of consistency in the on-campus circulation experience. In addition, the total project cost may increase due to the phased nature of implementation. It was determined that both the full integrated solution and the progressive solution have their advantages and challenges, and the choice between them will depend on the specific needs and constraints of each campus. The main objective of these sanctions is to ensure the proper use of facilities and to maintain a rigorous control over the vehicular circulation system.

Although the traffic management model proposed for the UTP VLS Campus has been shown to be effective for proposals to improve road safety and traffic efficiency, it is crucial to recognize that its implementation may not be equally feasible at all educational institutions. Differences in financial resources, government support and available infrastructure may limit the ability of other universities to adopt these solutions. Smaller institutions, with fewer students and limited resources, may encounter significant challenges when attempting to implement improvements such as installing speed bumps, rearranging parking lots, or constructing new roadways. Therefore, it is important to consider more affordable alternatives that can be implemented gradually and adapted to the economic capabilities of each institution. For example, low-cost solutions such as improved signage and educational campaigns could be considered before resorting to more expensive infrastructure such as speed tables.

One of the most interesting and counterintuitive phenomena in traffic theory is the Braess Paradox, which states that the addition of a new road to a traffic network can, under certain conditions, increase congestion rather than reduce it. In the context of this study, our initial simulations with PTV Vissim showed no obvious signs of this phenomenon, it is critical to recognize that the Braess Paradox could occur if the proposed new routes induce drivers to make decisions that collectively make the situation worse. For example, if a new roadway attracts too many drivers, it could quickly become saturated, which would increase congestion rather than reduce it. This phenomenon highlights the need to analyze not only the direct impact of a new infrastructure, but also how it interacts with the rest of the road network. The construction of new routes must be accompanied by a careful evaluation to ensure that it actually improves traffic efficiency throughout the system and not just in specific sections.

These findings provide a solid basis for the planning and implementation of strategic improvements in the infrastructure and regulation of the campus, adapting to the current and projected needs of the university community. In the scientific field, these findings provide new perspectives and methodologies for urban planning and traffic management, underlining the importance of integrated and technological approaches in solving complex mobility problems. Although the operation of the Campus corresponds to an internal (closed) model confined to the Campus itself, the implementation of the proposals described in this paper should be complemented with other analyses that explore alternatives such as the implementation of parking lots near the Campus that prevent cars from entering the confined space, which would reduce traffic density on the Campus".

The research not only improves the quality of life on campus, but also establishes a framework that can be adapted and applied in similar contexts globally, contributing to the advancement of knowledge in driving safety. For future research, it is recommended that comprehensive validation and verification studies be conducted to ensure that the simulation models are representative of actual conditions. This includes comparison of simulated results with empirical data and field observations. In addition to encouraging multidisciplinary research that integrates knowledge from traffic engineering, urban planning, behavioral psychology, and information technology. This integration can provide a more holistic understanding and innovative solutions to mobility problems.

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