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Implementation Of Micromobility Corridors Through the Road Diet Strategy on A Congested Urban Road

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Abstract

The study was conducted on an urban roadway segment in Lima, Peru, characterized by high levels of traffic congestion. The objective was to evaluate the implementation of a road diet strategy with the incorporation of micromobility corridors. Unlike previous studies, the roadway serves a dual urban and interurban function, connecting Lima with cities in the central region of the country, resulting in more complex operating conditions and critical Level of Service (LOS F) conditions. Initially, the existing conditions were modeled, and subsequently, a geometric redistribution of the roadway was proposed. The intervention does not involve the conventional lane reduction (4 to 3 lanes), but rather a functional reconfiguration that increases operational performance, increasing from 4 to 5 effective lanes and incorporating 2 exclusive side lanes for micromobility. Both scenarios were microsimulated in PTV Vissim, with calibration using the Wiedemann 74 car-following model and validation through metrics such as MAPE and GEH. The results showed improvements in Level of Service from F to D, as well as reductions in travel time, although queue delay increased, exceeding the results reported in previous studies. The road diet significantly improved roadway performance under high congestion and complex functional characteristics.

Keywords: Micromobility, Microsimulation, PTV Vissim, Road diet, Urban Traffic.

1. Introduction

Over the past decades, urban design has undergone a transformation focused on sustainable mobility and the reallocation of roadway space. In this context, a road diet is the geometric redistribution of lanes on urban roadways. Its primary objective is to alleviate traffic congestion and promote a multimodal transportation system [1]. Several cities, including Los Angeles, Toronto, and Seoul, have successfully implemented road diet strategies. These interventions have reduced congestion and improved safety by converting traffic lanes into dedicated spaces for bicycles and scooters [2]. In Latin America, studies conducted in Bogotá and Mexico City have shown that urban congestion significantly increases pollution levels [3]. In response, micromobility has emerged as an alternative for roadway reallocation in high-density areas [4], while its integration with public transportation has become a key component in the development of more inclusive and multimodal networks [5].

In the Peruvian context, studies on the use of bicycles and electric scooters in Lima have demonstrated their potential to reduce travel times and dependence on motorized transportation [6]. At the local level, the district of Ate experiences heavy traffic along the Central Highway, particularly between Juan Velasco Alvarado Street and Juan Pablo II University, where educational institutions, factories, and shopping centers are concentrated. Mixed traffic conditions and the lack of adequate infrastructure generate congestion, delays, and road safety concerns. It should be noted that the Central Highway was originally conceived, as its name suggests, as a highway; however, it currently functions as an urban roadway known as Nicolás Ayllón Avenue. Nevertheless, it also continues to serve as an interurban roadway, connecting Lima with cities throughout the central region of Peru.

Given this context, the following research question arises: Is it feasible to implement a bidirectional micromobility corridor through a road diet strategy on Nicolás Ayllón Avenue, along the segment between Juan Velasco Alvarado Street and Juan Pablo II University, as a measure to improve urban mobility? The general objective was to analyze the feasibility of implementing a micromobility corridor within the aforementioned study area. The specific objectives were to collect the main roadway characteristics of the study segment, including traffic volumes, vehicle counts, travel times, roadway dimensions, and signal timing data. Furthermore, a calibrated and validated traffic simulation model was developed to represent existing conditions and identify current congestion problems. In addition, an alternative model was proposed to evaluate the feasibility of the intervention within the study area. Finally, the feasibility of the proposal was assessed by comparing existing conditions with an alternative scenario that included a bidirectional micromobility corridor.

In this sense, the current research can be considered as a first attempt to analyze the implementation of the road diet strategy in Peru while contributing new knowledge to the growing literature on this topic. This study, as opposed to the majority of previous studies based on reducing from 4 lanes to three in an urban arterial, is performed at an infrastructure that has a double function: it serves –and should, therefore, be measured– both as the main urban roadway for Lima and, in addition act as an interurban corridor connecting Lima with cities in the central region of the country. In this context, the proposal did not include a capacity reduction; it was purely geometrical, redesigned to improve traffic flow and shifting from an operational configuration with four lanes to five with an additional central lane and micromobility corridors. Analysis of the real-life conditions added from PTV Vissim modeling demonstrates that even under very congested conditions, this intervention can yield major wins in terms of roadway performance, thus offering insights into a context with no proof having been provided in international literature.

2. State of the Art

Traffic microsimulation has become increasingly important in recent years due to the need to reduce congestion and travel times in urban environments [7]. Likewise, integrating micromobility with public transportation is essential for improving connectivity through intermodal mobility systems. In Germany, a modal shift of approximately 1.6% was reported following the implementation of dedicated public transport lanes [8]. During the COVID-19 pandemic, Geneva and Lausanne marked a turning point in the adoption of micromobility and other light mobility modes. These alternatives proved to be viable and environmentally friendly compared with conventional public transportation, and their benefits became evident in cities that redefined their transport planning strategies [9]. Furthermore, the reallocation of roadway space based on the principles promoted by the National Association of City Transportation Officials (NACTO) [10] enhances transportation equity while making mobility systems safer and more sustainable [11].

The inclusion of micromobility vehicles such as bicycles and scooters introduces an additional level of complexity to roadway design and modeling. This reflects the heterogeneous interactions that emerge when different transport modes share the same space, as observed in Shanghai [12]. The presence of cycling infrastructure influences users' travel choices. Well-designed bicycle facilities increase the likelihood that users will choose micromobility modes instead of motor vehicles [13]. Likewise, comparisons among different transport modes influence public perception and Levels of Service (LOS), as reported in Bogotá [14].

PTV Vissim is a valuable tool for evaluating micromobility strategies, as it enables the analysis of multimodal traffic operations in complex urban environments. The software allows the assessment of alternative scenarios, providing a robust basis for infrastructure decision-making [15]. When vehicle and pedestrian flow parameters are properly calibrated, real-world traffic conditions can be replicated with a high degree of accuracy. Achieving this requires the configuration of variables such as reaction times, acceleration rates, and vehicle-following distances [7]. Furthermore, PTV Vissim is highly adaptable to a wide range of applications, including urban logistics and sustainable micromobility planning, extending beyond conventional traffic analysis [16]. Previous studies have shown that the implementation of protected bicycle facilities in PTV Vissim does not compromise vehicular traffic efficiency or adversely affect LOS indicators when bicycle mode share remains below 15%. In addition, such facilities can reduce bicycle-related conflicts by up to 80% [17].

PTV Vissim modeling involves two essential stages: calibration and validation. Some basic parameter adjustments, such as speed and travel time adjustments, and some advanced methods based on sensitivity analysis, ANOVA, and genetic algorithms can be used to optimize human driver behavior parameters so that driving skills are within a certain range of observed deviations [18]. In this respect, Vissim includes car-following models like Wiedemann 74 and Wiedemann 99, which represent driver behavior per roadway type. The former are more appropriate in urban areas, while the latter are used at higher speeds on freeways [19]. Additionally, calibration is an iterative process incorporating microscopic variables, such as following time, safety distance, and lane-changing behavior, that has a direct impact on the accuracy of the model [20]. Validation is frequently based on MAPE, GEH, and correlation coefficients [20] and global methods that take into account a comprehensive set of performance measures (e.g., traffic volume, speed, travel time, or queue length) [21], [22]. The model is also validated through comparisons of simulated data with observed data. Alternative methods, like discrete-event simulation, have yielded similar performances for operational variables but at lower computational costs [20], [23].

Studies of road diet reviewed in the discussion were grouped into four categories: geometric-operational, multimodal, systemic, and perceptual. The first category is the most reported intervention, where we have the four-to-three lane conversion that has always shown significant improvements in road safety through speed moderation and conflict reduction [24], [25]. Results show a 33% reduction in conflict, between 19% and 47%, as well as crash reductions, and also reduced speeds of up to 6.7% during peak periods and up to 7.9% off peak, all very beneficial for traffic flow stability [25]. High-volume roadways have also shown these benefits of lower operating speeds with safety enhancements and without a substantial adverse impact on traffic operations, where average crash reductions of 35.7% were achieved [2]. From the operational point of view, these studies also note modest effects like reduced travel speeds and a 9.3% increase in maneuvering and total travel times (with higher impacts for turning movements), reflecting the capacity-safety trade-off. In addition, research on vehicle behavior shows that there is an effect of road diets on lateral vehicle positioning and engagement with bicycle facilities, as encroachment rates of up to 73.64% are observed when lane width is decreased. While this evidence supports the safety advantages of road diets, it also introduces novel operational characteristics [26]. Also, many studies show that these effects can differ by driver characteristics and behavior of specific vulnerable populations (eg, older drivers) [27].

The second category includes multimodal, intensive implementations such as lane reductions and bicycle facilities, pedestrian places, or on-street parking. Moreover, alongside the health benefits, such interventions can offer supplementary ends in accessibility, walking, and urban quality (consistent with complete streets) [28], [29]. They reported that LOS for pedestrians improved from C to B and LOS for cyclists—from B to A, as well as significant increases in the number of cyclists—over 243% on some routes—even when traditional capacity indicators only change slightly [14]. However, these strategies could also pose greater operational challenges due to localized delay increases and diversion to higher priority intersections as a result of reducing roadway capacity. For example, the delay decreases from 171.97 to 31.12 veh-s when road reconfiguration and operational optimization measures are combined [2], [24].

At the network level, simulation studies suggest that transportation networks remain robust to lane reductions, and similar effects have revealed speed or travel time changes generally limited to less than 10% at all system locations [28]. However, the problems caused by localized bottlenecks, traffic redistribution, and other unintentional dangerous driving behaviors have been reported in order of their lane overlap rate from 14.2~73.64% for less operational control environments [25], [26].

Last but not least, with a 4th angle that has an evaluation metric which evaluates users' perception and performance in extreme conditions. In Bogota, traditional LOS measures and perception-based assessment methods show improvement for pedestrians and cyclists after implementing road diet strategies, highlighting that the user perspective must be included in transportation assessments [14]. In addition, studies of emergency response operations have shown no significant change in the response times for four-to-three lane conversions and claim that operational impacts under such adverse conditions are negligible and dependent more on driver behavior than on roadway geometry [30].

Despite the growing body of research, several gaps remain. One important limitation is the lack of long-term sustainability assessments, as many of the infrastructures implemented during the pandemic were not maintained over time [31]. Likewise, studies validating PTV Vissim models in complex urban environments such as the one examined in this research remain limited [7]. In addition, methodological constraints persist due to the limited integration of variables such as traffic flow, speed, and user perception, which may reduce the overall accuracy of analyses [16]. Furthermore, most studies examining micromobility implementation within road diet strategies have been conducted in European or North American settings, limiting their applicability to developing urban contexts [32]. In Peru, roadway design is primarily governed by the geometric highway design standards established by the Ministry of Transport and Communications (MTC) [33], and no specific guidelines currently exist for sustainable multimodal microsimulation.

Given the absence of such guidelines in the Peruvian context, the present study is grounded in sustainable mobility theory, considering both travel behavior and traffic modeling. Previous research has shown that substantial changes in urban mobility patterns can result from low-cost interventions, such as the implementation of temporary infrastructure [34]. Likewise, simulation models have proven effective for analyzing mode choice at the individual route level [13]. Evidence also suggests a complementary relationship between shared micromobility services and public transportation within intermodal travel chains [35]. Furthermore, evaluating cycling infrastructure performance requires the use of surrogate safety measures and the application of traffic flow theory through microsimulation techniques [36]. In addition, geometric characteristics such as roadway grade directly influence bicycle speed and flow density, making them important considerations in infrastructure design [37].

Overall, the reviewed literature highlights the effectiveness of road diet strategies and cycling infrastructure as key mechanisms for promoting safer and more sustainable urban mobility [38]. Nevertheless, the evidence based on experience from Latin America, in particular Peru, is still lacking, with particularised regulatory guidelines missing. This means more empirical studies are needed to assess the deployment of multimodal systems in these settings. In this sense, the objective of the present work is to cover a first analysis of a feasibility scenario for multilevel design of a bi-directional micromobility corridor on a highly congested limited-access avenue in Lima with dual character as a functional condition both an urban and interurban road, giving an initial idea of what could be included in future changes in urban mobility models.

3. Materials and Methods

This study adopted a quantitative applied approach with a descriptive-explanatory scope and a quasi-experimental comparative design. The PTV Vissim microsimulation models were then replicated to replicate existing conditions and proposed conditions, where the validated models were calibrated against existing traffic data. We based our study on direct observation and photography, the efficacy of which has been shown in previous studies [39]. At the same time, these techniques are employed to build calibration models of signalized intersections under heterogeneous traffic conditions [18]. This analysis also included methods for predicting micromobility demand predominantly in large metropolitan areas, where models used to predict bike-sharing systems have been tested using spatial simulation [40]. The analysis also included literature focused on pedestrian interaction with micromobilities [41] and on proof of the traffic calming effects that come with designated bike facilities [42]. Conclusions: This study gives simulation-based evidence on the viability of a roadway reallocation strategy using road diets in very congested urban areas and therefore helps to inform sustainable solutions for balanced motorized and non-motorized mobility in eastern Lima.

Four stages were established to achieve the proposed objectives. First, data were collected from a specific segment of a highly congested roadway to understand prevailing traffic conditions and operational characteristics. Next, the existing conditions were microsimulated, calibrated, and validated using PTV Vissim. Subsequently, an alternative scenario based on the road diet strategy was developed and simulated. Finally, the results obtained from the proposed and existing scenarios were compared to evaluate the feasibility of the intervention.

3.1. Study Area

The study area was located in the district of Ate Vitarte, Lima, Peru, and consisted of an approximately 1-km segment of Nicolás Ayllón Avenue, extending from the intersection with Juan Velasco Alvarado Street to Juan Pablo II University (start and end points, respectively, in Fig. 1). According to the Peruvian Ministry of Transport and Communications (MTC), the roadway is classified as a first-class highway, as it serves as a major corridor connecting Lima, located in western Peru, with the cities situated in the eastern region of the country.

It was originally intended to be a highway connecting Lima with cities in the central part of Peru. But with Lima continuing to grow into a sprawling urban landscape, the corridor is now surrounded by a sea of lined-up commercial malls, factories, and schools. Therefore, the road now serves urban and interurban purposes. José Balta Passage is one of the main access points within the study area due to its high inbound and outbound traffic volumes, which link surrounding urban areas with the study corridor. La Esperanza Avenue is also a secondary access, and it is mostly used by vehicles arriving at the industrial plants located in these areas.

Additional field observations identified that the study segment is not supported by an appropriate roadway redesign or planning strategy for its existing urban function. Such as no designated public transport stops or any properly implemented

Figure 1. Study Area.

Retrieved from: Google Earth (Coordinates 12°01'22"S 76°54'40"W and 12°01'15"S 76°54'16"W).

3.2. Data Collection

The field data collected for the study segment included vehicle composition (light vehicles, heavy vehicles, and non-motorized vehicles), travel times between predefined reference points, and roadway lane geometry.

Data were collected through field surveys. Traffic counts were conducted between 5:00 p.m. and 8:00 p.m., from Monday to Sunday. This period corresponds to the evening peak, which was confirmed by field observations at the study site. The selected time window was also supported by previous research conducted on nearby segments of the same corridor, which identified the evening period as the most congested portion of the day. In particular, the highest traffic volumes were recorded between 6:00 p.m. and 7:00 p.m. [43]. In addition, speed data were collected during the peak hour on Thursdays and Fridays. To do this, two stationary reference points marked by streetlight poles were used as information for the fixed vehicle travel times, which were taken with digital stopwatches. Typical roadway geometric features were also collected in the field.

To ensure accurate data collection during the traffic surveys, the vehicle classification forms established by the MTC were used [33]. These forms served as a guide for vehicle classification and for determining roadway capacity and Level of Service (LOS). Traffic data were recorded at 15-minute intervals to minimize potential measurement errors [33].

Despite this, MTC does not supply referential forms for speed measures or other factors related to traffic, as its guide is measurably limited to geometric highway design.

3.3. Modeling in the PTV Vissim Program of Segments from this Section

Based on the initial assessment of the study corridor and the field data collected, the existing scenario was modeled in PTV Vissim using 10 simulation runs. The model was developed to accurately represent the roadway geometry, observed traffic volumes, and operational characteristics of the study corridor.

The field observations also suggested that around 40% of corridor traffic volume consisted of vehicles entering and exiting through its main access point. Conversely, modes of transport associated with the second access point were viewed as insignificant and were omitted from the analysis.

According to the Highway Capacity Manual (HCM) [44], traffic performance can be effectively evaluated under peak-hour conditions, as they reflect traffic behavior during periods of high demand. Likewise, urban traffic operations can be modeled and assessed using data collected over specific or short-duration intervals, provided that these intervals represent critical operating conditions [15]. Peak-hour data have also been used to analyze the behavior of non-motorized vehicles under homogeneous traffic conditions [12]. Collectively, these studies suggest that representative periods such as the peak hour provide a reliable basis for reproducing traffic flow conditions.

The average traffic volumes from Tuesday to Thursday were used for model calibration, since these days were taken as representative of normal weekday conditions. Validation used traffic data from the highest traffic demand period of Friday. In the same way, Thursday speed data were used to calibrate the model, and Friday speed data were used for validation.

While the corridor is designated as a highway, it currently operates in an urban context [7]; thus, the Wiedemann 74 car-following model was chosen to be calibrated. The calibrated parameters, which can be described as driver behavior parameters, were average standstill distance (ax), addendum of safety headway (bxadd), and supplemental part of safety headway (bxmult). Values of 2, 3, and 3 represent the typical urban driving conditions in Germany. Mean Absolute Percentage Error (MAPE) is used for the validation of speed and GEH statistics for traffic volumes to validate model outputs with field observations recorded on Friday.

3.4. Simulation of the Bidirectional Corridor Using the Road Diet Strategy

In this stage, the existing roadway configuration was restructured using a road diet approach. Roadway space previously allocated exclusively to vehicular traffic was reallocated to accommodate dedicated bidirectional micromobility corridors. The proposed design considered operational, capacity, and safety requirements, as well as the physical and geometric constraints of the urban corridor. In addition, the FHWA Road Diet Informational Guide [1] was used to identify the most appropriate reconfiguration strategy for the study corridor.

This design included an outbound left-turn lane (3.00 m exclusive) and two up to 30m wide micromobility corridors on both sides of the roadway; In addition, the access management system implemented controls that restricted outbound traffic flows from José Balta Passage. The proposal was drafted on the assumption that it would be included in a major urban mobility plan from which they dispensed alternative exit paths. The redesigned configuration was subsequently implemented in PTV Vissim to realistically simulate traffic operations under the proposed roadway layout while incorporating dedicated infrastructure for micromobility.

3.5. Comparison Between Current Scenario vs. Proposed Scenario

In the final stage, the existing and proposed scenarios were analyzed and compared. The evaluation was based on key roadway performance indicators, including average speed, travel time, and changes in traffic congestion levels. The analysis of these indicators enabled a quantitative assessment of the differences between the two scenarios and provided a basis for determining whether the implementation of the proposed bidirectional micromobility corridor improved mobility conditions along the study segment. The combined effects of these performance measures were ultimately reflected in the Level of Service (LOS) assessment, conducted in accordance with the Highway Capacity Manual (HCM) [44] and the guidelines established by the MTC [33].

4. Results

4.1. Road Geometry

Fig. 2 illustrates the layout of the Nicolás Ayllón Avenue study segment. The roadway consists of two lanes in each direction. The carriageway extending from Juan Velasco Alvarado Street toward Juan Pablo II University has a total width of 6.80 m, while the opposite carriageway is 7.50 m wide. The two directions of traffic are separated by a 3.15-m-wide median.

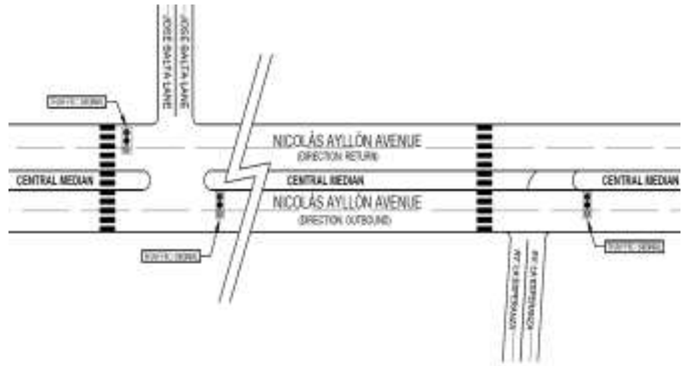

Figure 2. Traffic Signal Location Scheme.

Signal timing data were also collected for the two control points (see Table 1), located at the intersections of the study corridor with La Esperanza Avenue and José Balta Passage. The José Balta Passage intersection was identified as the primary control point due to the substantial volume of inbound and outbound traffic, particularly from Pedro Ruiz Gallo Avenue, which provides a key connection between the surrounding urban area and Nicolás Ayllón Avenue. In contrast, traffic volumes at the La Esperanza Avenue control point were considerably lower, as this access is used primarily by vehicles serving the adjacent industrial facilities and their workforce.

Table 1. Signal Timings in the Study Section.

Intersection	Red	Green
Esperanza Avenue	30 s	40 s
José Balta Passage (Control Point)	30 s	70 s

4.2. Traffic Study

The traffic analysis focused on the study segment of Nicolás Ayllón Avenue. As shown in Fig. 3, traffic volumes on Friday were the highest compared to all other days evaluated. It was chosen as validation for the model for this reason. This finding goes along with earlier studies that show Friday evening usually is the time of peak congestion when most traffic volumes occur [43].

Likewise, from the traffic study carried out, it was confirmed that the time period with the greatest vehicular congestion is from 6 p.m. to 8 p.m. In Table 2, the “outbound” direction for the Velasco Street – San Pablo section has the highest congestion peak from 6 to 7 p.m.

Speed data were also collected during the peak hour on Thursday and Friday. Table 3 presents the mean speeds by vehicle category in both travel directions, according to the vehicle classifications used in PTV Vissim.

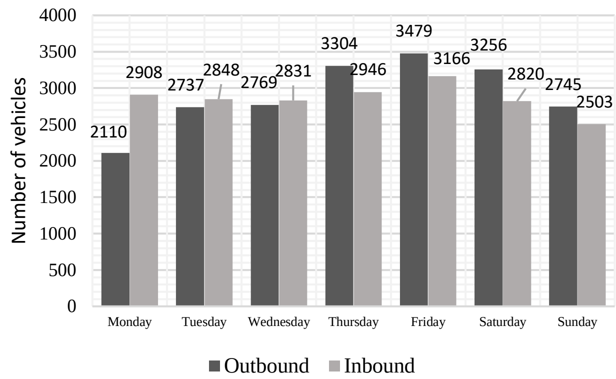

Figure 3. Bar chart of vehicular flow in both directions.

Table 2. Vehicular flow per hour in both directions.

Segment	Time interval (p.m.)	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Outbound	5:00 to 6:00	1061	801	946	1088	1145	1058	948
Outbound	6:00 to 7:00	714	815	778	1067	1195	1064	764
Outbound	7:00 to 8:00	1005	1121	1045	1149	1139	1134	1033
Inbound	5:00 to 6:00	887	1001	1129	1079	1152	1099	746
Inbound	6:00 to 7:00	1074	956	929	1020	1086	1041	1015
Inbound	7:00 to 8:00	947	891	773	847	928	680	742

Table 3. Speed in both travel directions during peak.

Direction	Passenger car		LGV		Bus		HGV	
	Mean (km/h)	SD. (km/h)	Mean (km/h)	SD. (km/h)	Mean (km/h)	SD. (km/h)	Mean (km/h)	SD. (km/h)
				Thursday				
Outbound	17.16	0.58	14.97	0.50	12.97	0.35	12.68	0.44
Inbound	15.42	0.29	13.89	0.67	13.46	0.17	11.40	0.14
				Friday				
Outbound	17.11	0.67	15.20	0.55	12.95	0.33	12.74	0.36
Inbound	15.08	0.28	13.89	0.61	13.31	0.13	11.30	0.15

4.3. Existing Conditions Model

For traffic volumes, average peak-hour data collected from Tuesday through Thursday were used for model calibration, while Friday traffic data were used for validation. Similarly, speed data collected on Thursday were used for calibration, whereas those collected on Friday were used to validate the model.

The field data collected according to the MTC vehicle classification system [33] were reclassified to align with the vehicle categories used in PTV Vissim. The passenger car category included automobiles and station wagons. The light goods vehicle (LGV) category included pickup trucks and panel vans. The bus category comprised combis, minibusses, and buses with configurations ranging from 2E to 4E. Finally, the heavy goods vehicle (HGV) category included all truck types, semi-trailers, and tractor-trailers. Table 4 summarizes the traffic volume distribution for each vehicle category, along with the corresponding mean speeds used for model calibration.

Table 4. Traffic volume distribution and mean speeds by vehicle category used for PTV Vissim calibration.

Direction	Passenger car		LGV		Bus		HGV	
	Volume	Speed. (km/h)	Volume	Speed. (km/h)	Volume	Speed. (km/h)	Volume	Speed. (km/h)
Outbound	58.91%	17.16	5.46%	14.97	24.67%	12.97	10.96%	12.68
Inbound	54.90%	15.42	3.77%	13.89	28.34%	13.46	12.99%	11.40

Next, the study corridor existing conditions model was built in PTV Vissim (Fig. 4) with roadway geometry and lane configuration. The model mimics an urban corridor with a predominating excessive vehicular demand and multiple intersections inviting interactions between the mainline traffic and physical access points, creating potential conditions for persistent congestion. Signal timing configuration and vehicle composition were also taken into account in the simulation. In addition, average operating speeds of 15 km/h for passenger cars and LGVS were adopted from the field measurements presented in Table 4 for buses and HGVs, with a typical speed of 12 km/h.

Figure 4. Modeling of the study area in the PTV Vissim program.

Due to its importance in affecting the workings of the corridor, the analysis was conducted only on this main control point (see

Fig. 5) for calibration and validation purposes. This position corresponds to the intersection between Nicolás Ayllón Avenue and José Balta Passage, where several traffic flows interact through merging, diverging, and turning movements. Such operational characteristics become a significant bottleneck as they channel conflicts and flow disturbances that impair traffic progression, facilitate queue formation, and lower operating speeds. Thus, modeling was focused on this intersection because it is the primary bottleneck limiting the overall operation of the study corridor.

Figure 5. Modeling at the central control point with vehicle entry and exit from Pedro Ruiz Gallo Ave. through José Balta Passage

Calibration of the models was done through iterative calibrations using the Wiedemann 74 car-following parameters, where simulated traffic volumes mimicked field data. This is in agreement with prior work using microsimulation models in urban environments where the calibration of car-following models such as Wiedemann 74 and Wiedemann 99 must replicate real-world traffic conditions [7]. The parameter combination that showed the best fit to field observations was ax = 1, bxAdd = 1, and bxMult = 1.5 (Table 5). Unlike the default urban driving parameters, these indicate a more aggressive behavior in the corridor—lower spacing and smaller safety margins.

Table 5. Iterative calibration of Wiedemann 74 parameters.

ax	bxAdd	bxMult	Wiedemann 74 Field Data		Vissim	
			Mean	SD.	Mean	SD.
Outbound						
2	3	3			956	74
1.5	1.5	2.5			1006	79
1	1	2			1033	61
1.5	1	1	1080	67	1041	63
1	1.5	1			1043	50
1	1	1.5			1068	62
1	1	1			1055	65
0.5	0.5	1			1071	73
Inbound						
2	3	3			881	71
1.5	1.5	2.5			919	76
1	1	2			981	87
1.5	1	1	995	65	956	72
1	1.5	1			968	74
1	1	1.5			981	89
1	1	1			1016	87
0.5	0.5	1			1030	74

Then, the traffic flow between PTV Vissim and Friday based on simulation results was validated against the actual data for memoization model validation. Table 6 lists the observed mean speeds recorded along with each of the three vehicle categories operating across the corridor during the Friday peak hour and their associated modeled Vissim mean speeds.

Table 6. Comparison of Average Speeds: Field Observed vs. Simulated.

Direction	Average Speed Observed in Field (km/h)	Average Speed Simulated (km/h)	MAPE
Outbound	14.50	16.03	10.55%
Inbound	**13.39**	**15.35**	**14.64%**

The Mean Absolute Percentage Error (MAPE) is used to validate speed by calculating the mean of | simulated value observed value| /observed values according to (1).

$$\mathrm{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{V_{real}-V_{simulated}}{V_{real}}\right| \text{x } 100 \qquad (1)$$

MAPE values of 10.55% and 14.64% were obtained for speed in the outbound and inbound directions, respectively. As this value is lower than the 15% acceptance threshold, the model can be considered sufficiently accurate [7]. The result confirms the adequacy of the calibration process and the model's ability to realistically represent observed traffic flow conditions.

Besides, we calculated the GEH statistic (see Table 7) to check the calibration of traffic volumes by Equation (2). The goodness of fit (GOF) was evaluated using the GEH statistic to assess the marginal agreement between observed and simulated traffic volumes. The values of GEH 3.78 and 3.27 were obtained, which meet the internationally accepted calibration criterion (GEH < 5) [7]. A larger R^2 shows that the model is an accurate representation of observed traffic flow and is more likely to represent actual Traffic conditions in reality. Hence, the calibration can be considered good.

$$\mathrm{GEH}_{total} = \sqrt[2]{\frac{2(Q_{sim\ total}-Q_{real\ total})^2}{Q_{sim\ total}+Q_{real\ total}}} \qquad (2)$$

Table 7. Comparison of Observed and Simulated Peak-Hour Traffic Volumes.

Direction	Observed Friday Peak-Hour Traffic Volume (veh/h)	Simulated Traffic Volume (Veh/h)	GEH
Outbound	1195	1068	3.78
Inbound	1086	981	3.27

Besides, the field data collected during the site surveys were used to determine the Level of Service (LOS) of the roadway. The assessment was conducted in accordance with the methodology and criteria established in the HCM. Under this framework, roadway operating conditions are classified into six levels of service, ranging from LOS A to LOS F, based on traffic density and the resulting quality of traffic flow. The analysis required a set of input parameters obtained from field observations and traffic surveys.

Based on the data presented in Table 8, the traffic density for each direction of travel was calculated in accordance with the procedures specified in the HCM [44]. The resulting density values are presented in Table 9.

Table 8. Input data obtained in the field for LOS calculation.

Direction	Total hourly volume (veh/h)	max. 15 min volume (veh/15min)	Heavy vehicles (%)	Observed average speed (km/h)
Outbound	1195	299	12.68%	14.50
Inbound	1086	278	11.40%	13.39

Table 9. Calculated values according to HCM.

Direction	Peak Hour Factor (PHF)	Adjusted hourly volume (Veh/h)	Heavy vehicle adjustment (Veh/h)	Vehicular density (veh/km/lane)
Outbound	1	598	675	46
Inbound	0.98	554	618	46

The traffic density thresholds provided by the HCM [44] are expressed in Imperial units (miles). To maintain consistency with the analytical framework adopted in this study, these thresholds were converted to the International System of Units (IS). Table 10 summarizes the corresponding Level of Service (LOS) classification criteria as a function of traffic density, expressed in vehicles per kilometer per lane.

Table 10. Adaptation of the levels of service (LOS) to the IS.

Level of service (LOS)	Operability	Density (veh/km/lane)
A	Free flow	≤7
B	Stable flow	>7-11
C	Constant flow with significant interaction between automobiles.	>11-16
D	Flow close to unstable conditions	>16-22
E	Flow close to unstable conditions	>22-28
F	Forced flow, severe congestion	>28

Based on the results presented in Table 10, the Level of Service (LOS) was classified according to the roadway's current operating conditions. For the inbound direction, a traffic density of 46 veh/km/lane was obtained, corresponding to LOS F. Similarly, for the outbound direction, a density of 46 veh/km/lane was recorded, which also corresponds to LOS F. These results indicate severely congested operating conditions in both directions, consistent with the HCM criteria.

4.4. Modeling of the Road Diet Proposal

Given the severe congestion observed in the study corridor, alternative and effective measures were explored to improve current traffic conditions. Among these, the road diet strategy emerged as an innovative and inclusive solution [1]. The selected design consists of introducing a dedicated central left-turn lane and providing 1.50 m multimodal lanes on each side of the roadway (see Fig. 6).

For the implementation of this proposal, the existing median was removed to accommodate a 3.00 m exclusive left-turn lane in the outbound direction, consistent with the guidelines for road diet implementation proposed by the FHWA [1]. Right-turn movements toward José Balta Passage are maintained in the outbound direction. In addition, egress movements from José Balta Passage toward the outbound direction of Nicolás Ayllón Avenue are restricted. This intervention is part of a broader planning strategy aimed at reducing conflict points along the corridor.

Regarding lane width, no reduction of the existing lane dimensions was proposed, given the high traffic volumes along this urban corridor. However, spatial efficiency was improved through the reallocation of the right-of-way, as illustrated in Fig. 6, resulting in an optimized geometric design.

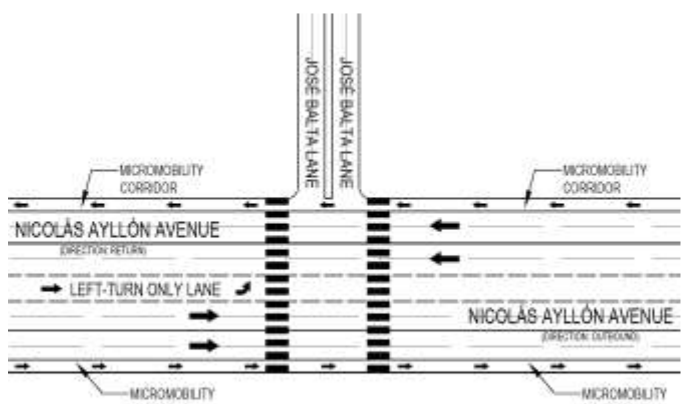

Figure 6. Proposal approach implementing Road Diet and micromobility corridors.

On the other hand, consolidating left-turn movements into a dedicated central lane contributed to the optimization of operating speeds. For this purpose, the maximum allowable speed for urban roads was adopted in accordance with current regulations. Specifically, Supreme Decree No. 025-2021-MTC issued by the Peruvian Ministry of Transport and Communications [45] establishes a maximum speed of 50 km/h on urban avenues; however, in areas with commercial activity, schools, or hospitals, the speed limit must not exceed 30 km/h. Given the characteristics of the study area, the latter value was adopted for the analysis.

Similarly, for the incorporation of micromobility corridors, the Urban Bikeway Design Guide of NACTO was used as a reference, which provides typical demand ranges and operating conditions for cyclists. For the proposed scenario, an average bicycle flow of 150 bicycles per hour and a design speed of 20 km/h were assumed.

Regarding signal timing, the green phase at the intersection with Av. La Esperanza was adjusted, increasing from 40 seconds to 70 seconds to achieve coordination with the signal timings at the intersection with José Balta Passage. Finally, the proposed scenario was modeled in VISSIM, as illustrated in Fig. 7.

Figure 7. Modeling of the proposal with Road Diet at the intersection with José Balta Passage.

During the simulation process, the software enabled the estimation of average speeds in both directions of the roadway. These values were subsequently used to recompute the Level of Service (LOS). It was assumed that traffic demand under real-world conditions remains within the range obtained from the traffic study. Based on this, the results presented in Table 11 were derived.

Table 11. Vehicular density calculated with the application of the Road Diet strategy.

Direction	Heavy vehicle adjustment (Veh/h)	Average speed (km/h)	Vehicular density (veh/km/lane)
Outbound	674	31.23	22
Inbound	618	31.06	20

According to Table 11, a reduction in traffic density is observed in both directions under the proposed scenario compared to existing conditions. This improvement is reflected in a better Level of Service (LOS) classification, with estimated density values ranging between 19 and 22 veh/km/lane. Consequently, the proposed alternative, based on the road diet strategy and the implementation of lateral multimodal corridors, improves the operational performance of the corridor, achieving a classification of LOS D. This represents a significant enhancement compared to the current operating conditions, indicating a more efficient use of roadway capacity.

Joint analysis of travel times (Table 12) and queue formation (Table 13) indicates that both cycle tracks perform satisfactorily. The travel times, which translate to speeds of about 19 km/h — a speed range typical for urban operation. On the other hand, an average queue length of 1.31 m suggests that very few cyclists are queuing and therefore there is no evidence of serious congestion. Moreover, all the recorded stops match localized interrupts which do not disrupt flow continuity. In summary, the cycle facilities are mostly characterized by near free-flow conditions and a good standard of service.

Table 12. Micromobility travel times over 750 m.

Section	Vehicles (Veh)		Average time	
	Mean	**SD.**	**Mean**	**SD.**
Outbound cycle facility	17	5	138.79	3.13
Inbound cycle facility	17	4	144.41	9.44

Table 13. Micromobility queue length.

Cycle Track	Average Queue Length (m)	SD.	Maximum Queue Length (m)	SD.	Average Stop Length (m)	SD.
Outbound cycle facility	1.31	0.35	9.48	2.17	12	3
Inbound cycle facility	1.31	0.30	9.73	2.14	11	3

4.5. Comparison between Existing and Proposed Scenarios

After simulating both scenarios, we did a comparison. The results are shown in Table 14, where travel times under the proposed configuration decrease for all three analyzed segment types. This reduction is mainly due to roadway space reallocation through a road diet strategy that allows the rearrangement of turning movements, eliminates longitudinal traffic conflicts, and ensures continuous flow along the main corridor. This means a decrease of 46.06% on average for outbound travel and 44.56% less in the inbound direction. The results indicate that the reduction of operational conflict and consolidation of traffic movements into fewer conducting paths lead to increased operating speeds and thereby reduced travel times.

In terms of the behavior through which it was acted in each segment analyzed, there were variations in delay times, which, if you can tell, indicates that it was affecting the operating cycle of vehicles as a consequence of this proposal. This behavior can be further mechanistically understood as the geometric redistribution of roadway space using this road-diet strategy that changes conditions for vehicle interaction and queuing. In particular, the central turning lane and the new access point organize traffic flow better than before but are faced with higher demand at a few key points.

Table 14. Travel time Comparison.

Segment	Vehicles (Veh)		Average travel (s)	
	Mean	SD.	Mean	SD.
Outbound (Existing)	93	5	229.71	9.39
Outbound (Proposed)	136	10	123.89	4.20
Inbound (Existing)	88	8	210.67	6.06
Inbound(proposed)	124	13	116.82	7.97

Table 15 summarizes that the gain in queue time was 18.95% for outbound and 8.92% for inbound, which is a locally limited impact of vehicle accumulation from the new roadway configuration despite global improvements to speed and travel times.

Table 15. Performance results.

Direction	Speed (km/h)		Queue delay (s)		Occupancy	
	Mean	SD.	Mean	SD.	Mean	SD.
Outbound (current)	15.63	1.16	19.58	7.08	26.18%	4.19%
Outbound(proposed)	31.23	0.38	23.29	3.00	12.42%	1.32%
Inbound (current)	16.50	0.74	20.62	7.04	29.94%	4.55%
Inbound (proposed)	31.06	0.20	22.46	2.92	12.68%	1.04%

Conversely, Table 16 is included to compare queue lengths across the analyzed scenarios. It displays the maximum queue generated under congested conditions for both travel directions. The outbound direction yields a decrease of 12.51%, and the return direction is presented with an increase of 35.76%. The behavior can be mechanistically explained as a function of the new geometric distribution around the intersection channeling turning movements toward the middle lane, and limiting negative interaction with the main channel flowing outward on approach. This is, at the same time, also inducing demand to concentrate and vehicle congestion in given spots in the return direction. Accordingly, the proposed intervention leads to different effects on queue formation.

Table 16. Queue comparison.

Queue	Average Length (m)		Maximum Length (m)		Stop	
	Mean	SD.	Mean	SD.	Mean	SD.
Outbound (current)	33.78	23.68	175.65	83.46	139	79
Outbound(proposed)	24.28	7.56	153.67	40.58	81	15
Inbound (current)	18.43	16.89	123.58	67.53	95	62
Inbound (proposed)	38.60	18.83	167.78	51.58	149	63

5. Discussion

From the traffic study conducted, it was diagnosed that the Central Highway, in its urban segment corresponding to Av. Nicolás Ayllón, exhibits high levels of vehicular congestion due to its dual function as both an urban and interurban corridor, generating elevated demand levels and operational friction.

It was observed that Friday concentrates the highest peak demand, constituting the critical scenario for analysis. This information was essential for calibrating the current-condition model in the PTV Vissim software, enabling a more accurate representation of the actual operating conditions of the roadway. In line with Abdeen et al. [7] and Otković et al. [39], the evaluation and calibration of traffic models under high-demand conditions allow for a more realistic reproduction of vehicular flow behavior in urban environments. Likewise, the selected time interval (18:00–19:00) is supported by empirical evidence, which identifies this evening period as the peak congestion window [43]. It should be noted that the referenced study was conducted at an intersection located near the study area, reinforcing the consistency and applicability of these traffic behavior patterns. Therefore, the selection of Friday evening hours is grounded not only in field data but also in existing literature, strengthening the validity of the model and the representativeness of the study scenario.

For the modeling of existing conditions, the results in terms of level of service validate what was observed during the traffic study. The service level at present is Grade F, which means the roadway operates under extremely congested conditions with high travel times and delays. From a theoretical perspective, this condition occurs when demand exceeds roadway capacity, raising density and slowing speeds relative to free-flow conditions (as established by the HCM [44]).

Similarly, Venegas et al. [2] explain that low levels of service such as E and F occur when vehicular demand meets or exceeds roadway capacity, resulting in reduced speeds and high delays. Additionally, Av. Nicolás Ayllón lacks formal bus stops, which increases lateral friction, causing frequent stops and irregular maneuvers that disrupt flow continuity, as also described in the HCM [44].

Additionally, in urban settings, the inadequate mix of behavior across road users is a crucial component associated with the level of service, with detached drivers and uncontrolled pedestrian crossings. Mechanistically, these situations increase traffic friction and create barriers to flow, which slow operating speeds and adversely affect continuity without necessarily increasing volume. In contrast, other studies show that after implementing a road diet strategy, levels of service do not experience generalized deterioration, remaining stable in most intersections, although localized impacts are observed, such as transitions from LOS B to C and from LOS C to D at specific intersections due to reduced capacity and flow redistribution; however, operational improvements are also observed at unsignalized intersections, where performance is enhanced [24].

Furthermore, the MAPE of speed also confirmed the accuracy of the microsimulation model, which may be considered acceptable as its value is under 15%, indicating a good match between field-recorded and PTV Vissim-derived speeds [7]. Similarly, GEH values less than 5 were achieved, which indicates reasonable calibration [7].

With regard to the proposed modeling scenario applying the road diet strategy, which includes micromobility corridors along the lateral edges of the roadway, an enhancement in system performance and misalignment of simulation scores was experienced. The phased increase in level of service in both directions, from F to D, reflects considerably improved congestion conditions, but some operational constraints persist nevertheless. The highly critical Level of Service at first (LOS F) for these critical points relates to the dual nature of the corridor as an urban arterial and an interurban link, resulting in a very high demand and friction from operation. In this regard, the proposal differs from a classical lane-reduction scheme by focusing on a distribution of lanes aimed at better flow continuity. Mechanistically, the improvement has been explained by the redistribution of road space that channels turn through a center lane while segregating micromobility flows to the edges, which reduces lateral friction. This minimizes interruptions and non-compliant stopping behaviors, which supports smoother and more effective traffic flow [46].

Additionally, Zhou et al. [47] and Venegas et al. [2] have reported similar findings, noting that geometric road reallocation directly impacts roadway operational performance. Likewise, studies [13] and [4] highlight that the inclusion of micromobility infrastructure indirectly reduces congestion by promoting multimodal transportation systems, which is consistent with the results obtained in this proposal. In summary, the implemented geometric redesign based on the road diet strategy was key to reducing congestion along the studied corridor. This reduction is also reflected in the simulation outputs, showing decreases in travel times, queue lengths, and informal stopping points.

Regarding the scenario comparison, it was confirmed that the proposed roadway redistribution significantly improved congestion conditions, as evidenced by reductions in travel time delays and queue lengths. It is important to note that, according to the literature, typical road diet interventions involving a reduction from four to three lanes tend to produce slight deterioration or moderate changes in operational performance, which contrasts with the results obtained in this study [2]. Properly designed road diets can improve roadway performance and reduce lateral friction [2], [46]. Furthermore, the reduction of informal stops contributes to smoother system operation, attributed to the separation of traffic streams aimed at creating a multimodal transportation system divided into motorized and micromobility modes. This aligns with studies [13] and [36], which establish that modal segregation reduces lateral conflicts and improves traffic stability and flow, consistent with the indicators obtained through simulation.

6. Conclusions

The field traffic study allowed for the characterization of the selected corridor, identifying severe congestion conditions, with the most critical scenario occurring on Fridays between 18:00 and 19:00 hours. Hourly traffic volumes of 1,195 veh/h (outbound) and 1,086 veh/h (inbound) were recorded, with heavy vehicle shares of 12.68% and 11.40%, respectively. Average operating speeds reached 14.50 km/h and 13.39 km/h in each direction. Regarding roadway geometry, lane widths of 6.80 m and 7.50 m per direction were measured, with a central median of 3.15 m. Signal timing analysis revealed cycle splits of 30/40 s (red/green) at Av. Esperanza and 30/70 s at José Balta Passage. This information provided a robust baseline for model calibration and validation in PTV Vissim.

Regarding the microsimulation of current conditions in PTV Vissim, the objective was to accurately replicate existing roadway performance. The average travel time to traverse approximately 750 m was found to be 229.71 s (outbound) and 210.67 s (inbound). A level of service F was obtained, with densities of 46 veh/km/lane for both directions. Operational performance indicators showed maximum queue lengths of 175.65 m (outbound) and 123.58 m (inbound), average speeds of 15.63 km/h and 16.50 km/h, and average queue delays of 19.58 s and 20.62 s, respectively. Road occupancy was 26.18% (outbound) and 29.94% (inbound). Model validation using MAPE for speed and GEH for traffic flow confirmed simulation reliability, yielding 10.55% and 14.64% MAPE and 3.78 and 3.27 GEH, demonstrating acceptable agreement between field data and simulated outputs.

The proposed model incorporating a road diet strategy was developed based on FHWA guidelines [1], eliminating the median to introduce a 3 m central turning lane and adjusting signal timing at Av. Esperanza (40 to 70 s green time). Additionally, the Urban Bikeway Design Guide [10] informed the inclusion of 1.50 m micromobility corridors on both sides, with a bicycle demand of 150 bic/h and operating speed of 20 km/h. This configuration resulted in improved performance, with LOS D in both directions, travel times of 123.89 s and 116.82 s, and maximum queue lengths of 153.67 m and 167.78 m. Average speeds increased to 31.06 km/h and 31.23 km/h, while queue delays averaged 23.29 s and 22.46 s. Road occupancy decreased to 12.42% and 12.68%. For the micromobility lanes, travel times of 138.79 s and 144.41 s were recorded, corresponding to average speeds of 19.45 km/h and 18.70 km/h, with average queue lengths of 1.31 m and maximum values of 9.48 m and 9.73 m, and 12 and 11 stops in each direction.

The quantitative comparison of both scenarios confirms the feasibility of implementing a road diet with micromobility corridors, evidenced by an improvement in level of service from F to D in both directions. Travel time reductions reached 46.06% (outbound) and 44.56% (inbound); queue delays increased by 18.95% and 8.92%; maximum queue length decreased by 12.51% (outbound) while increasing by 35.76% (inbound); and occupancy decreased from 26.18% to 12.42% and from 29.94% to 12.68%. Overall, these results indicate improved traffic flow, reduced lateral friction, and more stable system operation, providing technical evidence applicable to roadway redesign decisions in high-demand urban corridors in Latin American contexts.

Finally, although an optimal feasibility outcome was achieved through the PTV Vissim model, it is recommended that future studies compare alternative solutions and test them using different simulation platforms to strengthen the robustness of the findings. Additionally, relevant variables such as road safety and environmental impacts, which are fundamental in sustainable transportation studies, were not included in this analysis; therefore, their incorporation in future research would enable a more comprehensive evaluation of the proposal. Likewise, this study is intended as a starting point for larger-scale research that further explores the implementation of road diets along the Central Highway and across Peru.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Author Contributions

Marlym Collao-Quintana and Stefany Mendoza-Ventura contributed equally to all stages of the research, including problem identification, methodological design, literature review, fieldwork, and data collection. Likewise, the microsimulation of both the existing and proposed roadway scenarios was jointly developed. Both authors were equally responsible for data analysis and interpretation, as well as for writing, revising, and approving the final manuscript.

Nathalie Chacón contributed as methodological advisor, ensuring alignment between the defined objectives, the adopted methodological approach, and the field data collection techniques, thereby maintaining the rigor and coherence of the research process.

Cesar Abraham Reyes Virhuez contributed as technical advisor, providing expertise in transportation engineering, guiding the analysis of the proposed roadway design, and verifying the technical consistency of the parameters used in the microsimulation model.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, the authors used the Copilot AI service to improve the clarity and comprehension of the text, after its translation. Likewise, the authors corrected the text as necessary after the use of Copilot, thus assuming full responsibility for the content of the published article.

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