The use of microsimulation to support the design of cycling networks. The case of Av. de Roma, Lisbon

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INTRODUCTION

According to the United Nations, it is predicted that around 68% of the world's population will live in urban areas by 2050. Currently, in Portugal, the urban population constitutes 66.8% of the total, and it is estimated that it will grow up to 79.3% by 2050. (United Nations, 2018)

For many years, urban areas were designed to facilitate the use of private vehicles. As a result of this massive use and with the increase of motorization levels, cities today are suffering from high traffic congestion problems, saturation of public areas, pollution and noise.

Thus, there is a paradigm shift in mobility, in which the increase in the use of cycling can serve as best option, in a perspective of ensuring the transportation of goods, services and people, while causing the least environmental, economic and social impact, and having sustainable mobility as its main driver.

In view of this new reality, it is imperative to formulate a strategic plan that, mirroring the best practices recommended throughout Europe, can promote the creation of more bike lanes allowing the use of bicycles as an accessible mobility solution. (Neto et al., 2021)

This context triggered a need to develop this work as a way to understand the use of microsimulation (VISSIM software) in the design of cycling networks by exploring the case of Avenida de Roma.

OBJECTIVES

The general objective of this work is to analyze, using VISSIM software, the impact on traffic generated by implementing several solutions for a cycling corridor on Avenida de Roma.

The specific objectives are:

- To analyze which cycling infrastructure is best suited to the road under study;
- Analyze the feasibility of implementing this cycling infrastructure, using the results obtained through microsimulations
- Analyze the best cycling infrastructure, using the results obtained through microsimulations.

METHODOLOGY

METHODOLOGICAL APPROACH

The flowchart (figure 1) explains the various stages of construction and application of the simulation model used in this dissertation.

The initial step consisted of modeling the (base) road network where the simulation model for the base scenario runs. This base scenario intends to reproduce the reality of Av. de Roma where mobility data was collected through on-site counting. At the same time, several study scenarios are defined for the inclusion of the cycle path. These scenarios will be tested by changing either the road network or some base scenario simulation parameters.

The construction of the base model went through the respective coding (that is, parameterization of the arcs and network connectors, as well as the vehicles tested). In order for the simulation model to best reproduce the observed reality, the model is calibrated, seeking to approximate the simulation results (for example, flows in the arcs) with the data collected in the field.

After calibration, the model is validated using the GEH statistical test.

With the tool calibrated, the study scenarios were simulated for the various solutions for the inclusion of the cycle path.

With the various alternative scenarios built, the respective results were analyzed and discussed, always comparing the performance of the alternative scenarios with the base scenario, for a set of selected performance indicators.

Finally, the dissertation ends with a set of conclusions from the work presented.

Figure 1 – Flowchart

CHARACTERIZATION OF THE CASE STUDY AREA

The project "MOVE Lisboa – strategic vision for mobility 2030", published by Lisbon Municipality, comprises the project to implement bike lanes by the year 2030. This project includes an intervention at Avenida de Roma, which will be the subject of this study. Avenida de Roma is characterized by being one of the main streets in the city of Lisbon, with a wide variety of commerce and services (figure 2). These characteristics generate a large flow of daily users, which generates traffic and pollution that can be reduced with the implementation of a bike lane.

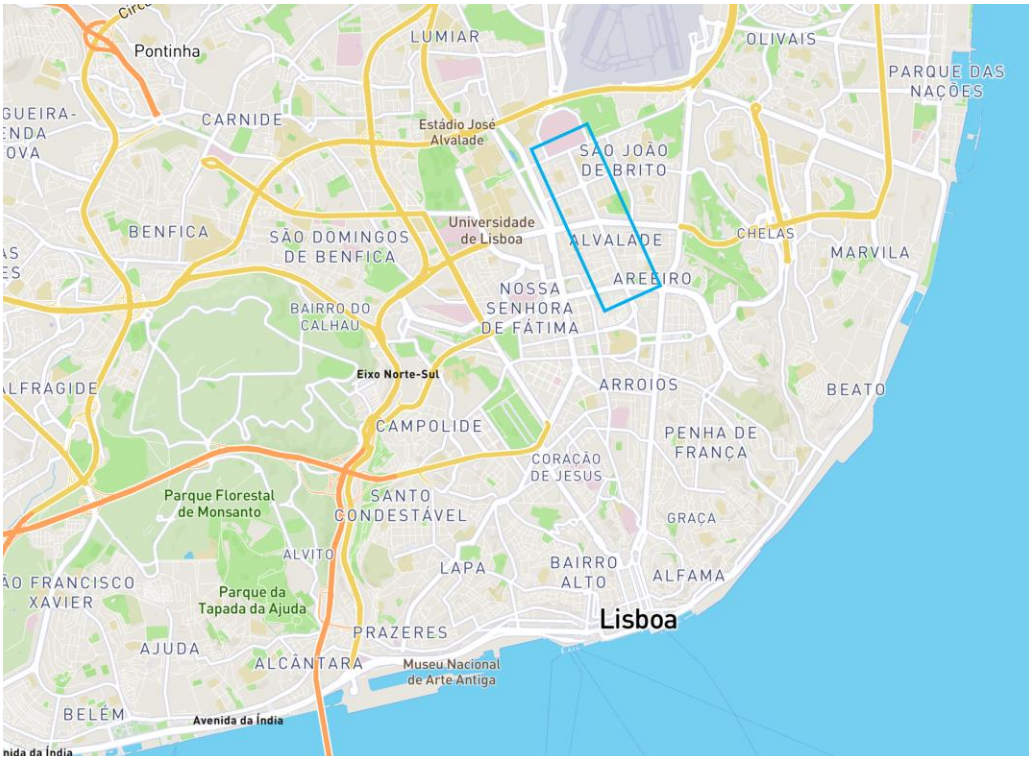

Figure 2 – Case study area (marked with blue rectangle)

DATA COLLECTION

Traffic data collection of was carried out on site, over a period of a week (20 to 22 July 2021), from 7:30 am to 9:30 am, as this is the time interval corresponding to the highest peak hour of the day.

For each one of 12 intersections in total at Av. de Roma (figure 3), a 15-minute video was recorded, where it was possible to observe all the movements allowed at each intersection. Subsequently, the recordings were viewed and the volume of traffic entering and leaving the intersection and its respective routes was counted. A (4 times) proportionality coefficient was applied to the collected information with the purpose of obtaining the average values of traffic volume per hour.

During the data collection period, traffic lights cycles were also counted (a total of 137) and measured the

Figure 3 – Case study pathways. In blue are the lanes with hierarchical level 3 and in green the lanes with hierarchical levels 4 and 5

times of the phases in each traffic-lighted intersection.

The data from the cyclists was extracted from the manual counting carried out by CERIS (IST) in October 2020 (8am-10am and 5pm-7pm). Although these observations were made in different parts of the city of Lisbon, only the information referring to the studied area along the axis of Av. de Roma in 5 places of intersection with Av. de Roma was used: Av. Brasil, Praça de Alvalade, Av. Frei Miguel Contreiras (Roma-Areeiro Station), Av. Óscar Monteiro Torres and Praça de Londres.

SCENARIO DEFINITION

Scenario for validation

This scenario seeks to express, as closely as possible to the observed reality, all traffic volumes, traffic-lighted intersections and number of lanes in the area. It serves only to validate the simulation model.

Base Scenario

The base scenario of the case study originates from the 30% increase in traffic in the scenario for validation. This was an attempt to approximate the pandemic context to the pre-pandemic reality, as the counts were made in a pandemic situation and, therefore, the traffic volume was obviously lower and would not reflect a regular set of circumstances during peak hour. Thus, the proposed changes would not simulate a situation that, in itself, would be one of potential congestion. In order to avoid an under-evaluation, a 30% increase in counted traffic was suggested.

Scenario 2

This scenario is a variant of the Base Scenario and intends to simulate the simplest solution in the system, which is a reduction in traffic speed. With this solution, bicycles' circulation can be compatible with the traffic of motor vehicles.

The enforced speed reduction was from 50km/h to 30km/h, allowing a safer coexistence with bicycles. The traffic light intersections were also adjusted in order to change the Base Scenario green wave (from 50km/h to 30km/h).

Scenario 3

In scenario 3, a bidirectional bike lane was introduced in the south-north direction of Av. de Roma (lower traffic volume direction), removing one traffic lane. With the creation of the bike lane, there is a prediction of increase in the volume of cyclists, so a 100% increase in the volume of cyclists was introduced. However, the traffic volume of motor vehicles was kept, as it is not known what changes these could present. Regarding the maximum allowed speed, the base scenario was maintained.

Scenario 4

Regarding the last scenario, this one derives from scenario 3, with the same changes between base scenario and scenario 2. The maximum speed of motor vehicles was reduced to 30km/h, as well as the readjustment of the green wave.

It should be noted that, in both scenarios (3 and 4), it was also necessary to adjust the traffic light phase plan due to the introduction of the bike lane. For these same scenarios, the traffic volume of motor vehicles was not changed, as when restrictions on traffic conditions occur, 3 phenomena can happen: route deviation, trip cancellation or transport mode transfer. As it was not possible to quantify the change, it was decided to keep the volume (most unfavorable scenario).

It was decided to place the bike path on the left lane to minimize conflicts (among all stakeholders). Bus stops, car parking and right-hand turns would cause more conflict areas between cars and cyclists (when compared to the presented solution), thus reducing the overall safety of the network. On the other hand, the turns to the right of the bicycles are impaired, so it was necessary to protect this movement with its own phases in the traffic light cycles.

VALIDATION (VISSIM)

After calibrating the simulation model, validation is required. Validation consists of the process of verifying the calibrated model in order to assess its predictive capacity, in scenarios other than those used in the calibration phase. This step intends to ensure that the conclusions obtained by the model are applicable to the system under study.

The variables mostly considered in this stage of the simulation process are: traffic volumes, speeds and queues with an emphasis on traffic volume (J. P. Tavares & João, 2015). Thus, it was based on the modeled traffic volumes that the validation of the model under study was carried out, i.e., comparison of the simulated volumes with the observed volumes (counts) through the GEH index (initials of the name of the transport engineer, Geoffrey E. Havers).

The GEH Index is a statistical method, based on the chi-square test, used to compare modeled and observed traffic volumes (counts). This index can be calculated for each section or for the entire network (Vilarinho, 2008) using the following formula.

$$GEH = \sqrt{\frac{2 * (x_i - y_i)^2}{(x_i + y_i)}} \quad (1)$$

Where x_i represents the number of vehicles counted in the observations for a certain location and the number of vehicles obtained in the simulations for that same location.

The formula presented was developed by Geoffrey E. Havers (1970) and consists of the square root of the absolute difference $(x_i - y_i)$ divided by the relative difference $\frac{2*(x_i-y_i)}{(x_i+y_i)}$. This formula also allows considering that the GEH index incorporates relative and absolute errors.

There are different approaches regarding the value to adopt for the GEH index. Morgan e Veysey (2013) define that a GEH index value of less than 5 for 95% of the cases of an individual section is an acceptable value. However, Dowling (et al., 2004) define the same range of values, however, they accept that it is related to only 85% of cases.

In order to compare traffic volumes, virtual counting points were inserted in the simulation model at all entrances and exits of the intersections (54 counting points distributed over 103 lanes) and 30 simulations were performed for a time interval of 15 minutes (period corresponding to the counting time).

In the following table it is possible to verify the values obtained through the simulation, the values obtained in the counts and finally the GEH. GEH results less than 5 appear with the cell filled in green; between 5 and 10 Ines yellow and finally, greater than 10 in orange.

Table 1 – GEH results

Counting points	Nº of modeled cars	Nº of observed cars	GEH	Counting points	Nº of modeled cars	Nº of observed cars	GEH
1	182	159	1,78	28	87	135	4,56
2	275	266	0,53	29	122	126	0,38
3	164	155	0,71	30	35	54	2,81
4	227	163	4,62	31	61	60	0,13
5	150	154	0,35	32	26	38	2,04
6	123	93	2,94	33	163	241	5,50
7	12	3	3,53	34	149	190	3,15
8	32	21	2,08	35	5	6	0,53
9	121	154	2,79	36	111	110	0,10
10	140	69	6,97	37	20	20	0,00
11	86	68	2,11	38	17	29	2,46
12	23	24	0,16	39	74	34	5,48
13	118	154	3,07	40	69	69	0,03
14	221	94	10,14	41	216	204	0,85
15	68	46	2,88	42	90	111	2,12
16	59	58	0,20	43	25	26	0,25
17	24	25	0,20	44	5	6	0,53
18	22	23	0,11	45	6	6	0,10
19	28	23	1,09	46	14	31	3,63
20	138	173	2,77	47	74	79	0,54
21	206	113	7,41	48	213	169	3,20
22	146	200	4,11	49	55	53	0,34
23	228	263	2,20	50	46	44	0,34
24	31	48	2,63	51	93	90	0,31
25	110	109	0,12	52	51	46	0,68
26	164	176	0,94	53	229	190	2,69
27	147	209	4,63	54	61	58	0,45

Performance Indicators

For the choice of performance indicators, it was necessary, a priori, to know which indicators were possible to withdraw from VISSIM. That said, and in accordance with the objectives of the work, the main one being to analyze the impacts that the creation of a segregated lane for bicycles generates on Avenida de Roma, the following were defined:

- **Delay time (s)** – total journey time minus the time it takes a vehicle to complete this journey, under ideal conditions (no traffic lights and no traffic);
- **Delay due to stops (s)** – total delay time in which the vehicle is stopped;
- **Number of stops** – number of times a vehicle is immobile;
- **Speed (km/h**);
- **Active vehicles** – number of vehicles that are in the system at the end of the simulation;
- **Vehicles arrived** – number of vehicles that completed the trip;
- **Entry delays (h)** – total delay time for each vehicle to enter the simulation;
- **Unsatisfied demand** – number of cars that do not enter the simulation due to entry delay;
- **Average queue size (m)** – average queue size, in meters, of the indicated traffic light;
- **Maximum queue size (m)** – maximum queue size, in meters, of the indicated traffic light;
- **Trip time (s)** – total time from start to finish of the trip.

PRESENTATION AND DISCUSSION OF RESULTS

30 simulations were carried out for each scenario, simulations that took 8100s, that is, two hours and fifteen minutes, for the network to warm up in the first fifteen minutes of the simulation. This heating serves so that,

when the results are measured, the network is already loaded with active cars, otherwise the network would be empty, without the natural constraints of a morning rush hour, and could bias the results.

As previously stated, these scenarios were all carried out with static routes and, therefore, to obtain the results, it was necessary to define routes so that, later, the values of the indicators of these same routes could be removed.

Table 2 – Car traffic results (North - South)

ROUTES	BASE SCENARIO						SCENARIO 2					
	Travel time (s)		Delay time (s)		Delay due to stops (s)		Travel time (s)		Delay time (s)		Delay due to stops (s)	
Brasil W - Londres	332,49		196,97	59,24%	129,33	38,90%	420,85	26,58%	202,49	48,11%	147,79	35,12%
Brasil E - Londres	378,31		241,58	63,86%	168,53	44,55%	448,08	18,44%	228,17	50,92%	171,53	38,28%

ROUTES	SCENARIO 3						SCENARIO 4					
	Travel time (s)		Delay time (s)		Delay due to stops (s)		Travel time (s)		Delay time (s)		Delay due to stops (s)	
Brasil W - Londres	366,18	10,13%	230,57	62,97%	157,23	42,94%	442,70	5,19%	224,11	50,62%	169,55	38,30%
Brasil E - Londres	404,71	6,98%	267,44	66,08%	191,73	47,37%	470,85	5,08%	251,21	53,35%	195,81	41,59%

This analysis (table 2) was made only for the longest route on Av. de Roma in the opposite direction to the direction in which the cycle path was introduced. It was concluded that the big difference between the scenarios with the same speed is the increase in downtime. This is in line with the changes made in the cycle path scenarios. With the introduction of the same, there was a need to create a specific traffic light phase for bicycles, increasing the cycle time. The results show that the impact, on the average travel time, is negative, but not more than 10% of the time. Intermediate pathways were not analyzed as they were not considered relevant for this study.

Table 3 – Car traffic results (South - North)

ROUTES	BASE SCENARIO						SCENARIO 2					
	Nº of cars	Travel time (s)	Delay time (s)		Delay due to stops (s)		Nº of cars	Travel time (s)	Delay time (s)		Delay due to stops (s)	
Londres - Brasil E	49	513,08	380,60	74,18%	271,61	52,94%	47	548,37	336,04	61,28%	250,25	45,64%
Londres - Brasil W	34	549,44	410,67	74,74%	296,48	53,96%	35	584,16	362,90	62,12%	274,47	46,99%
Londres - Alvalade E	32	377,12	258,02	68,42%	182,77	48,46%	35	429,76	241,83	56,27%	179,63	41,80%
Londres - Alvalade W	31	543,10	423,63	78,00%	321,60	59,21%	31	611,43	421,62	68,96%	330,30	54,02%
Joao XXI E - Alvalade E	18	356,84	236,00	66,13%	160,60	45,01%	19	403,48	218,04	54,04%	156,97	38,91%
Joao XXI E - Alvalade W	17	546,67	425,44	77,82%	318,53	58,27%	17	604,53	417,51	69,06%	322,61	53,37%
Joao XXI E - EUA W	19	196,03	118,13	60,26%	79,22	40,41%	19	218,48	103,67	47,45%	76,38	34,96%

	SCENARIO 3						SCENARIO 4					
	Nº of cars	Travel time (s)	Delay time (s)		Delay due to stops (s)		Nº of cars	Travel time (s)	Delay time (s)		Delay due to stops (s)	
Londres - Brasil E	46	777,28	645,21	83,01%	452,43	58,21%	47	853,49	640,29	75,02%	477,62	55,96%
Londres - Brasil W	35	806,44	668,21	82,86%	476,10	59,04%	33	889,25	668,25	75,15%	502,02	56,45%
Londres - Alvalade E	34	449,79	330,50	73,48%	223,39	49,66%	32	519,59	331,41	63,78%	244,01	46,96%
Londres - Alvalade W	28	634,27	514,76	81,16%	380,15	59,94%	29	696,83	506,00	72,62%	393,84	56,52%
Joao XXI E - Alvalade E	18	460,17	339,08	73,69%	234,39	50,93%	17	516,51	331,15	64,11%	245,11	47,46%
Joao XXI E - Alvalade W	17	648,85	527,73	81,33%	393,73	60,68%	16	702,89	514,89	73,25%	404,09	57,49%
Joao XXI E - EUA W	18	229,65	151,83	66,11%	102,99	44,85%	20	277,91	162,78	58,57%	122,79	44,18%

In the opposite direction and analyzing, in more detail, the south-north direction of Avenida de Roma, 7 routes were chosen that in their entirety reflected the impacts that the implementation of the cycle path caused (table 3). When analyzing the number of cars that complete the journeys in the different scenarios and on the various routes, no significant differences are found. Consistently and significantly, the introduction of the cycle path factor in both scenarios (50km/h and 30km/h) results in an increase in travel time on all analyzed routes. It can be concluded that if the traffic light is adapted for a green wave of 30km/h, the fluidity of traffic will be greater compared to 50km/h (the percentages of stopped time in relation to the total travel time are, for all routes, lower in the scenarios with 30km/h).

Table 4 – Car traffic results (South - North)

ROUTES	BASE SCENARIO	SCENARIO 2		SCENARIO 3		SCENARIO 4	
	Travel time (s)	Variation (s)		Variation (s)		Variation (s)	
		Absolute	Relative	Absolute	Relative	Absolute	Relative
Londres - Brasil E	513,08	35,28	6,88%	264,19	51,49%	340,41	66,34%
Londres - Brasil W	549,44	34,72	6,32%	257,00	46,78%	339,81	61,85%
Londres - Alvalade E	377,12	52,64	13,96%	72,67	19,27%	142,47	37,78%
Londres - Alvalade W	543,10	68,32	12,58%	91,17	16,79%	153,72	28,30%
Joao XXI E - Alvalade E	356,84	46,64	13,07%	103,33	28,96%	159,67	44,74%
Joao XXI E - Alvalade W	546,67	57,86	10,58%	102,18	18,69%	156,23	28,58%
Joao XXI E - EUA W	196,03	22,44	11,45%	33,61	17,15%	81,88	41,77%

Comparing now, the differences in absolute values in relation to the base scenario (table 4), it can be seen that, in the worst case, for a trip that would be, on average, about 9 minutes and 10 seconds (549.44s) , there was an increase of 5 minutes and 40 seconds (339.81s). In general terms, the average time difference per trip, in absolute value, for the analyzed routes, is just over 2 and a half minutes (2.60 min) for a respective average trip of 8 and a half minutes (8.55 min), ie a 30% aggravation.

Table 5 – Traffic lights queuing

TRAFFIC LIGHTS	BASE SCENARIO		SCENARIO 2	
	Average queue size (m)	Maximum queue size (m)	Average queue size (m)	Maximum queue size (m)
13	62,25	190,69	36,15	163,07
12	9,25	70,49	12,81	92,80
11	89,50	205,54	91,96	210,80
10				
9	8,41	58,50	7,72	50,24
8	23,18	124,67	22,64	133,21
7	9,96	64,51	10,91	67,76
6	3,28	24,97	3,55	28,22
5	11,68	115,44	13,07	117,64
4	23,81	89,20	25,01	89,22
3	11,19	71,50	11,11	74,23
2	5,69	65,72	6,48	76,26
1	1,40	39,74	1,53	40,03

TRAFFIC LIGHTS	SCENARIO 3		SCENARIO 4	
	Average queue size (m)	Maximum queue size (m)	Average queue size (m)	Maximum queue size (m)
13	158,88	272,81	160,87	279,27
12	52,88	214,14	71,60	237,40
11	36,94	64,24	41,46	65,15
10	96,46	184,10	100,63	186,52
9	16,61	91,91	17,18	97,00
8	77,27	199,42	83,95	194,66
7	12,01	69,07	13,89	83,02
6	3,55	30,49	3,88	39,73
5	58,94	196,38	71,12	196,11
4	33,23	88,74	48,62	88,74
3	32,22	149,64	44,73	155,67
2	13,11	87,25	14,82	87,95
1	3,09	86,27	3,45	95,56

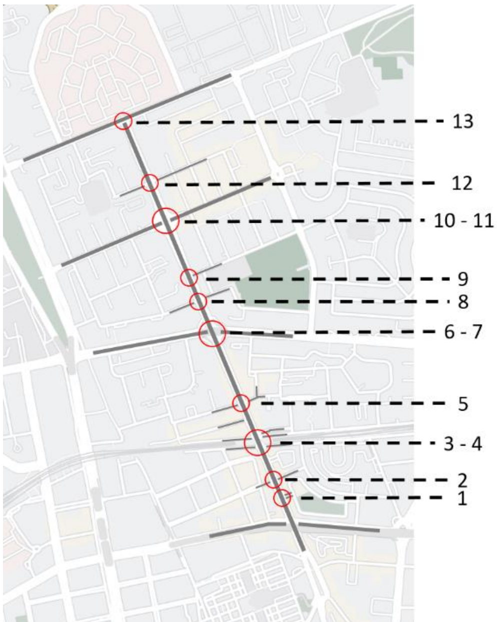

Figure 4 – Traffic lights localization

Table 5 shows the indicators: average size and maximum size of the traffic light queues located at the intersections of Figure 4, in the south-north direction (Praça de Londres – Av. do Brasil). It is in this sense that a route was removed, in almost the entire length of the VA. from Rome (for the creation of the cycle path) and therefore the reason for this analysis to be made for this direction of traffic. In the scenarios with a bicycle path (scenario 3 and scenario 4), there is a general increase in the average size of the vehicle queue, the maximum queue size and the number of stops in the queue, when compared to the scenarios without a bicycle path (base scenario and scenario 2). It should be noted that there is no scenario that stands out due to the smaller average size of the vehicle queue, maximum queue size and number of stops in the queue. This is true in the two scenarios without a cycle path (base scenario and scenario 2). On the other hand, the scenario with the highest average vehicle queue size, maximum queue size and number of queue stops is the scenario with a bike path at 30km/h (scenario 4).

Table 6 – Bicycle traffic results

ROUTES	BASE SCENARIO						SCENARIO 2					
	Nº of bicycles	Travel time (s)	Delay time (s)		Delay due to stops (s)		Nº of bicycles	Travel time (s)	Delay time (s)		Delay due to stops (s)	
Londres - Brasil W	7	745,22	336,09	45,10%	275,87	37,02%	5	703,84	273,91	38,92%	222,76	31,65%
Londres - Brasil E	5	695,10	311,23	44,77%	257,37	37,03%	3	656,17	299,30	45,61%	245,10	37,35%
Londres - RomaAreeiro W	6	222,66	92,87	41,71%	76,51	34,36%	4	223,45	93,34	41,77%	76,10	34,06%
Londres - RomaAreeiro E	7	178,62	61,99	34,71%	49,11	27,50%	5	183,62	65,75	35,81%	52,87	28,79%
RomaAreeiro E - Brasil W	3	642,65	318,16	49,51%	269,08	41,87%	2	577,64	297,97	51,58%	250,26	43,32%
RomaAreeiro E - Brasil E	2	601,77	287,06	47,70%	243,34	40,44%	3	627,15	267,02	42,58%	230,55	36,76%
RomaAreeiro W - Brasil W	2	601,64	270,16	44,90%	231,82	38,53%	2	592,29	263,08	44,42%	226,69	38,27%
RomaAreeiro W - Brasil E	1	586,85	279,47	47,62%	238,99	40,72%	0	-	-	-	-	-
Brasil E - RomaAreeiro W	8	496,60	176,26	35,49%	152,68	30,75%	8	489,02	167,11	34,17%	143,95	29,44%
Brasil E - RomaAreeiro E	0	-	-	-	-	-	0	-	-	-	-	-
Brasil W - RomaAreeiro W	4	473,47	155,81	32,91%	135,52	28,62%	4	448,35	131,79	29,39%	112,61	25,12%
Brasil W - RomaAreeiro E	0	-	-	-	-	-	0	-	-	-	-	-

ROUTES	SCENARIO 3						SCENARIO 4					
	Nº of bicycles	Travel time (s)	Delay time (s)		Delay due to stops (s)		Nº of bicycles	Travel time (s)	Delay time (s)		Delay due to stops (s)	
Londres - Brasil W	16	886,29	473,52	53,43%	414,97	46,82%	15	872,61	459,66	52,68%	403,15	46,20%
Londres - Brasil E	9	885,60	474,46	53,58%	417,17	47,11%	9	881,62	468,70	53,16%	412,67	46,81%
Londres - RomaAreeiro W	10	280,87	167,45	59,62%	154,66	55,07%	11	279,98	167,06	59,67%	154,25	55,09%
Londres - RomaAreeiro E	16	290,58	172,64	59,41%	160,01	55,07%	15	291,02	173,07	59,47%	160,38	55,11%
RomaAreeiro E - Brasil W	6	707,65	375,63	53,08%	324,12	45,80%	6	675,35	343,92	50,92%	296,95	43,97%
RomaAreeiro E - Brasil E	3	659,13	331,28	50,26%	287,71	43,65%	3	689,89	360,20	52,21%	313,77	45,48%
RomaAreeiro W - Brasil W	9	684,75	351,46	51,33%	301,64	44,05%	9	699,33	364,48	52,12%	314,45	44,96%
RomaAreeiro W - Brasil E	5	688,45	358,36	52,05%	307,69	44,69%	5	678,06	353,71	52,17%	302,00	44,54%
Brasil E - RomaAreeiro W	17	654,93	325,51	49,70%	300,22	45,84%	16	641,52	312,77	48,75%	288,12	44,91%
Brasil E - RomaAreeiro E	0	-	-	-	-	-	0	-	-	-	-	-
Brasil W - RomaAreeiro W	8	650,34	320,39	49,26%	295,26	45,40%	8	646,65	316,62	48,96%	291,09	45,01%
Brasil W - RomaAreeiro E	0	-	-	-	-	-	0	-	-	-	-	-

With regard to bicycles (table 6), 12 routes were defined. It appears that travel time increases with the introduction of the cycle path, as, as mentioned above, bicycles in these scenarios have their own traffic light phase to ensure their movements safely in the face of car traffic. Thus, it appears that the average travel time increased (average downtime increased by approximately 50%, base scenario and scenario 3, and approximately 80% in scenarios 2 and 4), but on the other hand, significant safety advantages can be seen, public health and environmental quality (Table 8).

Table 7 schematically shows the qualitative comparison of the impact of the different scenarios when compared to the base scenario.

Table 7 - Qualitative comparison of impacts compared to the base scenario

INDICATORS	Without bike lane	With bike lane	
	SCENARIO 2	SCENARIO 3	SCENARIO 4
Travel time (cars)	↘ (yellow)	↘ (red)	↘ (red)
Travel time (bicycles)	↗ (yellow)	↘ (yellow)	↘ (yellow)
Delay	↗ (yellow)	↘ (red)	↘ (red)
Parking	—	↘ (yellow)	↘ (yellow)

Note: Red is defined as aggravation; yellow is used for either slight improvement (positive slope) or slight worsening (negative slope); the dash is used to represent the non-variation.

Table 8 – Qualitative comparison of impacts compared to the base scenario 2

INDICATORS	Without bike lane	With bike lane	
	SCENARIO 2	SCENARIO 3	SCENARIO 4
Pollutant gas emissions	↗ (yellow)	↗ (green)	↗ (green)
Cyclists health	↗ (yellow)	↗ (green)	↗ (green)
Cyclists safety	↗ (yellow)	↗ (green)	↗ (green)
Pedestrian safety	↗ (green)	↗ (yellow)	↗ (green)
social interaction	↗ (yellow)	↗ (green)	↗ (green)

Note: Green is defined as improvement; yellow is used for slight improvement

Table 8 systematizes the qualitative analysis of the possible impacts of scenarios 2, 3 and 4 when compared to the base scenario, namely at the level of: emission of polluting gases, cyclists' health, cyclists' safety, pedestrian safety and social interaction. It should be noted that these parameters were not the object of this study, however, they can never be disregarded in the discussion of results and conclusions or even, ultimately, in decision-making.

Although scenario 2 proved to be more advantageous in the items analyzed, the introduction of the cycle path in scenarios 3 and 4 did not represent a significant aggravation compared to scenario 2 in the same items, translating in turn into significant advantages such as the reduction of polluting gases, improving the health and safety of cyclists. In short, the introduction of the cycle path represents a potential gain in safety and quality of life for residentes and visitors of Av. de Roma.

CONCLUSION

The simulation carried out and the analysis of the results obtained showed that the creation of a cycle path introduced delays (as expected before proceeding with the simulation). However, if considered in terms of absolute value, delays translate into approximately 5 minutes (on the longest route). These 5 minutes lost in completing the route are amply compensated by gains, namely in terms of pollution levels and benefits for the physical condition of users (with a positive impact on public health). On the other hand, the possibility of reducing the maximum speed limit, within cities, from 50km/h to 30km/h (which according to the simulations did not produce significant changes in motorized traffic) seems to improve the effective travel times of cyclists with optimization of their security.

The introduction of the cycle path and the reduction of the maximum speed could improve safety conditions so that more people can use bicycles with significant impacts on the environment and public health.

With the elaboration of this work, it was possible to verify that VISSIM proved to be a microsimulation software, capable of reproducing the scenarios under analysis, practical, and useful in the analysis of the problems raised.

As limitations, one can refer to the fact that the counting of cars for introduction in the simulation was carried out during a pandemic period and school holidays. In order to try to overcome this limitation, the traffic volume was increased by 30%. However, even so, the value used may not be a value adjusted to the reality of the rush hour context on the avenue under study. The present simulation seems to indicate a trend however, more studies need to be carried out in order to draw other conclusions.

As a suggestion, it is proposed that, in the future, the impact assessment in terms of emissions and pollution levels could be considered, as well as the realization of a macro simulation that could also assess the surrounding area.

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