# Use of bicycles as an alternative to reduce people's travel times in the face of the deficient public transport system

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***Summary – Currently, about 53% of the world's population lives in urbanized areas. Therefore, the great cities of the world must assure their inhabitants a sustainable and efficient transport system. In Lima, public transportation is the main mode of transportation for 66% of the people. However, this transport system is one of the main sources of infection for COVID - 19. For this reason, the capacity of public transport has been reduced, generating long queues at bus stops and delays in people's travel time. Faced with this problem, an alternative for personal transport such as bicycles is proposed to reduce people's travel time. This research proposes a comparative analysis of travel time in the study area between people who use public transport and the proposed bicycle path. For it, data is collected and modes of transport in a residential and commercial area are compared using a calibrated and validated microsimulation in VISSIM 9. The results show that during peak hours in the study area, the total average travel time for the public transport route is 40 minutes and for the conventional and electric bicycle on the proposed bicycle path it is 19 and 13 minutes respectively.***

***Keywords – Bicycles; Bicycle Paths; Public Transport; Travel Time.***

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## I. INTRODUCTION

In many countries of the world, it is necessary to manage the urban traffic generated by the public transport system because it represents a considerable part of the vehicle flow. The problems associated with this mode of transport are delays in travel time and long queues waiting for existing excessive demand [1]. During the last two decades, several Latin American cities have implemented proposals to improve public transport without satisfactory results [2]. This is because short-term solutions continue to be proposed to improve the poor public transport system instead of proposing a comprehensive long-term solution that includes other modes of transport [3].

An alternative to the problem is to use the bicycle as an efficient mode of transport. It is correct to affirm that for the use of the bicycle there are not many interconnected bicycle paths for its circulation and that people are more exposed to accidents on the streets [4]. However, bicycle users find autonomy that is not found in public transport [5]. This light vehicle is for personal use, takes up less space than a car, avoids traffic congestion and is very effective for intermediate distances as it allows direct transport [6].

In Lima, one of the areas where the saturation of public transport is evident is in La Marina Avenue and Faustino Sánchez Carrión Avenue [7], where 15 public transport lines and about 3,600 vehicles travel during peak hours. The accumulation of people in these trip-generating areas contributes to the constant increase in the flow of vehicles. Consequently, the total travel time increases for people in the study area [8].

In the present study compared the public transport system due to excess demand existing in the avenues affected, and the bicycle as a mode of transport which is characterized by without much effort to avoid traffic congestion.

## II. STATE OF ART

Faced with this problem, research has been carried out that analyzes public transport and bicycles as competitive and/or complementary modes of transport.

A study conducted during COVID-19 social distancing in New York used information regarding the subway and the bike-sharing system (BSS). With this study, it was possible to analyze the impact of bicycles on urban transport and it was shown that in the study area many metro users changed their way of moving to the active mode of transport due to the current situation [9].

Another research carried out in Madrid analyzed the effect of different causes to promote sustainable transport. A comparative analysis was carried out between private transport, public transport, bicycles and go on foot. The results show that cyclists are more efficient compared to their competitors in small and intermediate section trips [10].

Similarly, a study was able to define potential trips on Bogotá's bicycle paths. Information on the number of trips was used and they were categorized according to their distance traveled through mobile applications for cyclists. A way was achieved to find priority routes for cyclists and establish exclusive lanes in main avenues of the city [11].

Similarly, other research in Xánthi indicated that the implementation of a network of bicycle paths near generators and attractors points in the city is a sustainable way of displacement for an average person on short or intermediate routes. In addition, it is indicated that the bicycle has greater access to places compared to the main routes of public transport [12].

Finally, another study in New York analyzed the repercussions of the bike-sharing system (BSS) on the public transport system. The results show a decrease in the number of people using buses in the study area due to a modal transfer from public transport to bicycles. Also, it is indicated that in order to plan a sustainable transport network, it must be understood that both modes of transport are complementary [13].

## III. Methodology

The methodology used in this research is divided into the following stages, which are detailed in Figure 1.

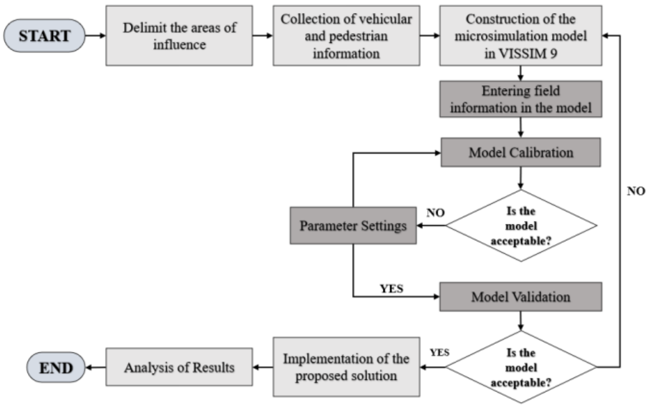


Fig. 1 Stages of the investigation process

### A. *Delimit the areas of influence*

The areas of influence are defined as the generators and attractors centers for people who need to travel daily. In Lima, the areas are separated by 3.5 km using the La Marina Avenue and Faustino Sánchez Carrión Avenue.

Area 1 is delimited by a radius of 300 meters whose center is the intersection of La Marina Avenue with Universitaria Avenue. In this place you can see a greater number of commercial areas than residential ones. This represents an attraction point that generates the travel of people from other nearby districts. In addition, in this area is the beginning of a 10.30 km long bicycle path on Universitaria Avenue.


Fig. 2 Delimitation of Area 1

Area 2 is delimited by a radius of 300 meters whose center is the intersection of Faustino Sánchez Carrion Avenue with Salaverry Avenue. In this place you can identify a greater number of residential areas than commercial ones. This represents a starting point for travel to other districts. Also, in this area there is a 4.80 km long bicycle path on Salaverry Avenues.


Fig. 3 Delimitation of Area 2

In both areas of influence there are bus stops and bicycle parking. On the one hand, bus stops correspond to the public transport line "Red Corridor". This public transport line was chosen because it has the most direct route to travel between the areas of influence and, consequently, has the highest passenger demand. On the other hand, the existing bicycle parking lots were considered as possible stops for this transportation alternative.

Figures 4 and 5 show the location of each bus stop and parking for the areas of influence. Bus stops 1, 2 and 4 represent the starting point of the Red Corridor and Bus stops 3 and 5 represent the arrival points.

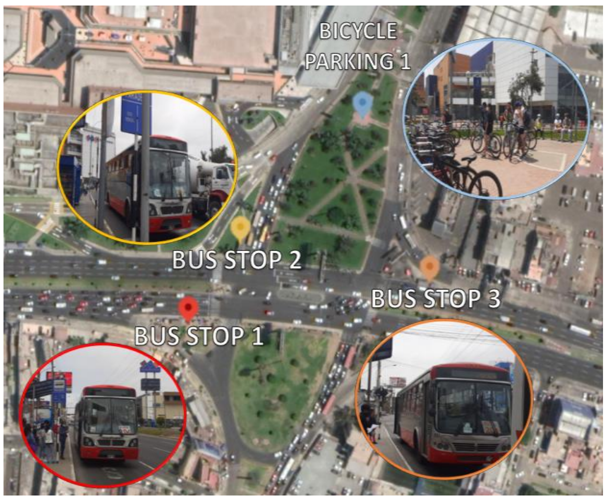


Fig. 4 Bus stops and parking in Area 1.

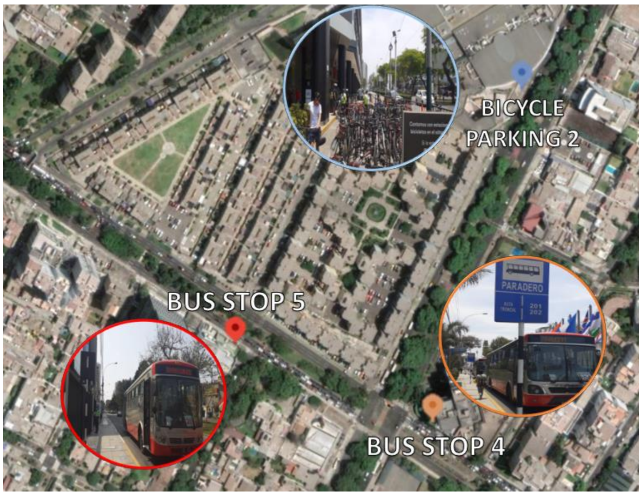


Fig. 5 Bus stops and parking in Area 2.

## B. *Collection of vehicular and pedestrian information*

The information is collected in the field considering the volumes of vehicles and pedestrians in the areas of influence and main intersections. It is possible to define the geometry of the vehicular infrastructure and identify the types of vehicles, the permitted movements, the traffic light cycles and the vehicular and pedestrian flow during peak hours. Figures 6 and 7 summarize the information collected regarding vehicle capacity at the main intersections.

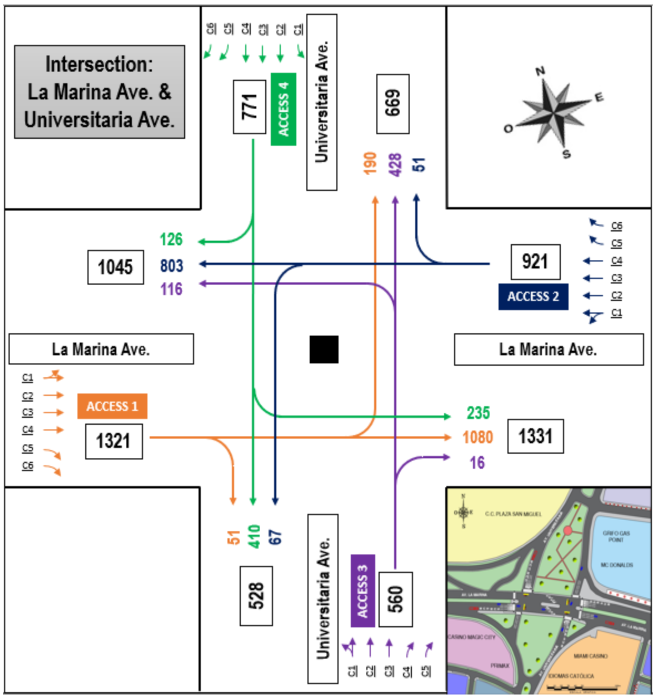


Fig. 6 Scheme movements in the signalized intersection in the Area 1

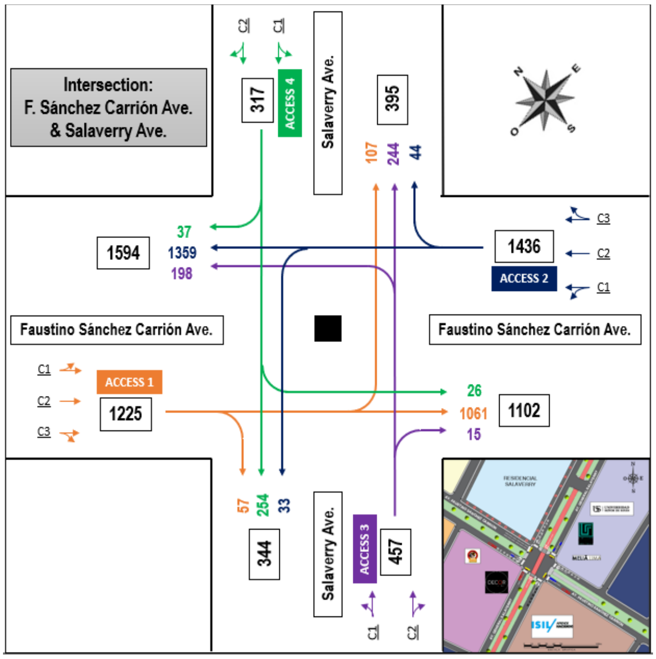


Fig. 7 Scheme movements in the signalized intersection in the Area 2

To collect data on the average speed of the Red Corridor, a distance of 30 meters is defined in the field to measure the speed reached by 30 buses at the 8 signalized intersections during peak hours. In Table 1, each signalized intersection between the areas of influence and the average speed of the Red Corridor are identified.

TABLE I
RED CORRIDOR SPEED FOR EACH INTERSECTION

| Red Corridor | | |
|---|---|---|
| Intersections | Speeds (km/h) | |
| | From Area 1 to Area 2 | From Area 2 to Area 1 |
| La Marina Ave. - Universitaria Ave. | 15.46 | 14.70 |
| La Marina Ave. - Unamuno St. | 15.18 | 14.66 |
| La Marina Ave. - Castilla St. | 15.09 | 14.53 |
| La Marina Ave. - Sucre Ave. | 14.86 | 15.20 |
| La Marina Ave. - Libertad St. | 14.83 | 15.62 |
| F. Sanchez Carrion Ave. - Hospital militar | 14.68 | 16.34 |
| F. Sanchez Carrion Ave. - G. Escobedo Ave. | 14.13 | 16.80 |
| F. Sanchez Carrion Ave. - Salaverry Ave. | 13.53 | 17.39 |

In addition, with respect to pedestrians, the time and average walking speed within the areas of influence were calculated. This was done considering the radius of influence (300 meters) towards the Red Corridor stops and the bicycle parking.

TABLE II
WALK TIME AND AVERAGE PEDESTRIAN SPEED

| Area of Influence | Start Point | Average Walking Time (minutos) | Distance (m) | Average Speed (km/h) |
|---|---|---|---|---|
| Area 1 | Bus Stop 1 | 5.03 | 300 | 3.579 |
| | Bus Stop 2 | 4.52 | 300 | 3.982 |
| | Bus Stop 3 | 5.45 | 300 | 3.303 |
| | Bicycle Parking 1 | 4.04 | 300 | 4.455 |
| Area 2 | Bus Stop 4 | 3.98 | 300 | 4.523 |
| | Bus Stop 5 | 5.75 | 300 | 3.130 |
| | Bicycle Parking 2 | 4.36 | 300 | 4.128 |

Also, it is relevant to know the waiting time of people at the bus stops. Due to the variation of this type of data, it was decided to group 100 people at each bus stop of the Red Corridor in 5-minute intervals during peak hours.

TABLE III

PERCENTAGE OF PASSENGERS AT EACH STOP ACCORDING TO THEIR WAITING TIME TO ACCESS THE RED CORRIDOR

| Waiting Time Interval (min) | Percentage of passengers waiting at the bus stop (%) | | |
|---|---|---|---|
| | Bus Stop 1 | Bus Stop 2 | Bus Stop 4 |
| 0 - 5 | 32.93% | 40.18% | 34.74% |
| 5 - 10 | 42.68% | 33.04% | 42.11% |
| 10 - 15 | 17.07% | 24.11% | 17.89% |
| + 15 | 7.32% | 2.68% | 5.26% |
| Total | 100% | 100% | 100% |

## *C. Construction of the microsimulation model*

The microsimulation model of the study area was carried out with the VISSIM 9 software. The available tools were used to model the routes, bus stops, sidewalks and pedestrian crossings respecting the existing geometry to achieve a model that resembles reality. Then, the data referring to the traffic light cycles, the volumes of light and heavy vehicles, the public transport lines, the pedestrian flows that cross the intersections in the areas of influence and the people waiting to board the buses were entered.

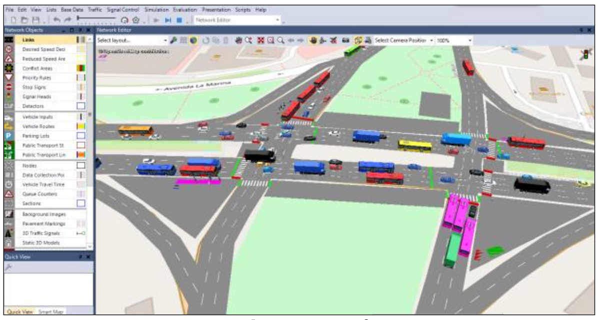

Fig. 8 3D microsimulation view of avenues in Area 1

Fig. 9 3D microsimulation view of avenues in Area 2

Afterwards, it proceeds to calibrate and validate the model generated in VISSIM 9. Regarding the simulation parameters, the minimum number of runs is calculated. For the present study, a total of 25 runs were carried out. Then, the warm-up period is defined as 600 seconds and the total simulation time is 4200 seconds.

On the one hand, for vehicle calibration, the Wiedemann parameters 74 (ax = 0.5, bxadd = 1.1 and bxmult = 3) are modified. On the other hand, for the pedestrian calibration, the social strength parameters are modified (Tau = 0.4, Lambda = 0.8 and Noise = 2.1).

In addition, the field data are compared with the data obtained in the VISSIM9. To do this, the online tool "Statkey" is used, with which the hypothesis test of the difference of means is carried out through 10 thousand permutations.

Tables 4 and 5 show the results of the calibration in the areas of influence:

TABLE IV

SUMMARY OF CALIBRATION RESULTS IN AREA 1

| | Calibration in Area 1 | | | |
|---|---|---|---|---|
| | Pedestrians | | Red Corridor | |
| | Field | Vissim | Field | Vissim |
| Sample | 30 | 25 | 30 | 25 |
| Average Time (seg) | 55.60 | 55.63 | 7.33 | 7.32 |
| Difference in Means (seg) | 0.03 | | 0.01 | |

TABLE V

SUMMARY OF CALIBRATION RESULTS IN AREA 2

| | Calibration in Area 2 | | | |
|---|---|---|---|---|
| | Pedestrians | | Red Corridor | |
| | Field | Vissim | Field | Vissim |
| Sample | 30 | 25 | 30 | 25 |
| Average Time (seg) | 156.10 | 156.13 | 7.02 | 6.98 |
| Difference in Means (seg) | 0.03 | | 0.04 | |

Tables 6 and 7 show the results of the validation in the areas of influence:

TABLE VI

SUMMARY OF VALIDATION RESULTS IN AREA 1

| | Validation in Area 1 | | | |
|---|---|---|---|---|
| | Pedestrians | | Red Corridor | |
| | Field | Vissim | Field | Vissim |
| Sample | 30 | 25 | 30 | 25 |
| Average Time (seg) | 55.55 | 55.58 | 7.34 | 7.32 |
| Difference in Means (seg) | 0.03 | | 0.02 | |

TABLE VII

SUMMARY OF VALIDATION RESULTS IN AREA 2

| | Validation in Area 2 | | | |
|---|---|---|---|---|
| | Pedestrians | | Red Corridor | |
| | Field | Vissim | Field | Vissim |
| Sample | 30 | 25 | 30 | 25 |
| Average Time (seg) | 156.08 | 156.11 | 6.95 | 6.97 |
| Difference in Means (seg) | 0.03 | | 0.02 | |

## *D. Implementation of the proposed solution*

A bicycle path is proposed to generate trips that directly connect the areas of influence. The proposed model shows pedestrian spaces, cyclists and the different types of existing vehicles. The average speed frequency was considered to be between 15 to 18 km/h for the conventional bicycle and between 20 to 25 km/h for the electric bicycle.

Figures 10 and 11 detail the main intersections modeled in VISSIM9 with the proposed solution.

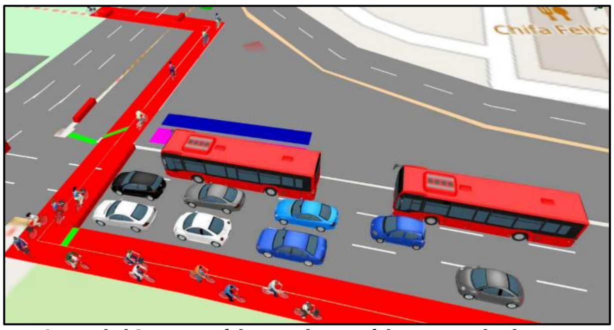

Fig. 10 Detailed 3D view of the simulation of the proposed solution in La Marina Avenue with Universitaria Avenue

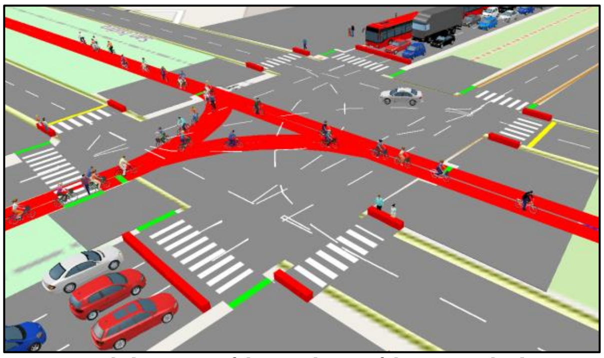

Fig. 11 Detailed 3D view of the simulation of the proposed solution in Faustino Sánchez Carrión Avenue with Salaverry Avenue

It is important to add that with this proposal it is possible to unite the existing bicycle paths on. Universitaria Avenue and Salaverry Avenue.

## IV. RESULTS

During the simulation of the proposed model, the travel times of people between the areas of influence are registered using public transport, conventional bicycle and electric bicycle.

Regarding to public transport, its total travel time is divided into four times called “Walking Time 1” (from its origin to the initial bus stop), “Waiting Time at the Bus Stop”, “Travel Time in the Red Corridor” and “Walking Time 2” (from the final bus stop to your destination).

Similarly, the travel time by conventional bicycle and electric bicycle is segmented into four times called "Arrival Time to the bicycle path" (time that the cyclist takes to integrate to the bicycle path from its initial point), “Bicycle Travel Time”, “Parking Time” (time it takes to park the bicycle) and “Walking Time” (from bicycle parking to your destination).

With the travel times defined, we proceed with the comparison between the modes of transport in the proposed model.

Tables 8, 9 and 10 show the results obtained from the total travel time of people between Area 1 and Area 2 in each mode of transport.

TABLE VIII

TOTAL TRAVEL TIME IN RED CORRIDOR BETWEEN AREAS OF INFLUENCE

| | Walking Time 1 (min) | Waiting Time (min) | | Travel Time in the Red Corridor (min) | Walking Time 2 (min) | **Total Travel Time (min)** |
|---|---|---|---|---|---|---|
| | | Interval | Percentage | | | |
| **Case 1**<br>From Area 1 to Area 2<br>Bus Stop 1 | 5.03 | 0-5<br>5-10<br>10-15<br>+15 | 40%<br>33%<br>24%<br>3%<br>100% | 20.59 | 5.75 | 33.87<br>38.87<br>43.87<br>+48.87 |
| **Case 2**<br>From Area 1 to Area 2<br>Bus Stop 2 | 4.52 | 0-5<br>5-10<br>10-15<br>+15 | 33%<br>43%<br>17%<br>7%<br>100% | 21.23 | 5.75 | 34.00<br>39.00<br>44.00<br>+49.00 |
| **Case 3**<br>From Area 2 to Area 1<br>Bus Stop 4 | 3.98 | 0-5<br>5-10<br>10-15<br>+15 | 35%<br>42%<br>18%<br>5%<br>100% | 16.21 | 5.45 | 28.14<br>33.14<br>38.14<br>+43.14 |

TABLE IX

TOTAL TRAVEL TIME BY CONVENTIONAL BICYCLE BETWEEN AREAS OF INFLUENCE

| | Arrival Time to Bicycle Path (min) | Conventional Bicycle Travel Time (min) | Parking Time (min) | Walking Time (min) | **Total Travel Time (min)** |
|---|---|---|---|---|---|
| **Case 4**<br>From Area 1 to Area 2<br>Bicycle Parking 1 | 1.50 | 13.43 | 0.5 | 4.36 | 19.79 |
| **Case 5**<br>From Area 2 to Area 1<br>Bicycle Parking 2 | 1.50 | 11.41 | 0.5 | 4.04 | 17.45 |

TABLE X

TOTAL TRAVEL TIME BY ELECTRIC BICYCLE BETWEEN AREAS OF INFLUENCE

| | Arrival Time to Bicycle Path (min) | Electric Bicycle Travel Time (min) | Parking Time (min) | Walking Time (min) | **Total Travel Time (min)** |
|---|---|---|---|---|---|
| **Case 4**<br>From Area 1 to Area 2<br>Bicycle Parking 1 | 0.70 | 7.23 | 0.5 | 4.36 | 12.79 |
| **Case 5**<br>From Area 2 to Area 1<br>Bicycle Parking 2 | 0.70 | 7.01 | 0.5 | 4.04 | 12.25 |

## V. CONCLUSIONS

In the results in Table 8, the Red Corridor registered an average total travel time between 28 to 49 minutes. In the results in Table 9, the conventional bicycle registered an average total travel time between 17 to 20 minutes. In the results in Table 10, the electric bicycle registered an average total travel time between 12 to 13 minutes. With these results, if the Red Corridor is compared with the total travel time of the conventional bicycle and the electric bicycle, a reduction of 51% and 68% respectively is evidenced.

The proposed bicycle path allows cyclists to travel a greater distance, since by unifying the existing bicycle paths of Universitaria Avenue (10.30 km) and Salaverry Avenue (4.80 km) they increase their route by around 25%, reaching a total length of 15.1 km.

It is important to add that the bicycle path proposal on the road infrastructure is efficient and functional because it has been designed using the “Guide for the implementation of sustainable non-motorized transport systems” developed by the Ministry of Transport and Communications (MTC) of Peru and other guides for the implementation of bicycle paths in Latin America. It was decided to select a two-way bicycle path in the lane least affected by traffic congestion between the areas of influence during peak hours. In this way, it is achieved that cyclists have the appropriate signs and routes for greater safety when traveling through the proposed bicycle path.

Getting around by conventional bicycle or electric bicycle is an efficient travel alternative for people who exceed the capacity of the Red Corridor or want to achieve less travel time. In addition, it is a transport for personal use that contributes to the current social distancing due to COVID-19.

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