

# CASE STUDY- SUSTAINABLE TRANSPORTATION ENGINEERING: CREATING A SUSTAINABLE URBAN AREA: AN EFFICIENT TRANSPORTATION NETWORK

## Abstract

For decades, transport has been seen as a connection to all aspects of life around the world. In such cases, the natural environment, social well-being, and economic development of the planet are usually dependent on transportation networks.

In most cases, safe, clean, sustainable, and fair transportation systems allow countries, especially in cities and urban centers, to prosper. The aim of this paper is to improve the sustainability of a part of the city or a small town or town. This report deals with the study of a network of the City of Bologna, Italy. The study focuses on the evaluation of the network, the area of the study area, also introduces some suggestions and solutions, that can improve the efficiency of the transit system. All analyses and guidance were based on the use of Openstreetmap (OSM) and SUMOPy tools that allowed the authors to produce the most reliable results. Artifacts are presented using a combination of graphical theory algorithms to obtain sustainable transportation using the example of a part of the City of Bologna, Italy.

**Keywords :** transportation networks; sustainable; transport policy; OSM; SUMOPy

## Acknowledgements

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## I. INTRODUCTION

The problem of the sustainability in transportation planning and re-organization is one of the most important aspect transportation engineering have to face off at the moment and of course in future visions.

The increasing people sensibility with environment problems and the depletion of fossil fuels should lead every new future project in a clear direction of planning, the most sustainable ones. Unfortunately, this is not always possible, cities are on the territory from a long time, but a lot still can be done to improve the sustainability of our transportations network, not only in bigger scale but also – and especially – on local scale, above all with an optimization of current transportation services and infrastructures.

In that point of view, we will study a small local portion of the network of Bologna, trying to make some operation to make more sustainable the study area.

## II. STUDY AREA

The area is situated on the northwest side of the old town center with a very good connection with the inner city by public and private transport networks (fig. 1 & 2). It is about **0.115 km<sup>2</sup>** with an average population density of **1.724,7 p/kmq**.



Figure 1: Study area position

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Figure 2: Study area, limits

It is a mainly residential area with some supermarkets and other services like stores and churches that makes it almost self-sufficient and interesting in transportation point of view (fig. 3).



Figure 3 Land use of the area

- 1. Motivation of the study:** The area yet presents good transportation networks and links with some punctual problems we will try to solve. Pedestrian and cycling users are in most of cases protected with dedicated services but here again there are some missing/interrupted infrastructures points.





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The same study could be done for pedestrian network but the area is all covered by sidewalks and reserved footpath so we just considered the only local points where not present to make the interventions.

**Traffic flows:** Traffic flows (cars, bus, bikes and pedestrian) are taken on the most indicative links of the area in date 27/04/2021 from 07:30 AM to 08:30 AM. In figure.9 are showed. The intersection that origins the relative links.



Figure 9: Intersection used as reference

|            |    |    |   |     |     |     |   |    |    |    |    |    |   |    |   |
|------------|----|----|---|-----|-----|-----|---|----|----|----|----|----|---|----|---|
| Zone(from) | 1  | 1  | 1 | 3   | 3   | 3   | 4 | 4  | 4  | 5  | 5  | 6  | 6 | 6  | 6 |
| Zone(to)   | 2  | 4  | 5 | 1   | 5   | 2   | 1 | 2  | 5  | 1  | 2  | 1  | 2 | 4  | 5 |
| No.        | 16 | 23 | 6 | 122 | 245 | 221 | 9 | 45 | 39 | 11 | 86 | 26 | 5 | 35 | 6 |

Table1- OD Matrix – Car

|            |    |    |    |    |    |    |    |     |    |    |     |     |    |    |    |    |    |    |    |    |
|------------|----|----|----|----|----|----|----|-----|----|----|-----|-----|----|----|----|----|----|----|----|----|
| Zone(from) | 1  | 1  | 1  | 1  | 2  | 2  | 2  | 2   | 3  | 3  | 3   | 3   | 4  | 4  | 4  | 4  | 5  | 5  | 5  | 5  |
| Zone(to)   | 2  | 3  | 4  | 5  | 1  | 3  | 4  | 5   | 1  | 2  | 4   | 5   | 1  | 2  | 3  | 5  | 1  | 2  | 3  | 4  |
| No.        | 13 | 25 | 27 | 39 | 25 | 85 | 34 | 105 | 52 | 71 | 174 | 166 | 13 | 25 | 29 | 44 | 15 | 18 | 48 | 39 |

Table2- OD Matrix – Pedestrian

|            |   |   |    |    |    |    |     |   |    |   |    |    |    |   |    |    |
|------------|---|---|----|----|----|----|-----|---|----|---|----|----|----|---|----|----|
| Zone(from) | 1 | 1 | 1  | 3  | 3  | 3  | 3   | 4 | 4  | 4 | 5  | 5  | 6  | 6 | 6  | 6  |
| Zone(to)   | 2 | 4 | 5  | 1  | 4  | 5  | 2   | 1 | 2  | 5 | 1  | 2  | 1  | 2 | 4  | 5  |
| No.        | 9 | 5 | 13 | 45 | 19 | 55 | 133 | 4 | 15 | 8 | 11 | 36 | 11 | 6 | 29 | 14 |

Table3- OD Matrix – Bicycle

|            |    |    |
|------------|----|----|
| Zone(from) | 2  | 3  |
| Zone(to)   | 3  | 2  |
| No.        | 14 | 13 |

Table4- OD Matrix – Bus

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**3. Blacklist:** The phenomenon of the blacklist is to identify the possible and visible damages or obstacles to the traffic flow, which of course considers both vehicle and pedestrian movements. Upon critical review, strategic measures are adopted and recommended as possible ways to reducing, combating the problem or improving the situation. The problems, which are present in the study area, have been divided in the following categories:

- Infrastructure wrong use – Parking Problems
- Unsafe cycling- Lack of cycle path
- Sidewalk interruptions – Obstacles on the sidewalks
- Garbage bins wrong position
- Bicycle racks missing
- Traffic jam caused by a bus stop
- Roads' surface quality issues

We have located some problems in the study area that may preclude the correct use of the infrastructures or the safety of pedestrian and the cycling users. Here is the list and for the general view the blacklist tables have been added at the conclusion part.

- **Infrastructure wrong use – parking problem (Attachment I, ref. A):** Reserved bus lane used as parking zone by residents in VIA SARAGOZZA (Fig. 10)



Figure 10



Figure 11

However, the people living in these buildings own the authorization to park their cars in that position, just on the bus lane (Fig. 11).

- **Unsafe cycling – Lack of cycle path (Attachment I, ref. B):** In VIA SARAGOZZA (Fig. 12 a, b) Unsafe cycling and in VIA ANDREA COSTA (Fig. 13 a, b) & in VIA IRMA BANDIERA (Fig. 14 a, b) cycle path is missing or interrupted.

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Figure 12 a



Figure 12 b



Figure 13 a



Figure 13 b



Figure 14 a



Figure 14 b

- **Sidewalk interruptions – Obstacles on the sidewalks (Attachment I, ref. C):** Side walks missing or fragmentation in a lot of point in the area, especially in VIA PIETRO BUSACHHI (Fig. 15 a, b) and VIA MARIO BASTIA (Fig.15 c).



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Figure 15 a



Figure 15 b



Figure 15 c

- **Garbage bins wrong position (Attachment I, ref. D):** Garbage bins are collocated on the roadway, producing the reduction of the width lane and the unsafe use of them by people in VIA SARAGOZZA (fig. 16 a,b). Some other garbage bins are on reserved car parking like in VIA MARIO BASTIA and VIA FRANCESCO ORIOLI



Figure.16a



Fig. 16 b

- **Bicycle racks missing (Attachment I, ref. E):** Bicycle racks are missing in the whole area, except the one or two parking zones, that cause people are now leaving bicycle tied on trees, traffic signs and electric rods (see Figures 17, 18, 19).

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Figure.17



Figure 18



Figure 19

- **Traffic jam caused by a bus stop (Attachment I, ref. E):** A traffic conjunction may occur because of the Bus stopping position, which is very close to the traffic signals in the intersection.



Figure 20 a



Figure 20 b

Even such as long lines of cars blocking the way along the intersection as the traffic light switches and major found in VIA SARAGOZZA (Fig. 20 a and Fig. 20 b.)

- **Roads' surface quality issues:** The variation in quality along the road occurs on some intersections between different surfaces used in the same street. For instance, at the node intersection between VIA SARAGOZZA and VIA ANDREA COSTA as shown in following figures, variation of levelling between two surfaces caused occurrence of potholes with unnecessary overly designed speed pump that road may cause damages to the cars. See (Fig. 21, Fig. 22, Fig. 23 and Fig. 24)

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Figure 21



Figure 22



Figure 23



Figure 24

4. **Critical Points:** We recognize some critical points that are in our opinion the biggest problems of the area, the ones that first of all needs to and can be solved, and they are:

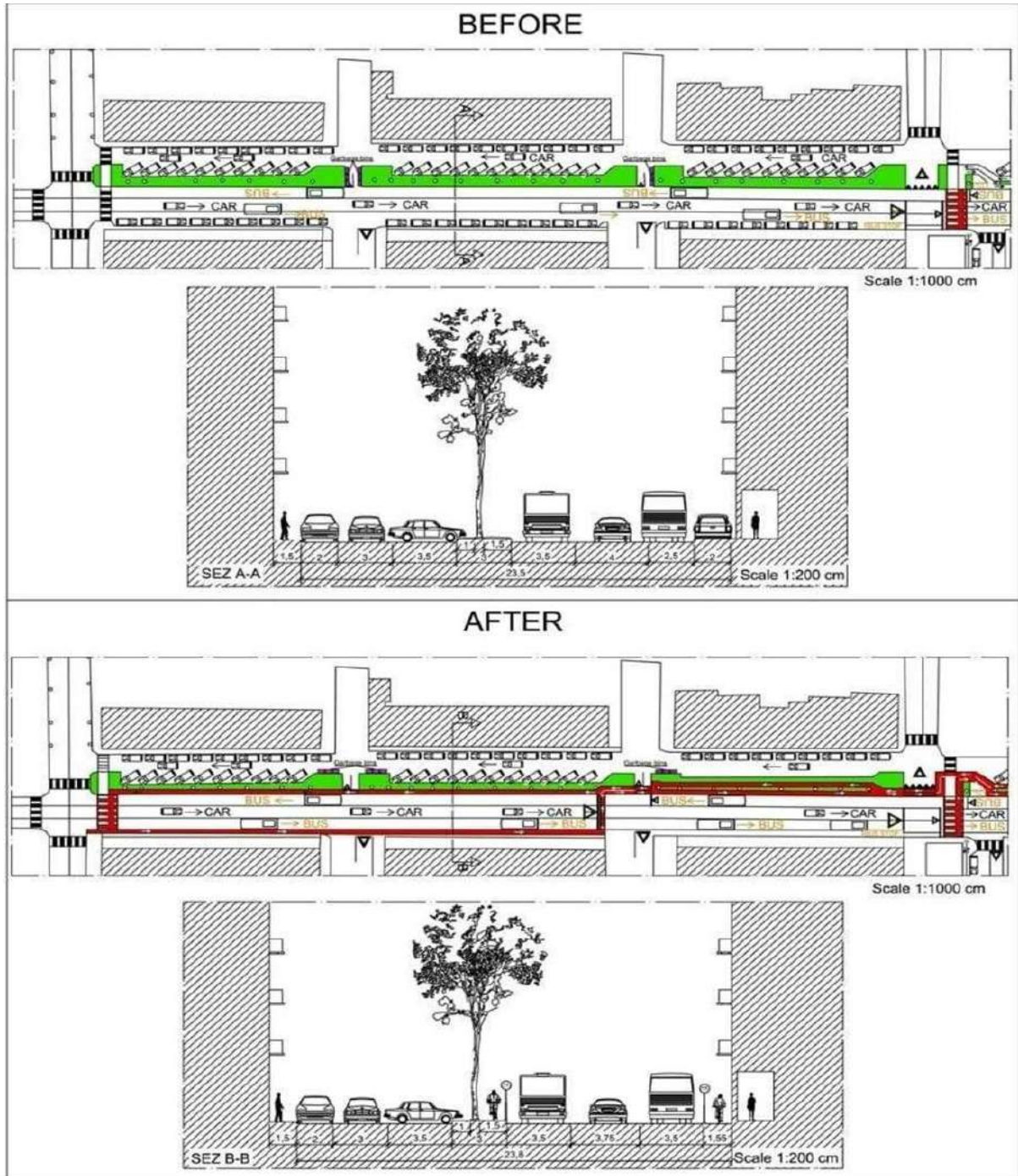
**Via Saragozza**

We consider VIA SARAGOZZA a critical point that include different problems and not only one category: there is a wrong use of the reserved bus lane (see Fig. 11) that limits the capacity of the street, garbage bins are situated in an unsafe position on the lane (see Fig. 16 a & 16 b) and the cycle path is missing.

- **Cycle path/racks missing:** There are some interruptions of cycle paths that can be considered as links missing. Bicycle racks are missing but are needed to encourage people use cycle mode.
- **Garbage bins positioning:** Garbage bins are often not situated on best position.

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5. Black spots and Necessary recommendations



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Table 5

B1: Lack of cycle path  
VIA ANDREA COSTA

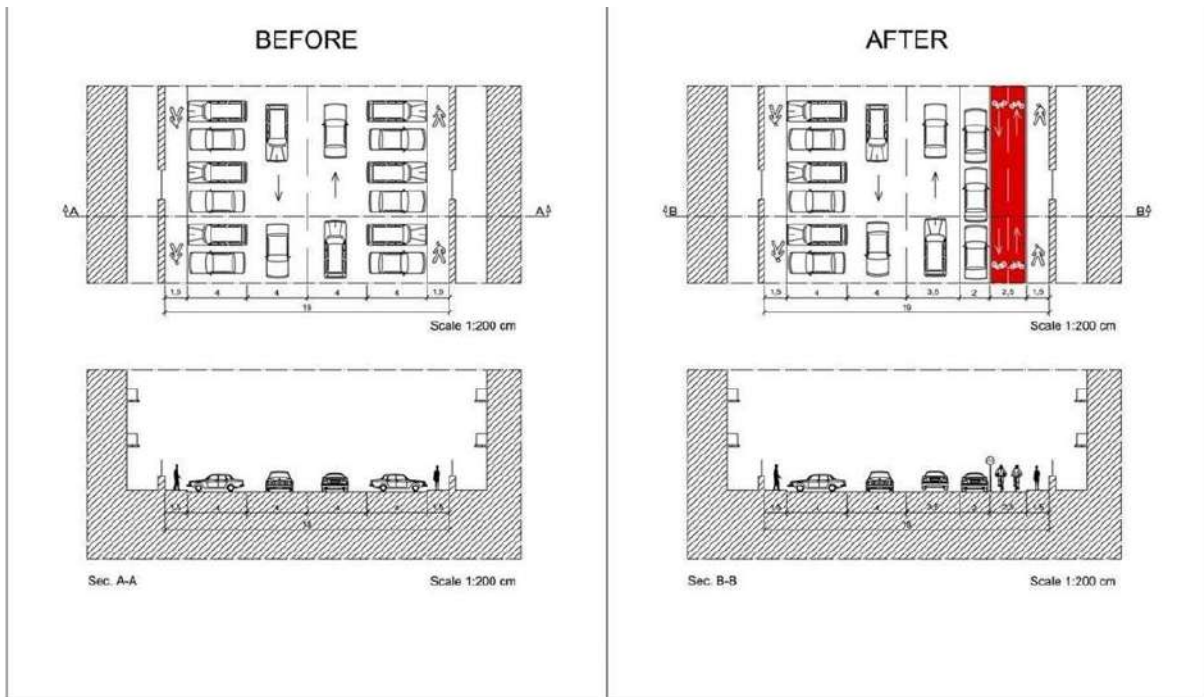


Table 6

B1: Lack of cycle path  
VIA IRMA BANDIERA

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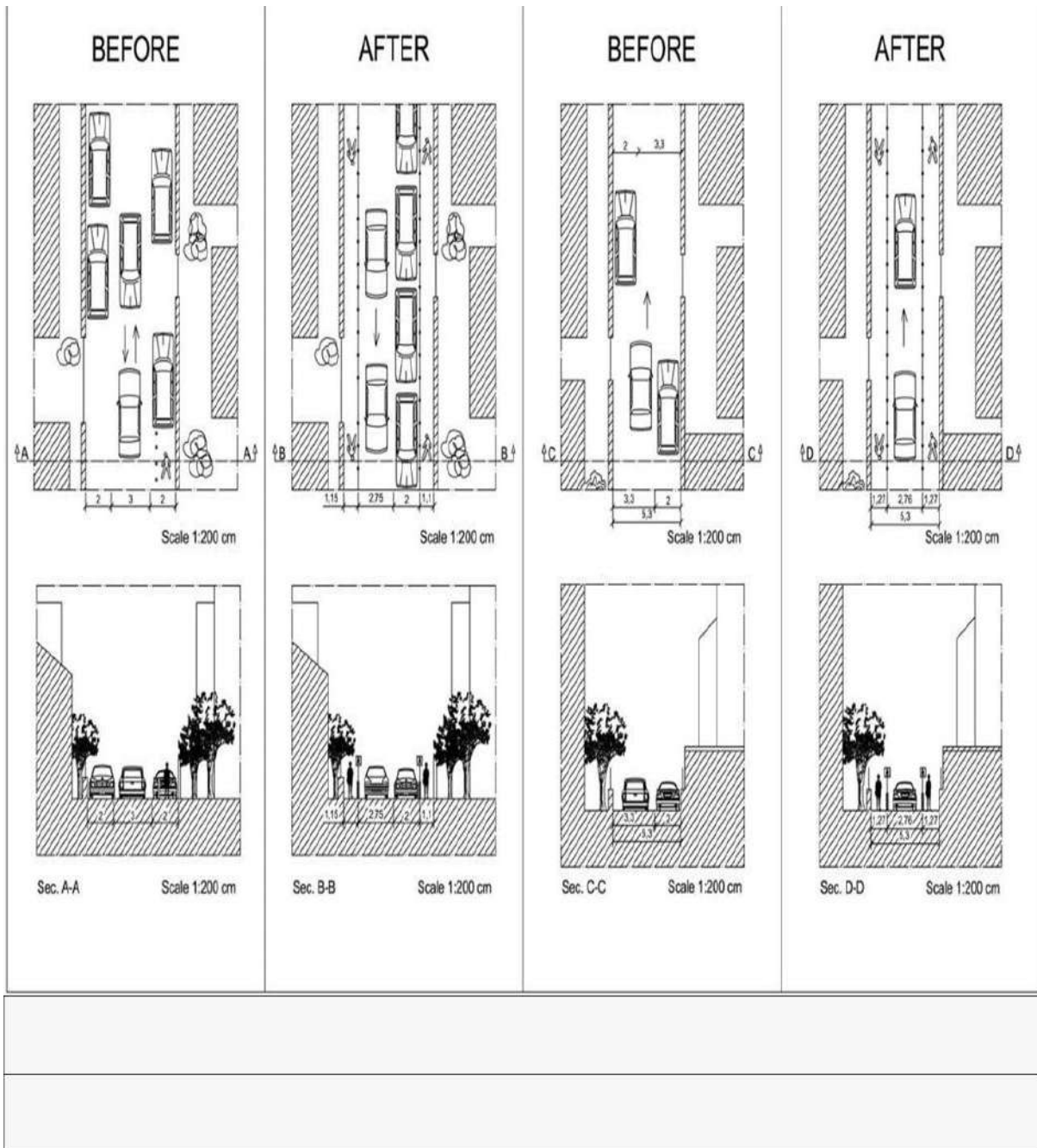


Table 7

C1-2: Interruption of sidewalk

C1: VIA PIETRO BUSACHHI

C2: VIA MARIO BASTIA



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**Figure 26: Parking relocation**

• **VIA ANDREA COSTA (Table II)**

Problem solved

- Lack of cycle path (see att. I, ref. B1)

Solution

- Car parking alongside the lane is changed from an oblique disposition type to a linear disposition type (from 3.5 m to 2 m space used) and the lane width is reduced from 4 m to 3.75 m. the total space earned of 1.75 m is used to introduce two mono directional cycle path between the footpath and the parking.

• **VIA IRMA BANDIERA (Table III)**

Problem solved

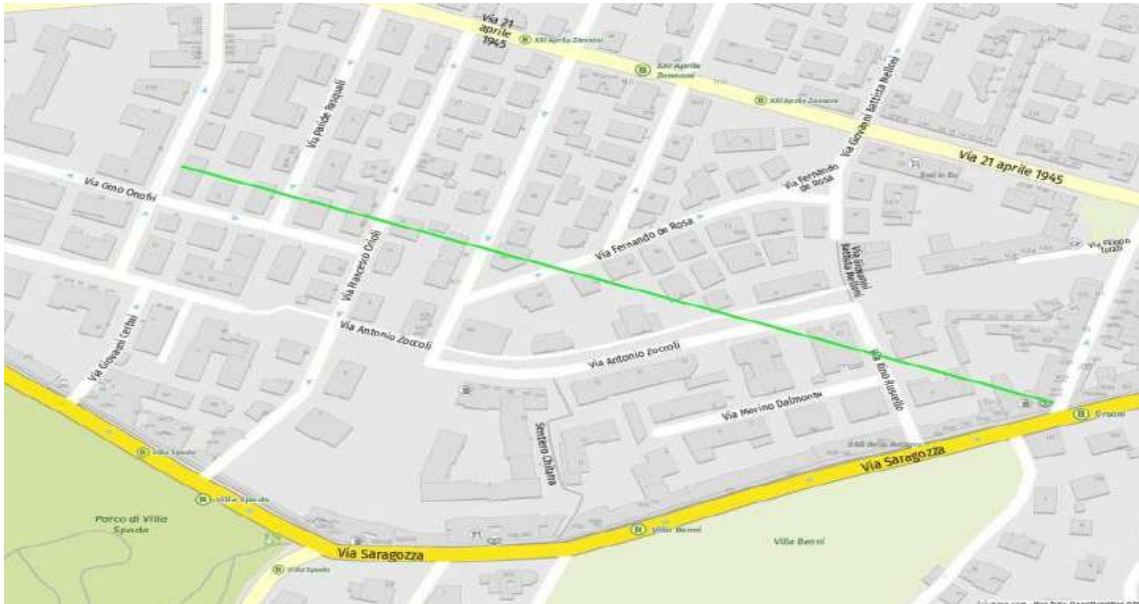
- Lack of cycle path (see att. I, ref. B4)

Solution

- Insert of a bidirectional 2.5 m width cycle path in order to carry on thesegment yet present at the beginning of Via Turati the space is obtained changing the disposition of the parking along the lane from oblique (4 m) to linear (2 m) and reducing the lane width from 4 m to 3.75 m. The parking loss is compensated by parking areas now low used (Figure: 27).



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**Figure 27: Car parking in the area**

- **VIA PIETRO BUSACHHI (Table IV)**

Problem solved

- Lack of footpath (see att. I, ref. C1)

Solution

- VIA PIETRO BUSACHHI is a mainly residential local street with no commercial activities or service. With the intervention the traffic flow is limited only to one direction, from Via Bastia to VIA PIETRO BUSACHHI changing the bidirectional street to mono directional and making possible parking only on one side. In addition, the lane is restricted to 2.75 m; this makes possible adding two footpaths on both side of the street protected with pickets to prevent cars invasions or stops.

- **VIA MARIO BASTIA (Table IV)**

Problem solved

- Lack of footpath (see att. I, ref. C2)

Solution

- Addition of two footpath on both sides protected with pickets using space earned from the prohibition to park on both side of the street. This is compensated by the others parking area in proximity (see figure: 27).

- **Cycle racks additions**

Problem solved

- Absence of cycle racks (see att. I, ref.E)

Solution

- Addition of cycle racks near the bus stops to support intermodal transport.



**Figure 28: Sample new bicycle racks to be installed.**

#### IV. ORIGIN-DESTINATION MATRIX



**Figure 29: Representation of Zones**

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Where:

- 1 = Study Area (TAZ)
- 2 = External Zone (Southwest)
- 3 = External Zone (Southeast)
- 4 = External Zone (Northeast)
- 5 = External Zone (Northwest)
- 6 = External Zone (Southeast)

Shown in figure above is the study area for the project. The study area was divided into six zones: one zone for study area; and five external zones.

Based on the conducted traffic counts survey, a total of 1675 vehicles/hr. were counted entering the study area and a total of 922 vehicles/hr. were counted exiting the study area. This will be aggregated to 10% of vehicles will be coming and going to the study area, respectively. The remaining 90% will be then distributed to between the in-coming and out-going links. Four (4) classification of vehicles were counted during the peak-hour survey. Table 1, 2, 3, 4 mentioned above, shows the OD Matrix for all vehicles. This matrix was aggregated into four (4) different classification of vehicles which will be used for the scenario.

### 1. Proposed Intervention

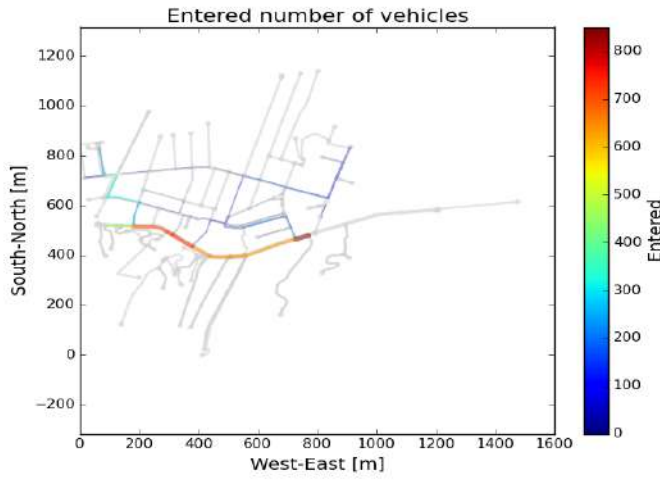
- A vehicle reduction scheme can be considered such as implementing a WINDOW HOUR WITH RESTRICTION OF SPEEDS AND ROUTE DIVERSION to all the heavy vehicles to traverse the roads prohibiting them to enter during peak hour by Incorporating dedicated separate speed lane and restricted access to the pedestrians, Public and Private Vehicle.
- Improving the traffic signal cycle can also be another option to improve the traffic flow.
- PROMOTING of GREEN TRANSPORTATION by reducing of traveling by car up to 10 % and increased travelling by Bicycle at least up to 10% by keeping the total nos. of vehicle same within the study area.
- PROPOSING NEW BYPASS FLYOVER with the restricted access and speed (50 Km/ Hr.)

**2. Baseline Scenario:** Baseline Scenario was simulated based on the existing condition of the study area. Existing road networks was used for the simulation as well as the traffic counts gathered during the survey.

It is necessary that the baseline simulation will depict with the real-world scenario of the study area. Roads must not be designed exclusively to a certain sector of users only. A complete street ensures that there are enough facilities for non-/motorized vehicles, pedestrians, PWD (person with disability), and other road users.

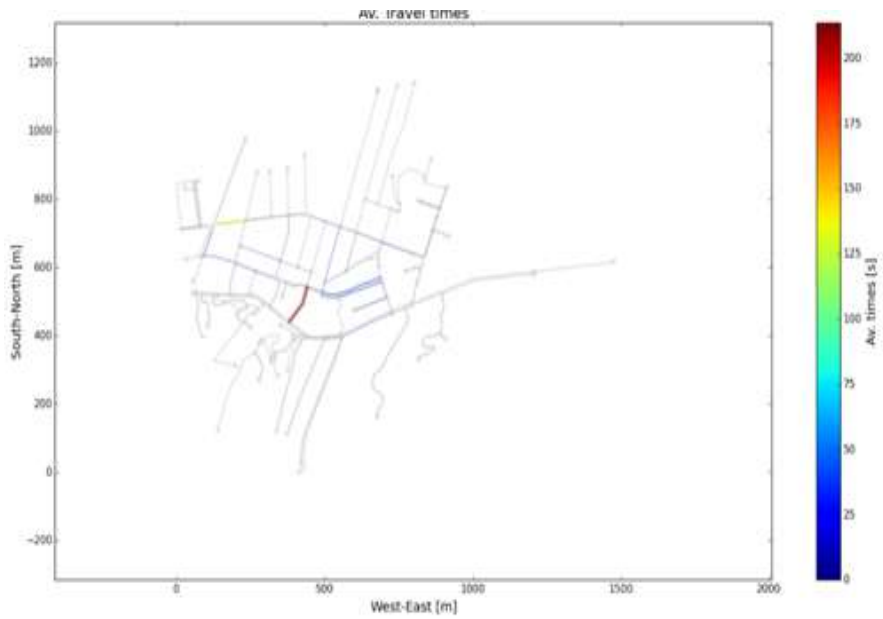
Table 1-4 shows the number of vehicles entered in the study area .Based on this figure, majority of vehicles are in the VIA SARAGOZZA corridor.

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**Figure 30: Entered number of vehicles.**

Meanwhile, Figure 31 shows the average travel time along edges in the study area. It may be observed that longer waiting time can be seen at the signalized intersection before approaching Via Saragozza.



**Figure 31: Average travel times of vehicles**

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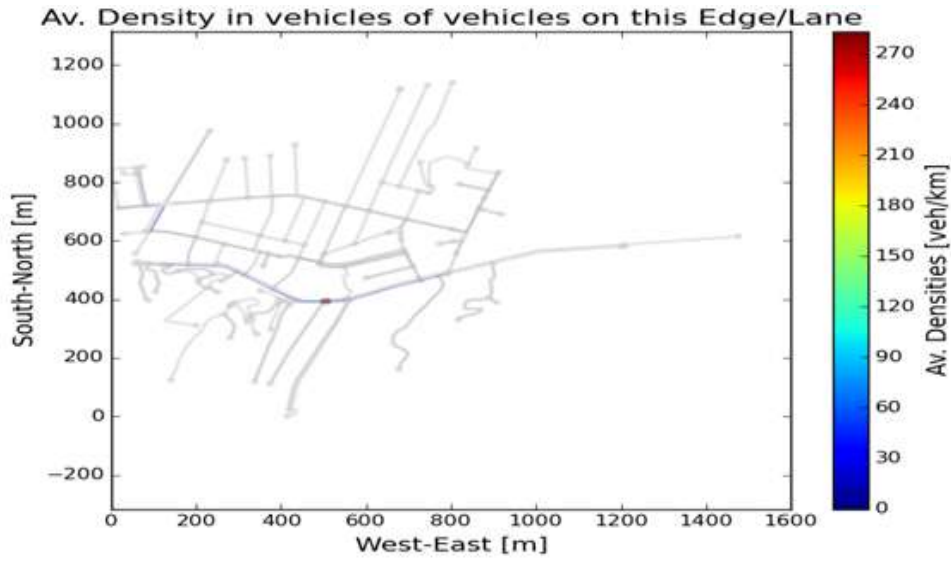


Figure 32: Average Density in vehicles of vehicles

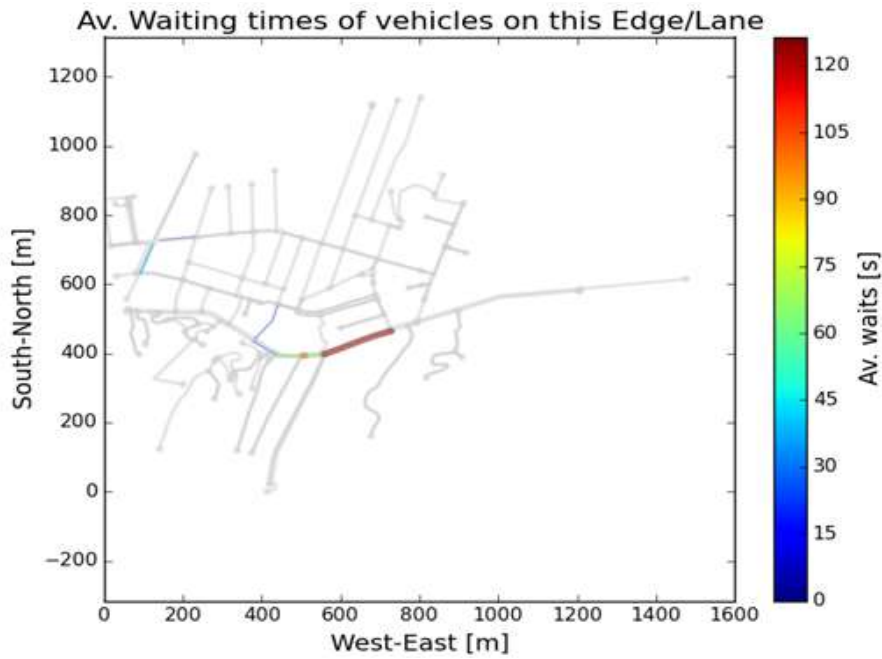
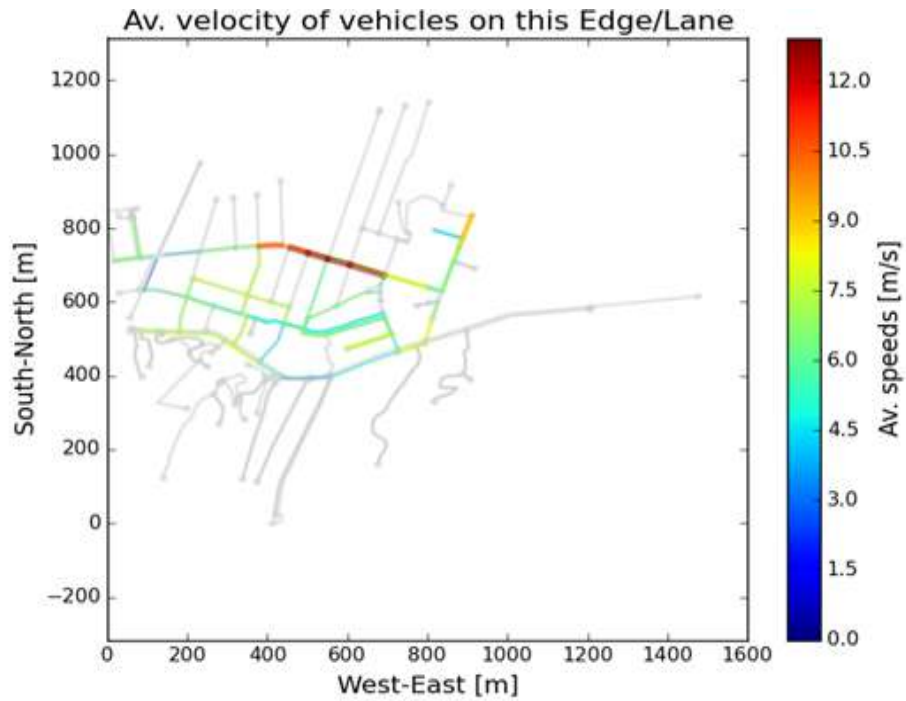
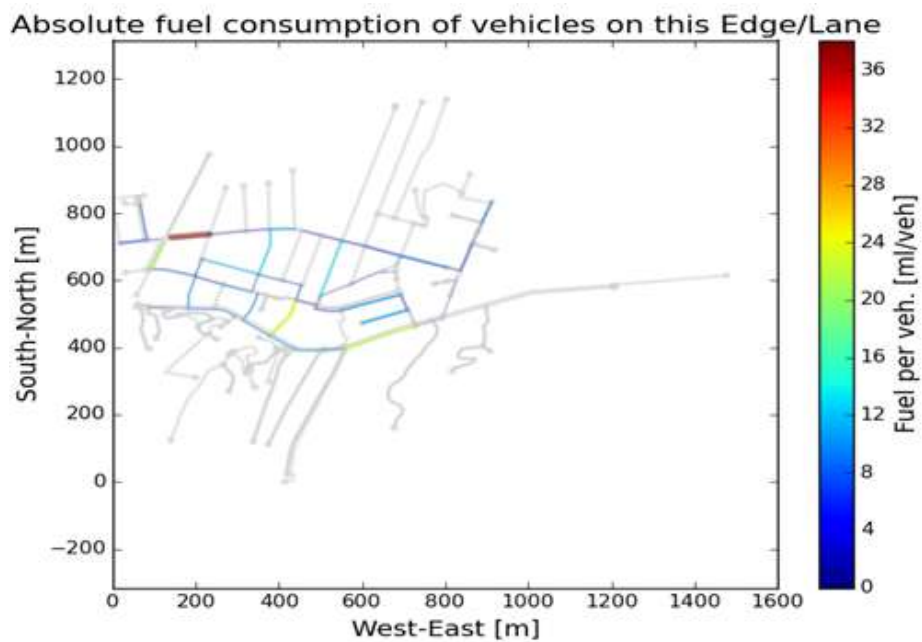


Figure 33: Average waiting time of vehicle

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**Figure 34: Average velocity of vehicles**



**Figure 35: Average fuel consumption of vehicle**

Vehicle noise was evaluated as well during the baseline simulation. These huge numbers are due to the high volume of motorized vehicle traversing the corridor. In connection to that, CO2 emission was evaluated as well as shown in Figure 38.

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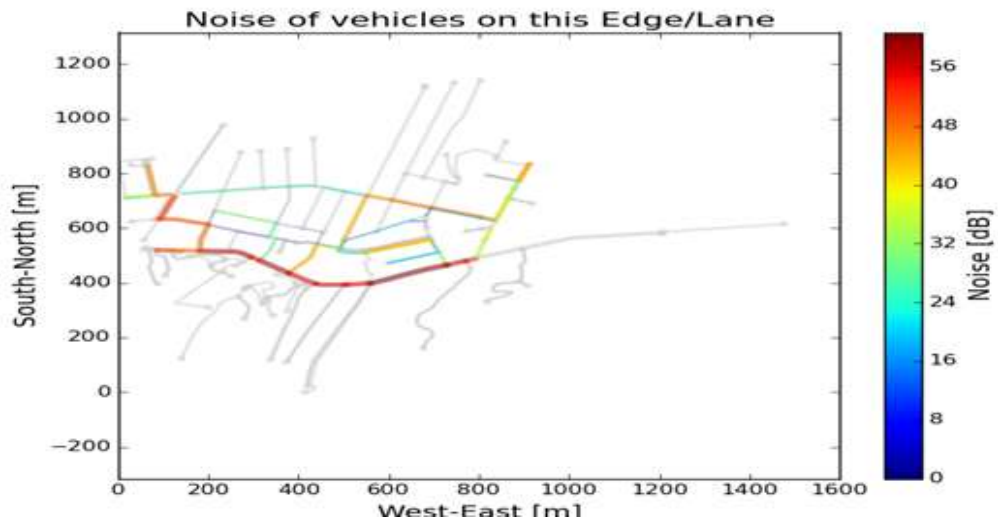


Figure 36 a: Noise of vehicles

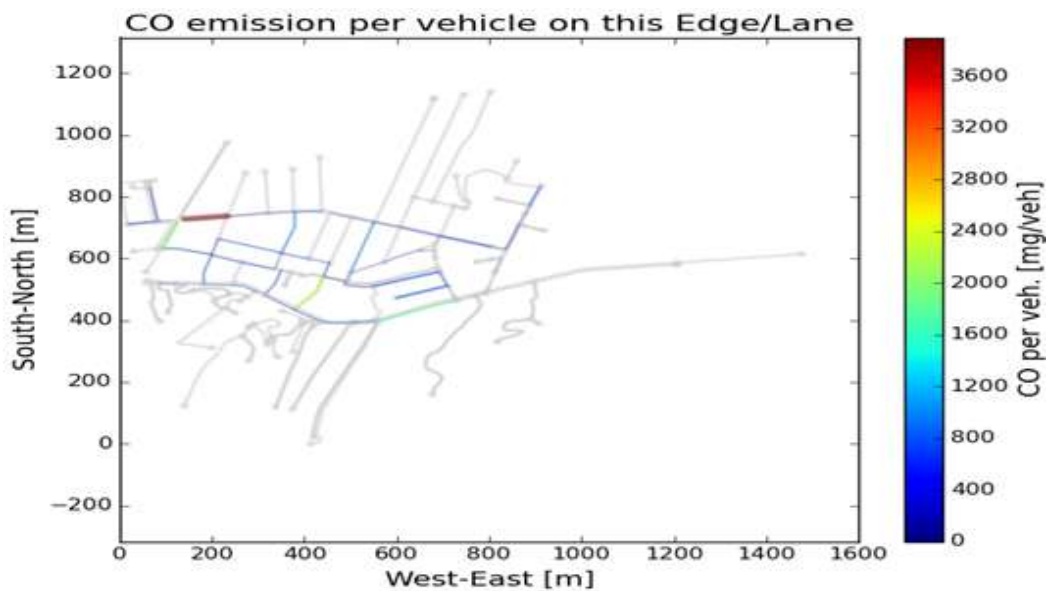


Figure 36 b: CO emission per vehicle

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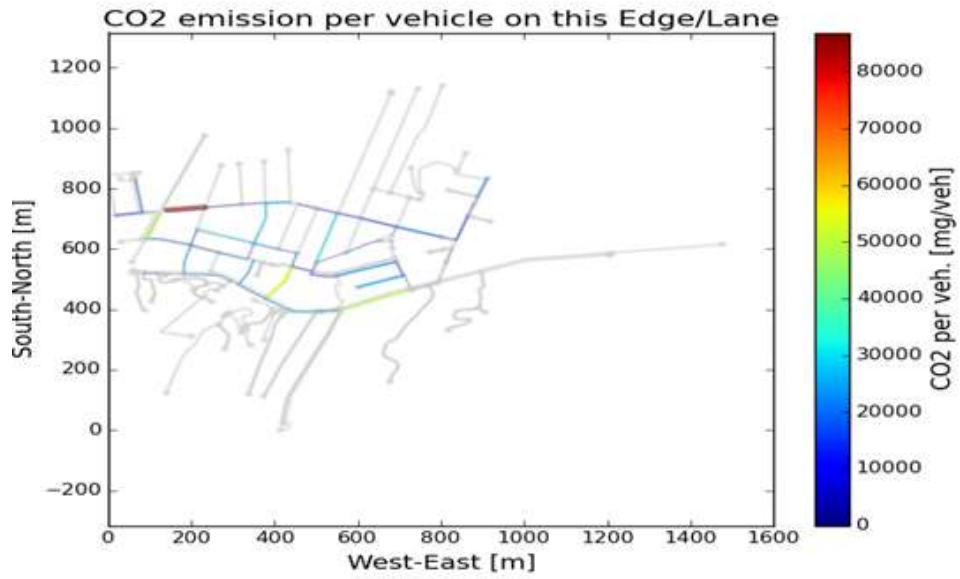


Figure 37: CO2 emission per vehicle

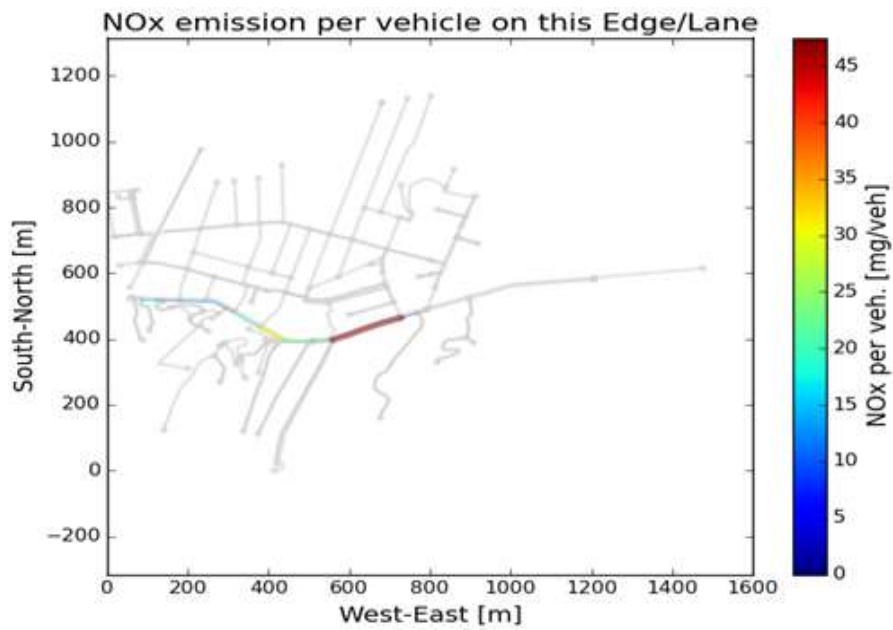
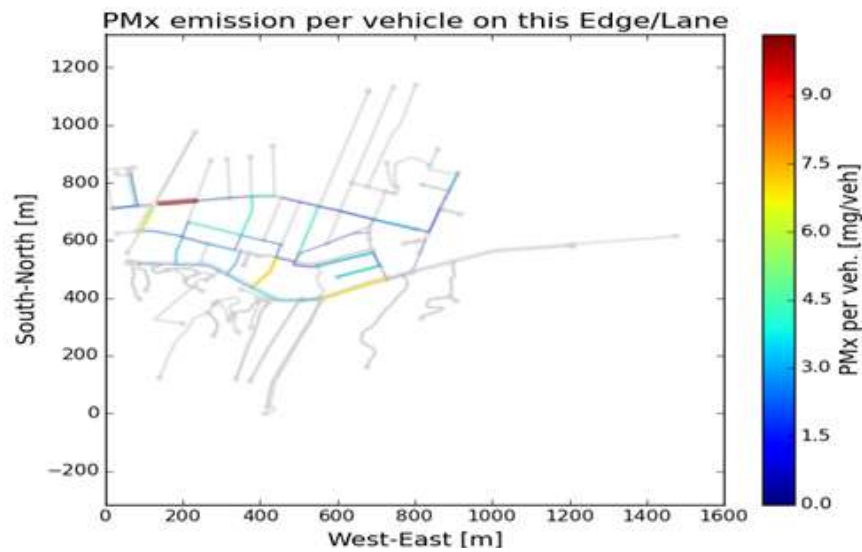


Figure 38: NOx emission per vehicle



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**Figure 39: PMx emission per vehicle**

With all these results, the group aims to improve the performance of the road network by decreasing the magnitude of these parameters. Thus, the group came up with the intervention presented in the previous section.

- Future Scenario:** To achieve the desired goals and objectives set by the group, the following proposals were made as per the seriatim, -

**Table 8: Action Plan**

| OBJECTIVES   | ACTION TAKEN IN TRAFFIC MODEL   |
|--|---|
| WINDOW HOUR WITH RESTRICTION OF SPEEDS AND ROUTE DIVERSION | Incorporated dedicated separate speed lane and restricted access for the pedestrians, Public and Private Vehicle)   |
| PROMOTE GREEN TRANSPORTATION                               | Reduction of traveling by car up to 10 % and increased travelling by Bicycle at least up to 10% by keeping the total nos. of vehicle same within the study area |
| PROPOSING NEW BYPASS FLYOVER                               | Proposed a separate Bypass Flyover with the restricted access (ref. Fig. 40 & 41) and speed (50 Km/ Hr.)  |

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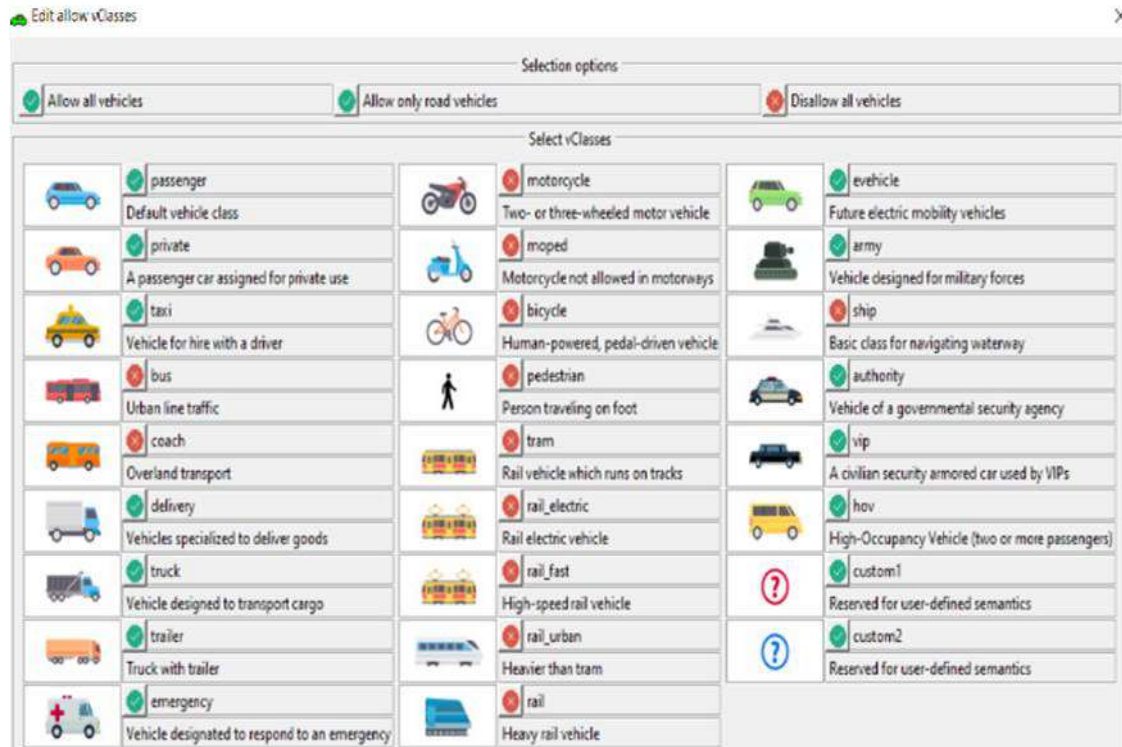


Figure 40

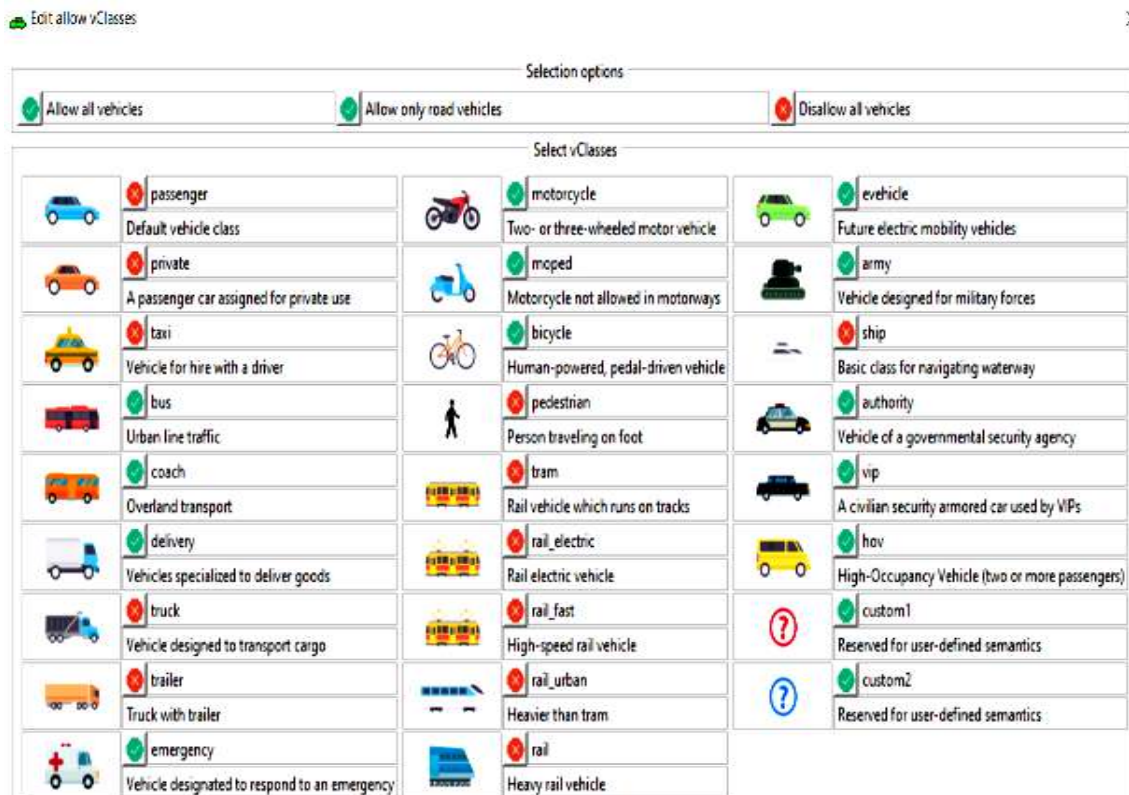
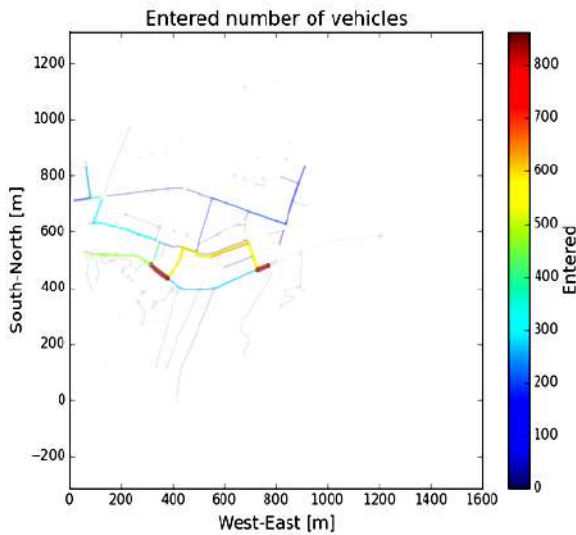


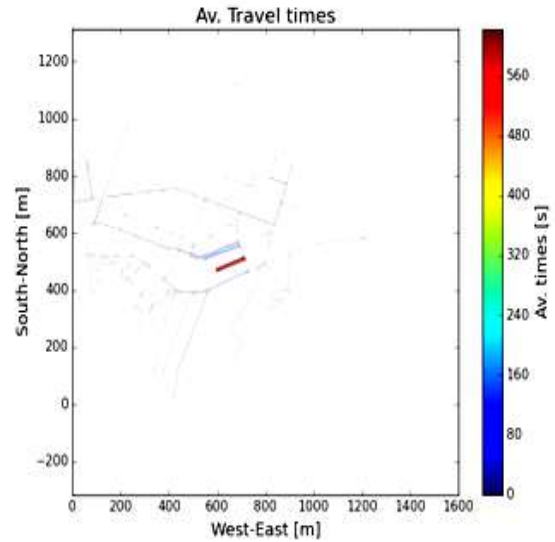
Figure 41

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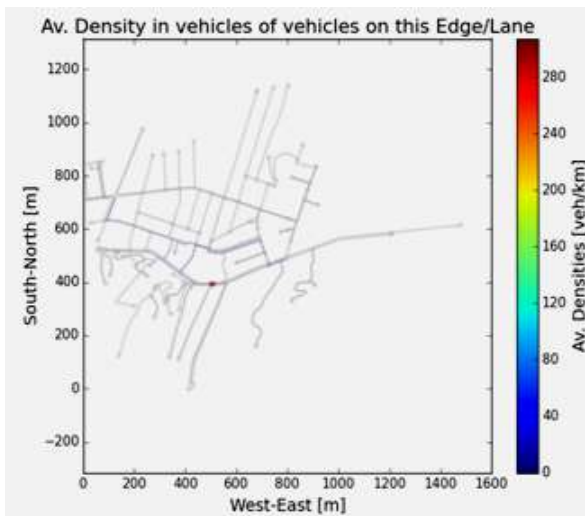
- **Edge data for window hour with restriction of speeds and route diversion:**



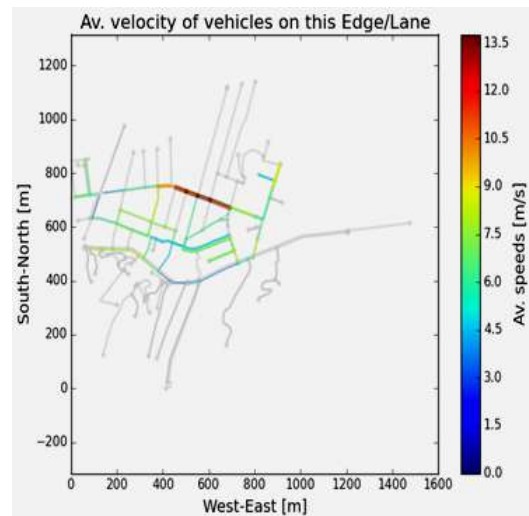
**Figure 42: Entered no. of vehicles**



**Figure 43: Av. Travel times**

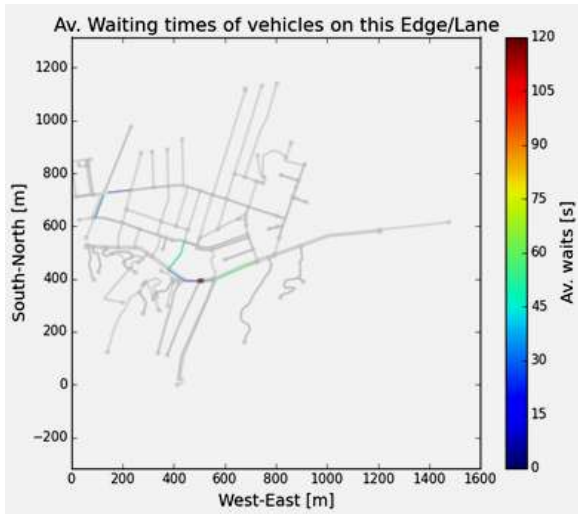


**Fig. 44: Density in vehicle of vehicles edge/lane**

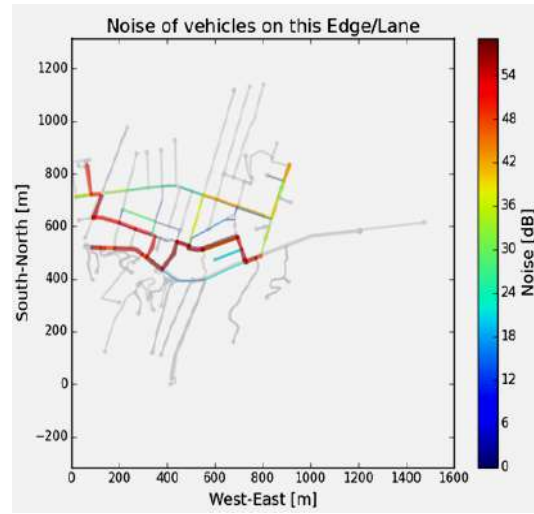


**Figure 45: Av. velocity of vehicle on this on this edge/lane**

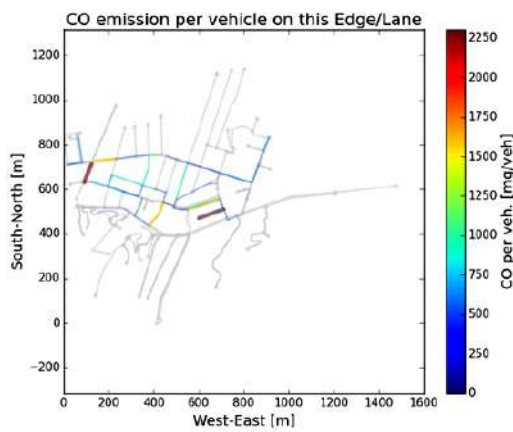
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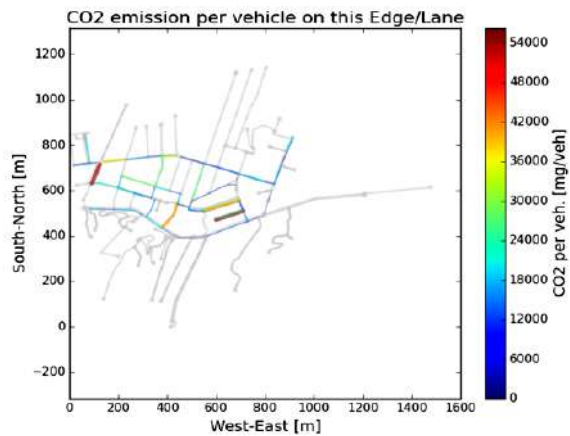
**Figure 46: Av waiting times of vehicle on this edge/ lane**



**Figure 47: Noise of vehicle on this edge/ lane**



**Figure 48: CO emission per vehicle on this edge/lane**



**Figure 49: CO2 emission per vehicle on this edge/lane**

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Absolute fuel consumption of vehicles on this Edge/Lane

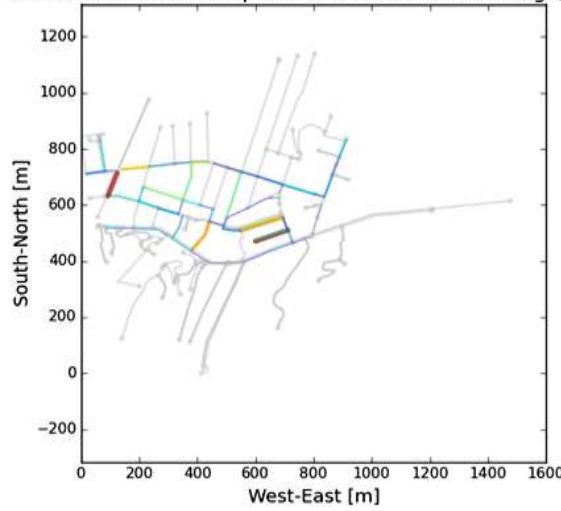


Figure 50: Absolute fuel consumption of vehicle on edge/lane

NOx emission per vehicle on this Edge/Lane

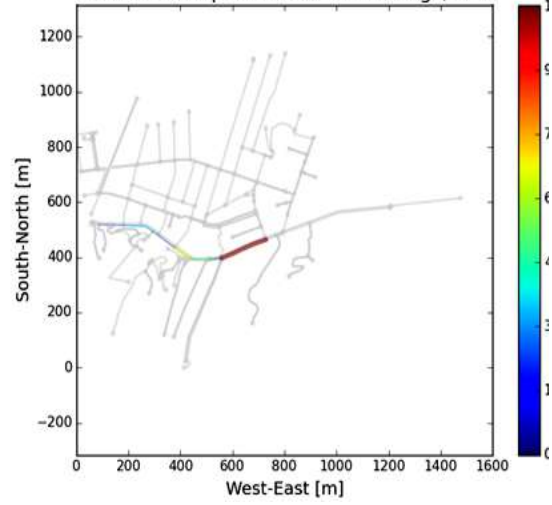


Figure 51: NOx emission per vehicle on this edge/lane

PMx emission per vehicle on this Edge/Lane

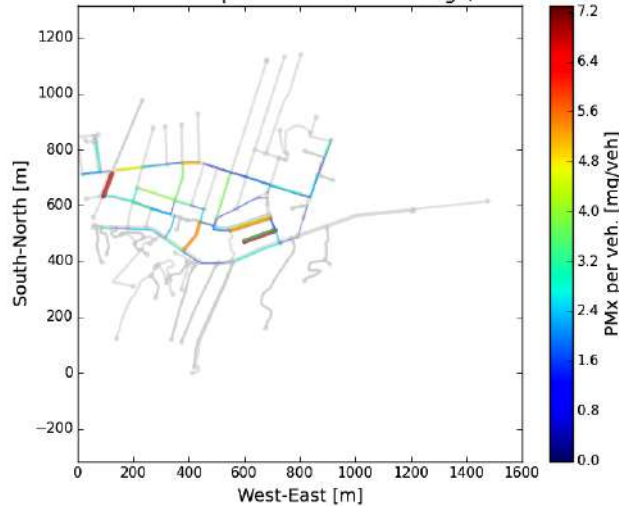
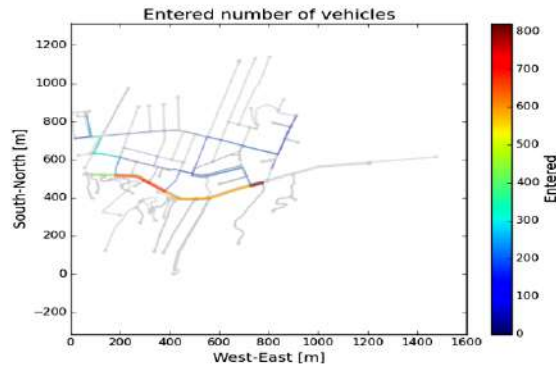


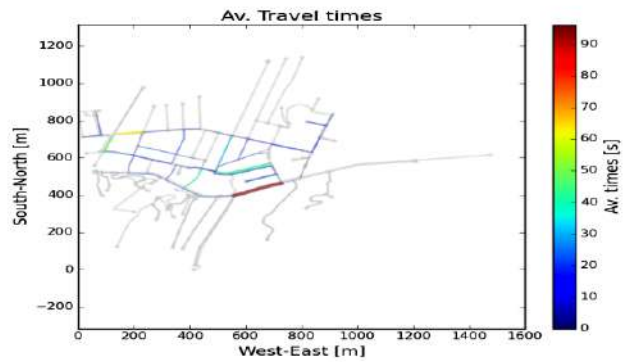
Figure 52: PMx emission per vehicle on this edge/lane

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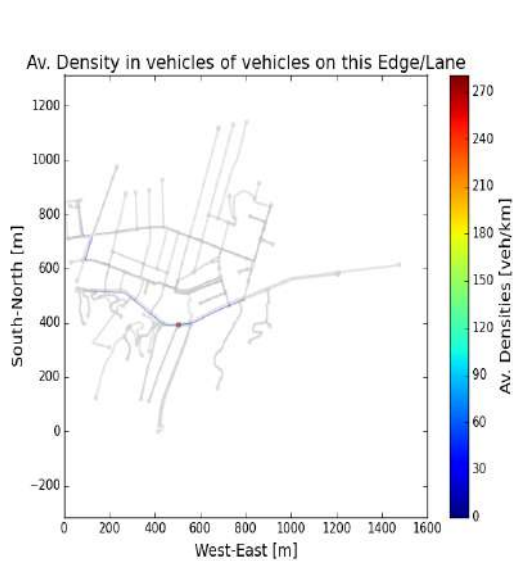
- **Edge data for promote green transportation**



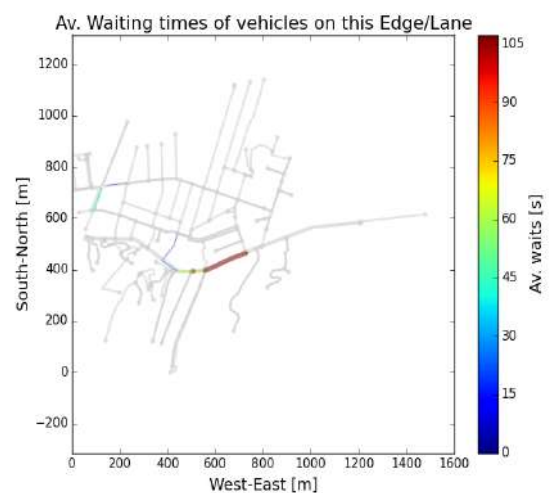
**Figure 53: Entered no. of vehicles**



**Figure 54: Av. Travel times**



**Figure 55: Density in vehicle of vehicles on this edge/ lane**



**Figure 56: Av. waiting times of vehicle on this edge/ lane**

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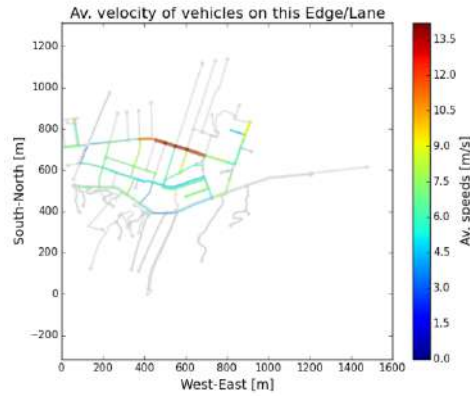


Figure 57: Av. velocity of vehicle on this edge/ lane

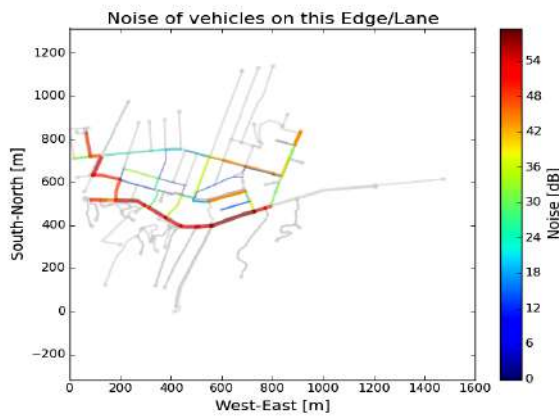


Figure 58: Noise of vehicle on this edge/lane

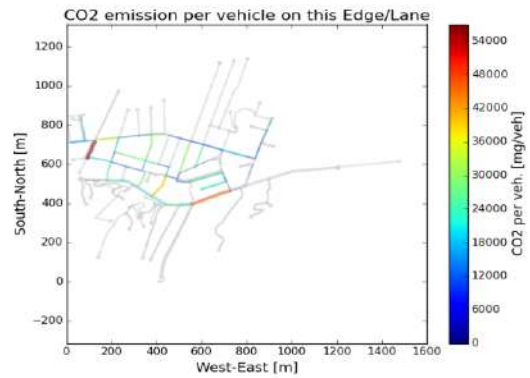


Figure 59: CO2 emission per vehicle on this edge/lane

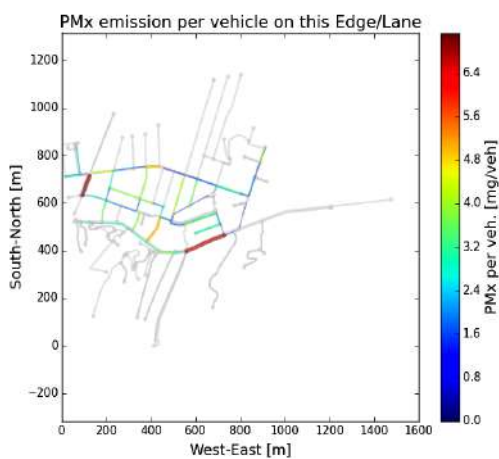


Figure 60: CO emission per vehicle on this edge/lane

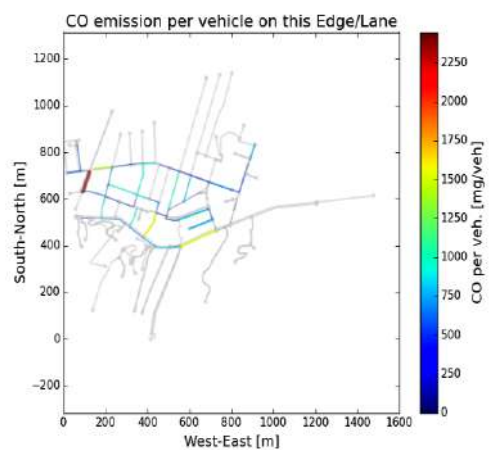


Figure 61: NOx emission per vehicle on this edge/lane

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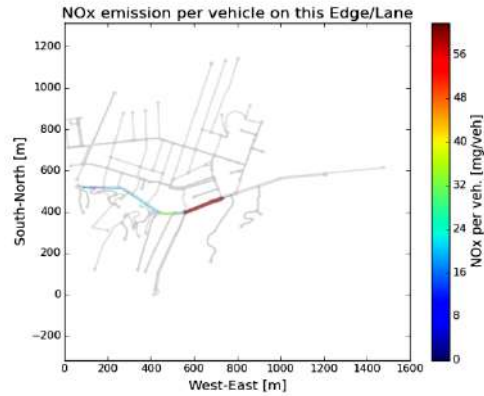


Figure 62: PMx emission per vehicle on this edge/lane

- Edge data for proposing new bypass flyover

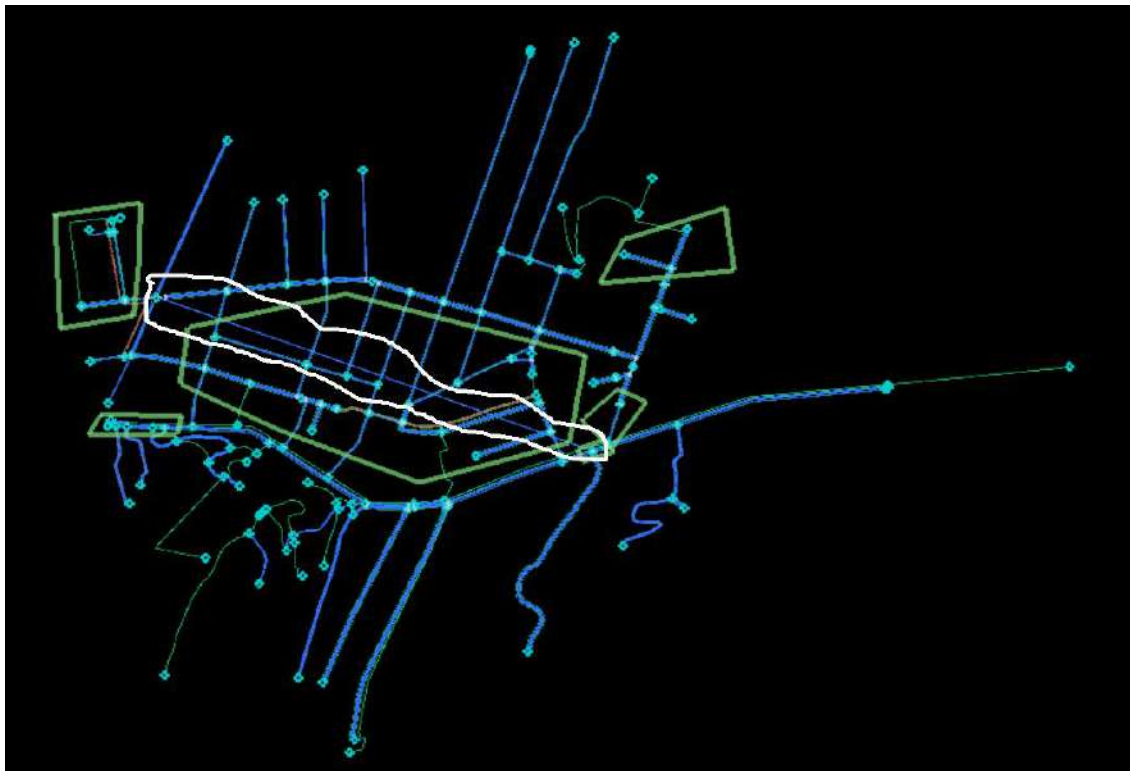


Figure 63



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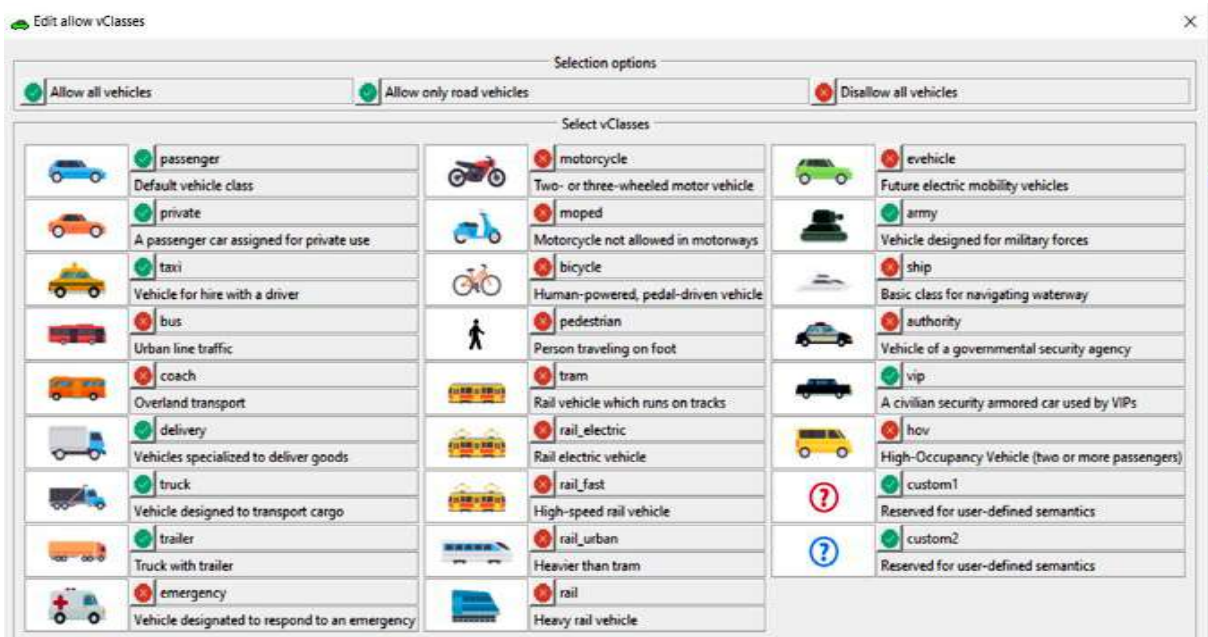


Figure 64

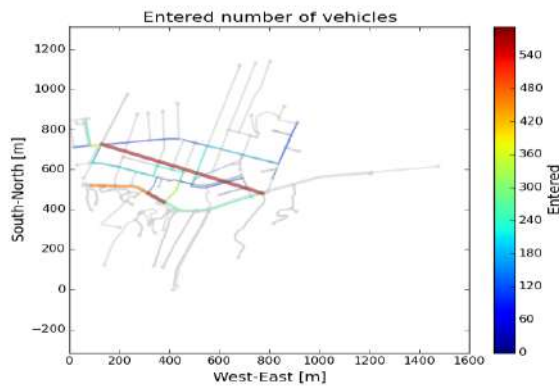


Figure 65: Entered no. of vehicles

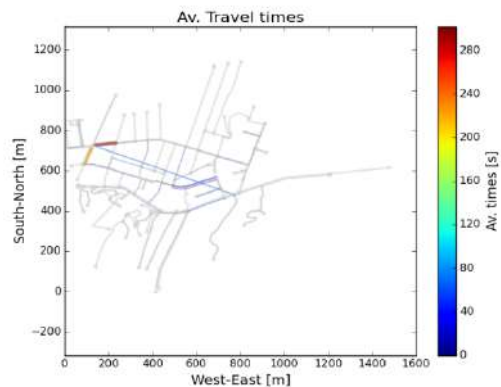


Figure 66: Av. Travel times

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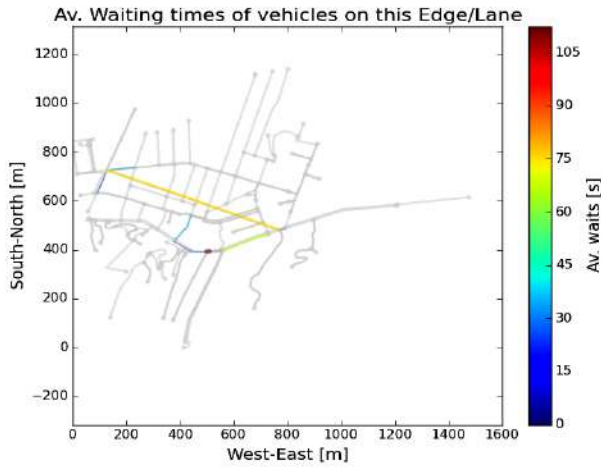


Figure 67: Av. waiting time of vehicle on edge/ lane

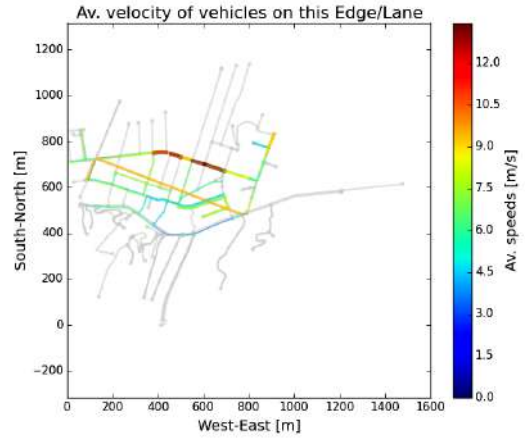


Figure 68: Av. velocity of vehicles on edge/ lane

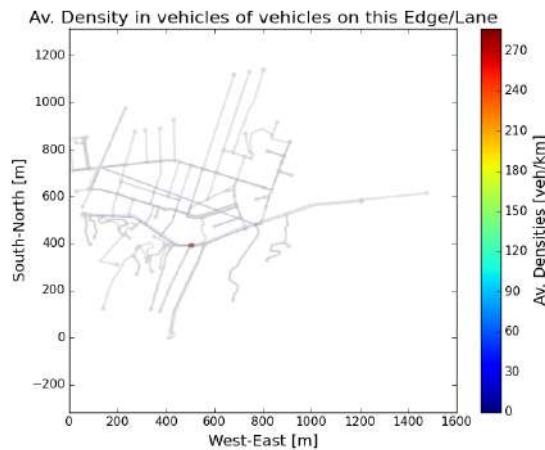


Figure 69: Density in veh. of vehicles on edge/ lane

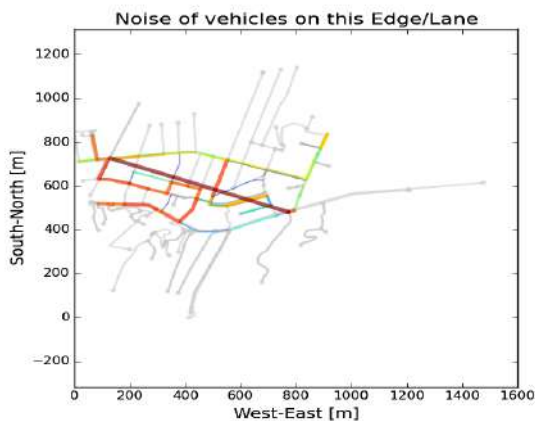


Figure 70: Noise of vehicles on this edge/ lane

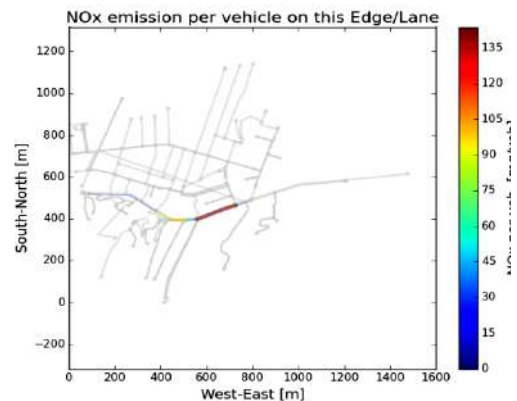


Figure 71: NOx emissions per vehicle on this edge/lane

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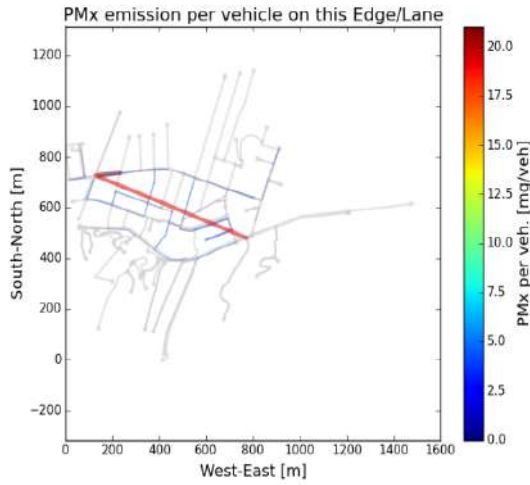


Figure 72: PMx emissions per vehicle on this edge/lane

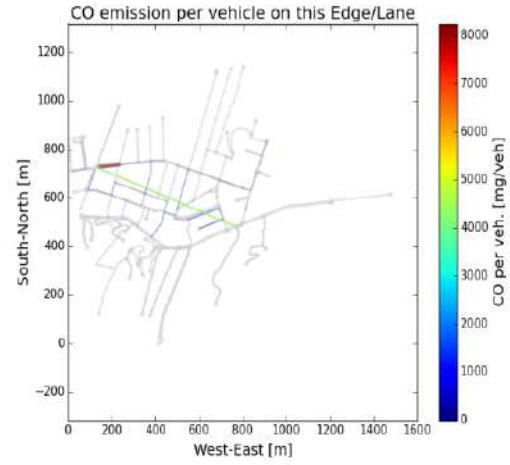


Figure 73: CO emissions per vehicle on this edge/ lane

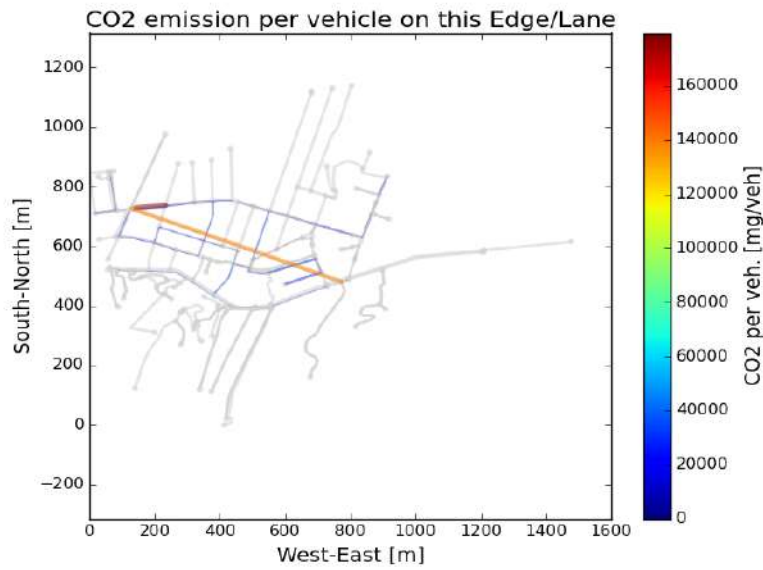


Figure 74: CO2 emissions per vehicle on this edge/ lane

**CASE STUDY- SUSTAINABLE TRANSPORTATION ENGINEERING: CREATING  
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| <b>SUMOPy Data Output Evaluation and Comparison</b> |                                   |                       |  |                              |                      |
|---|-----------------------------------|-----------------------|--|------------------------------|----------------------|
| SL. No.   | Major Edge Activity Name          | Base Scenario Results | Future Scenario Results                                    |                              |                      |
|   |                                   |                       | Window Hour With Restriction Of Speeds And Route Diversion | Promote Green Transportation | Proposing New Bypass |
| 1   | Av. times [s]                     | 1236.631              | 1853.171   | 1246.056                     | 1706.919             |
| 2   | Av. Densities [veh/km]            | 1195.001              | 1267.549   | 1189.974                     | 1137.220             |
| 3   | Av. waits [s]                     | 465.020               | 376.453  | 435.204                      | 423.152              |
| 4   | Av. speeds [m/s]                  | 615.972               | 609.662  | 627.869                      | 632.557              |
| 5   | Fuel per veh. [ml/veh]            | 535.496               | 491.193  | 509.816                      | 593.114              |
| 6   | CO per veh. [mg/veh]              | 43057.103             | 37778.319  | 39933.022                    | 45548.458            |
| 7   | CO <sub>2</sub> per veh. [mg/veh] | 1223362.380           | 1122734.014  | 1164865.084                  | 1356026.316          |
| 8   | NO <sub>x</sub> per veh. [mg/veh] | 230.465               | 405.651  | 217.304                      | 608.477              |
| 9   | PM <sub>x</sub> per veh. [mg/veh] | 172.034               | 162.935  | 166.137                      | 195.322              |
| 10  | Noise [dB]                        | 2432.018              | 2445.184   | 2321.532                     | 2682.022             |

**Table 9: Sumopy data output evaluation and comparison**

## V. RECOMMENDATIONS AND CONCLUSIONS

The main goal of the project is to create an overall sustainable transportation network by alleviating the current abnormalities in the existing network. The creation of a sustainable transportation network can consider different structures, such as sufficiently convenient sidewalks and bicycle lanes, to reduce the walking and cycling distance between the starting point and the destination in the network as well as reduction in pollution.

Although the existing network is very good, there is still some room for improvement. There are many bicycle lanes and sidewalks with dead ends. In order to meet all these requirements, new bicycle lanes and walking paths that connect to the existing network have been introduced, and walking distances and cycling distances should be reduced, which will ultimately promote behavioural changes in the use of different vehicles. In addition, when designing these paths, possible damage control to the existing environment is also considered. Likewise, existing obstacles in the path have been removed, and narrow circles can be enlarged.

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We have introduced all the above parameters in micro simulation software named as SUMOPy, where we have improved the existing network by increasing the bicycle paths and pedestrian paths. By comparing the results of existing and redesigned network in the micro simulation we have obtained less pollution and the behavior of the passengers changed (moved from car to bicycles). Eventually, the final design of the proposed transportation network should fill the gap in providing a sustainable transportation network system.

Based on the observed results (refer Table 6) and review of relevant data, it is recommended to adopt **WINDOW HOUR WITH RESTRICTION OF SPEEDS AND ROUTE DIVERSION**, because following advantages are there as per the seriatim.

1. It is very easy to execute and requires simple tools/ equipment.
2. Comparatively lesser cost at around ten times the cost for other proposed schemes such as NEW BYPASS FLYOVER, as for executing a NEW BYPASS FLYOVER, there will be huge cost implications along with it will be too difficult to acquire land for a NEW BYPASS FLYOVER for an existing developed city.

However, we also recommend PROMOTING GREEN TRANSPORTATION system, as it has less cost impact than other two proposals as mentioned above, and it will also create **less Noise**, if we will adopt public vehicle (Bus etc.) instead of personal vehicle (Car etc.) and use bicycle (it may be manual or electrically operated and environment friendly) instead of Motor Bike.

**Ethics declarations: Conflict of interest:** Both the authors state that there is no conflict of interest.

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