# REMEDIO - REgenerating mixed-use MED urban communities congested by traffic through Innovative low carbon mobility sOlutions

## Integrated tool and low carbon mobility solutions assessment (Activity 3.5)

## Assessment Report (Deliverable 3.5.1)

**Date:** 31/10/2019

**Dissemination Level:** Public

**Document Status:** Final Document

REMEDIO project is co-financed by the European Regional Development Fund

## *Authors*

**Aristotle University of Thessaloniki - School of Physics (AUTH) , Regional Agency for Environment Protection in Veneto Region (ARPAV), University of Seville (USE), Instituto Superior Técnico (IST), Municipality of Treviso (MT), Metropolitan Development Agency of Thessaloniki S.A. (MDAT S.A)., Municipality of Loures (CML), City of Split (CS).**

## *Document history*

| VERSION | DATE | AUTHOR | DESCRIPTION |
|---|---|---|---|
| Final | 31.10.2019 | Natalia Liora, Serafeim Kontos, Anastasia Poupkou, Charikleia Meleti, Dimitrios Melas | Assessment Report (AUTH) |
| Final | 31.10.2019 | Francesca Liguori, Massimo Bressan, Ketty Lorenzet, Lucia Caterina Da Rugna, Salvatore Patti with the collaboration of Corrado Lanera (UniPD) | Assessment Report (ARPAV) |
| Final | 31.10.2019 | José Antonio Becerra Villanueva, Ricardo Chacartegu | Assessment Report (USE) |
| Final | 31.10.2019 | Marina de Almeida Silva, Joana Ferreira, Susana Marta Almeida | Assessment Report (IST) |
| Final | 31.10.2019 | Rosella Sanfilippo, Roberto Granziol, Paolo Pierobon | Assessment Report (MT) |
| Final | 31.10.2019 | Stella Zountza, Chrysostomos Kalogirou | Assessment Report (MDAT S.A.) |
| Final | 31.10.2019 | Fernando Noivo, Ana, Catarina Ascensão Sabino, Rosario Costa, Luis Paulo Pereira | Assessment Report (ML) |
| Final | 31.10.2019 | Tomo Šundov, Radojka Tomašević, Tea Reić, Hrvoje Matas, Ivana.Bandalo, Ana Maretić, Ela Žižić | Assessment Report (CML) |

## *Internal review history*

| REVIEWED BY | DATE | DESCRIPTION |
|---|---|---|
| Francesca Liguori | 30/12/2019 | Minor corrections for final delivering and publication |

**REMEDIO project is co-financed by the European Regional Development Fund**

## *Document details*

| FILE NAME | VERSION |
|---|---|
| L3.5.1_REMEDIO_Assessment_Report_final | Final |

| DOCUMENT OWNER | ORGANISATION |
|---|---|
| REMEDIO partnership | AUTH, ARPAV, USE, MT, MDAT S.A., ML, CML |

**REMEDIO project is co-financed by the European Regional Development Fund**

## Executive Summary

Road transportation is a significant source of environmental pollution in urban centers and therefore during the last years many efforts have been done in order to plan and implement traffic congestion mitigation measures and improve air quality and environment. The measures are focusing mainly on the promotion of soft mobility and the upgrade of the public transportation systems. In the this effort, modeling tools are necessary to simulate and assess the impacts of mitigation measures in terms of energy consumption, traffic noise emissions, atmospheric pollution, as well as to investigate the impacts on the health of citizens. In this document, the results from the application of the Integrated Modeling Tool (IMT), developed in the framework of REMEDIO project, are presented. IMT was applied in order to evaluate specific low carbon mobility solutions (LCMS) in four pilot road axes in the Mediterranean cities Loures, Split, Thessaloniki and Treviso. The LCMS are associated with mobility scenarios for which IMT environmental results are presented and compared with the IMT results referring to the traffic conditions before the LCMS implementation (base case or baseline). The base case IMT results are presented in detail in REMEDIO Deliverable 3.4.1 “Present and future mobility and environmental settings scenarios in urban areas”. The reader should refer also to REMEDIO Deliverable 3.4.1 for a more comprehensive understanding of the results presented in this document.

For the city of Loures, the upgrade of a central road axis in the pilot zone of Moscavide (i.e. reduction in road lanes, increase of the pedestrian area etc.) was studied with the use of IMT for a traffic scenario associated with the reduction of the number of circulating vehicles in the road axis.

For the city of Split, IMT was applied taking into account the scenario of reduction of the traffic flows for cars and motorcycles in the Poljička Road because of the promotion of cycling with the new public bicycle sharing system in Split.

For Thessaloniki, two LCMS were assessed with IMT. The first one was the redesign of the pilot road axis (the Eastern Horizontal Axis of Thessaloniki) (i.e. reduction in road lanes, upgrade of bus lane, new cycling path etc.) resulting in two traffic scenarios associated with changes in the traffic flows of cars and motorcycles as well as buses (only for the second traffic scenario). The second LCMS was related with the regulated timetable of freight transport along the pilot road axis.

Finally, for the city of Treviso, the environmental impacts from the replacement of the existing traffic lights with roundabouts in the West Road of Treviso were assessed.

## *Table of contents*

# 1 Methodology of the Integrated Modeling Tool: Soundness and Transferability

The Integrated Modelling Tool (IMT)[1] of REMEDIO project is a modelling tool to assess the performance of low carbon urban mobility measures in terms of energy efficiency, noise impact, air pollution, and health and costs effects. The tool is user friendly and can support the local authorities and stakeholders to decide about possible interventions/solutions at street level to reduce traffic congestion considering also their environmental impacts.

IMT is novel since it integrates many modules as following:

- ✓ Traffic transport module based on the traffic model "Simulation of Urban Mobility" (SUMO)[2],
- ✓ Traffic related pollutant emissions, carbon footprint and energy consumption modules based on the model "Passenger Car and Heavy Duty Emission Model (Light)" (PHEMLight)[3],
- ✓ Traffic related pollutants dispersion module based on the model "Pollutant dispersion in the atmosphere under variable wind conditions" (VADIS)[4],
- ✓ Traffic related noise module based on the methodology "Common Noise Assessment Methods in Europe" (CNOSSOS-EU)[5],
- ✓ Health and cost module based on statistical modeling to relate air pollution and meteorology to health events (deaths, hospitalizations) and to estimate health related costs.

The modelling approach includes the next main steps that the user has to follow (Figure 1.1):

1) Insert the input data of the base case run related to the road description, the traffic load and synthesis, the buildings dimensions along the road, the meteorology and air quality,
2) Apply the selected module(s),
3) Get the output data (environmental, health and cost) as raw data, graphs and maps for analysis of the results,
4) Build traffic scenarios,
5) Get the traffic scenarios output data (environmental, health and cost) and compare the results with those of base case.

---

[1] Integrated Modelling Tool for low carbon mobility solutions: User's guide. In REMEDIO website: https://remedio.interreg-med.eu/

[2] SUMO website: http://sumo.dlr.de/wiki/SUMO_User_Documentation

[3] PHEMLight User Guide Version 1. Passenger Car and Heavy Duty emission model. Technische Universität Graz. Erzherzog-Johann-Universität, Institut für Verbrennungskraft - Maschinen und Thermodynamik.

[4] Borrego, C., Tchepel, O., Barros, N., Miranda, A.I., 2000. Impact of road traffic emissions on air quality of the Lisbon region. Atmospheric Environment 34, 4683–4690.

[5] Kephalopoulos, S., Paviotti, M., Anfosso-Lédée, F., 2012. Common Noise Assessment Methods in Europe (CNOSSOS-EU). https://doi.org/10.2788/31776.

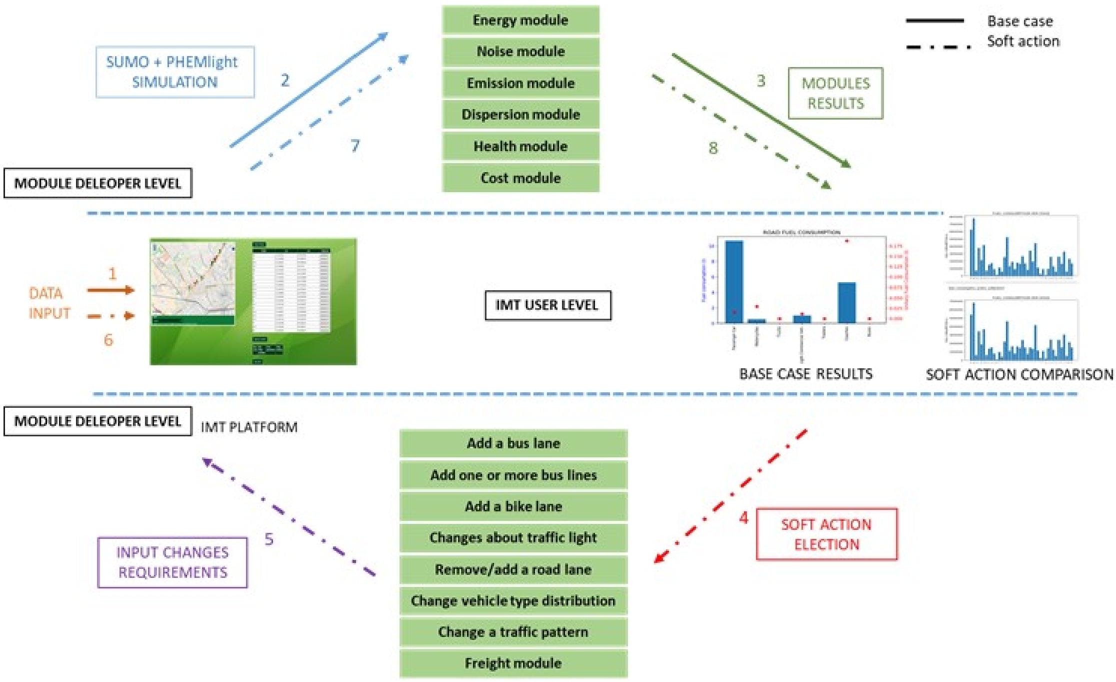



**Figure 1.1** IMT conceptual modelling approach.

The user option for mobility scenarios building in an easy way is an important feature of IMT. The user can set and simulate his customized mobility scenarios. However, it is also possible to define scenarios and examine their impacts while selecting among eight different mobility interventions/solutions already integrated in the IMT and presented in Figure 1.2.

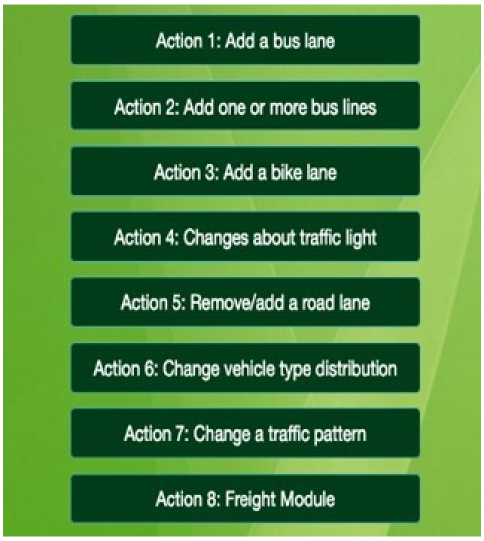



**Figure 1.2** Soft actions integrated in IMT to reduce traffic congestion at street level.

More details about the theoretical scientific background and methodology for each of the modules and a manual to facilitate the users in the IMT application can be found in REMEDIO

Deliverable 3.3.1 “Integrated Modelling Tool for low carbon mobility solutions”. In Deliverable 3.3.1, the validation of IMT for the pilot area of Treviso is also presented as an advocacy of its soundness and reliability.

IMT has been developed so as to have high replicability and transferability potential. This potential has been confirmed within REMEDIO project since IMT has been applied for:

- the pilot road axis of the same Mediterranean city accounting for different mobility scenarios (replicability potential),
- the pilot road axes of four Mediterranean cities (Loures, Split, Thessaloniki and Treviso) characterized by different road descriptions, traffic conditions, dimensions of buildings along the axes, meteorological and air quality conditions (transferability potential).

# 2 Pilot Zones Analysis for Low Carbon Mobility Solutions: Comparison with the Base Case Scenario

In this Chapter, the results of the IMT application for the pilot road axes in Loures, Split, Thessaloniki and Treviso are presented. The results refer to mobility scenarios that are associated with low carbon mobility solutions selected with participatory process within REMEDIO project for each pilot area. The IMT results are compared with those for the base case presented in REMEDIO Deliverable 3.4.1 “Present and future mobility and environmental settings scenarios in urban areas”. Comparison is performed with the estimation of the absolute Difference (Diff) and/or percentage Difference (Diff (%)) between scenarios and base case results according to the following equations:

$$\text{Diff} = (\text{Scenario} - \text{Base Case})$$

$$\text{Diff (\%)} = \frac{(\text{Scenario - Base Case})}{\text{Base Case}}\ \%$$

## 2.1 Loures

REMEDIO project conducted an upgrade of a central axis in the pilot zone of Moscavide-Loures (Figure 2.1.1). The transformation included a participative process to give voice to local stakeholders, neighbors, business, and citizens in general. After the participative process, a consensus was achieved including the following measures:

(a) two road lanes transformed into just one,

(b) increase of the pedestrian area,

(c) inclusion of street furniture, small gardens and equipment.


**Figure 2.1.3** Pilot area of Moscavide/Loures before (top left corner) and after the implementation of the low carbon mobility solution.

The requalification of the pilot area of Loures resulted to a reduction of the number of vehicles in the main avenue of Moscavide, according to Table 2.1.1.

**Table 2.1.1** Road traffic flow for the evening rush hour (18:00-19:00), over the main avenue of Moscavide, for the reference situation and for the low carbon scenario.

| Edge | From/To | Passengers | | Motorcycles | | Trucks | | Trailers | | LCV | | Coaches | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | B | A | B | A | B | A | B | A | B | A | B | A |
| 1 | N5/p12 | 510 | 329 | 14 | 15 | 69 | 19 | 0 | 0 | 69 | 19 | 0 | 0 |
| 2 | p12/N4 | 510 | 329 | 14 | 15 | 69 | 19 | 0 | 0 | 69 | 19 | 0 | 0 |
| 3 | N4/t7 | 340 | 210 | 9 | 9 | 33 | 11 | 0 | 0 | 33 | 11 | 0 | 0 |
| 4 | t7/N3 | 340 | 210 | 9 | 9 | 33 | 11 | 0 | 0 | 33 | 11 | 0 | 0 |
| 5 | N3/b8 | 455 | 309 | 10 | 9 | 44 | 13 | 0 | 0 | 44 | 13 | 0 | 0 |
| 6 | b8/p11 | 455 | 309 | 10 | 9 | 44 | 13 | 0 | 0 | 44 | 13 | 0 | 0 |
| 7 | p11/N2 | 455 | 309 | 10 | 9 | 44 | 13 | 0 | 0 | 44 | 13 | 0 | 0 |
| 8 | N2/p10 | 340 | 208 | 8 | 7 | 29 | 16 | 0 | 0 | 29 | 16 | 0 | 0 |
| 9 | p10/N1 | 340 | 208 | 8 | 7 | 29 | 16 | 0 | 0 | 29 | 16 | 0 | 0 |
| 10 | N1/p9 | 450 | 298 | 11 | 10 | 35 | 9 | 0 | 0 | 35 | 9 | 0 | 0 |
| 11 | p9/t6 | 450 | 298 | 11 | 10 | 35 | 9 | 0 | 0 | 35 | 9 | 0 | 0 |
| 12 | t6/N0 | 450 | 298 | 11 | 10 | 35 | 9 | 0 | 0 | 35 | 9 | 0 | 0 |

B – Before the requalification; A – After the requalification

The IMT was used in order to assess the impact of the requalification on energy, noise, emissions and air quality. The IMT modules were applied for the traffic peak hour between 18:00 and 19:00. In the following sections, the IMT results for the requalification are presented along with the comparison with the IMT results for the base case (presented in detail in Deliverable 3.4.1).

### 2.1.1 Energy

**Figure** .1.2 depicts the hourly fuel consumption per vehicle type for the intervention while in Table 2.1.2 the comparison with the base case is presented.

**Figure** .1.2 shows that buses are the type of vehicle characterized by the largest fuel consumption. The hourly total fuel consumption is decreased by about -43% with respect to the base case, mostly due to the reduction of passenger cars fuel consumption (-27%), trucks (-50%) and LCV (-64%).

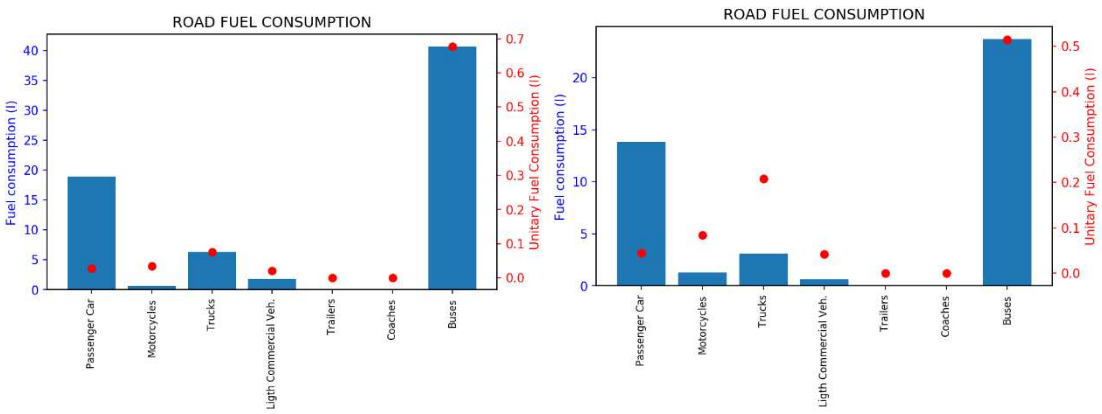



**Figure 2.1.2** Hourly fuel consumption per vehicle type for the intervention (hour 18:00-19:00) for the base (left) and requalification (right).

**Table 2.1.2** Differences (%) in hourly total fuel consumption between the base case and requalification for the pilot zone of Lisbon.

| | |
|---|---|
| Diff (%) in Fuel Consumption (Hour 18:00-19:00) | -43 |

### 2.1.2 Noise

The noise module was applied for the hour 18:00-19:00. Figure 2.1.3 illustrates the total and per vehicle type noise emissions along the pilot zone of Loures for the base and requalification. The buses are the type of vehicles producing the highest noise levels for both cases.

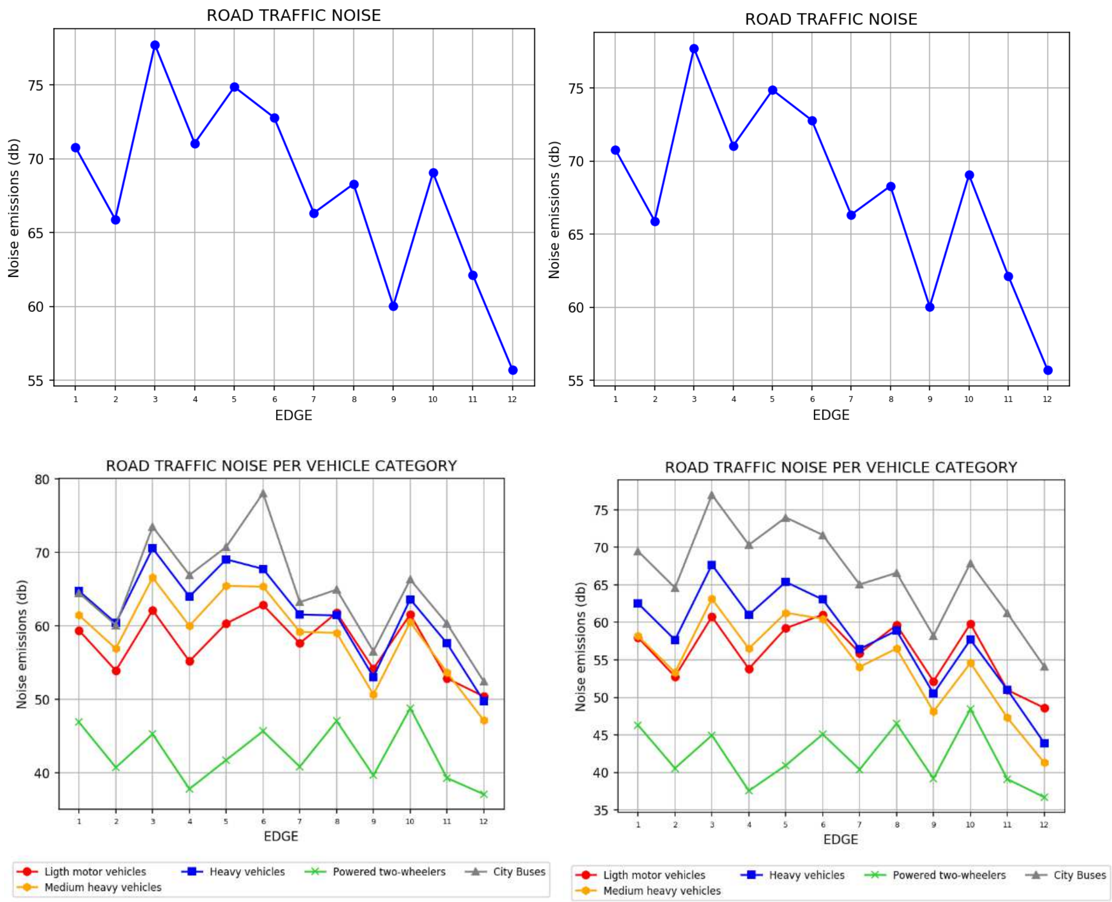



**Figure 2.1.3** Road traffic total noise (top) and per vehicle type noise (down) along the pilot zone of Loures at the hour of peak traffic flow (18:00-19:00) for the base (left) and requalification (right).

Table 2.1.3 summarizes the differences in the total noise emissions averaged along the road axis, and the road-wide maximum reductions in total noise emissions, between the base case and the requalification for the pilot zone of Loures. The mean noise emission reductions with respect to base case is -0.17 dB corresponding to -0.22% percentage values. The maximum noise emission reductions with respect to base case is -6.01 dB corresponding to -7.62% percentage values.

**Table 2.1.3** Absolute and percentage differences in total noise emissions between the base case and the requalification for the pilot zone of Loures.

| | |
|---|---|
| Diff in Mean Noise Values (dB) | -0.17 |
| Diff (%) in Mean Noise Values | -0.22 |
| Maximum Diff in Noise Values (dB) | -6.01 |
| Maximum Diff (%) in Noise Values | -7.62 |

### 2.1.3 Atmospheric pollution emissions - Carbon footprint

The atmospheric pollution emissions and carbon footprint (i.e. $CO_2$ emissions) module was applied for the hour 18:00-19:00. Figure 2.1.4 depicts the total and per vehicle type hourly pollutant emissions and carbon footprint for the requalification. The ranking of vehicle types in

REMEDIO project is co-financed by the European Regional Development Fund

terms of contribution to pollutant emissions and carbon footprint for the requalification is similar with that for the base case (see Deliverable 3.4.1). The buses are the vehicle type with the highest share to $NO_x$ emissions.

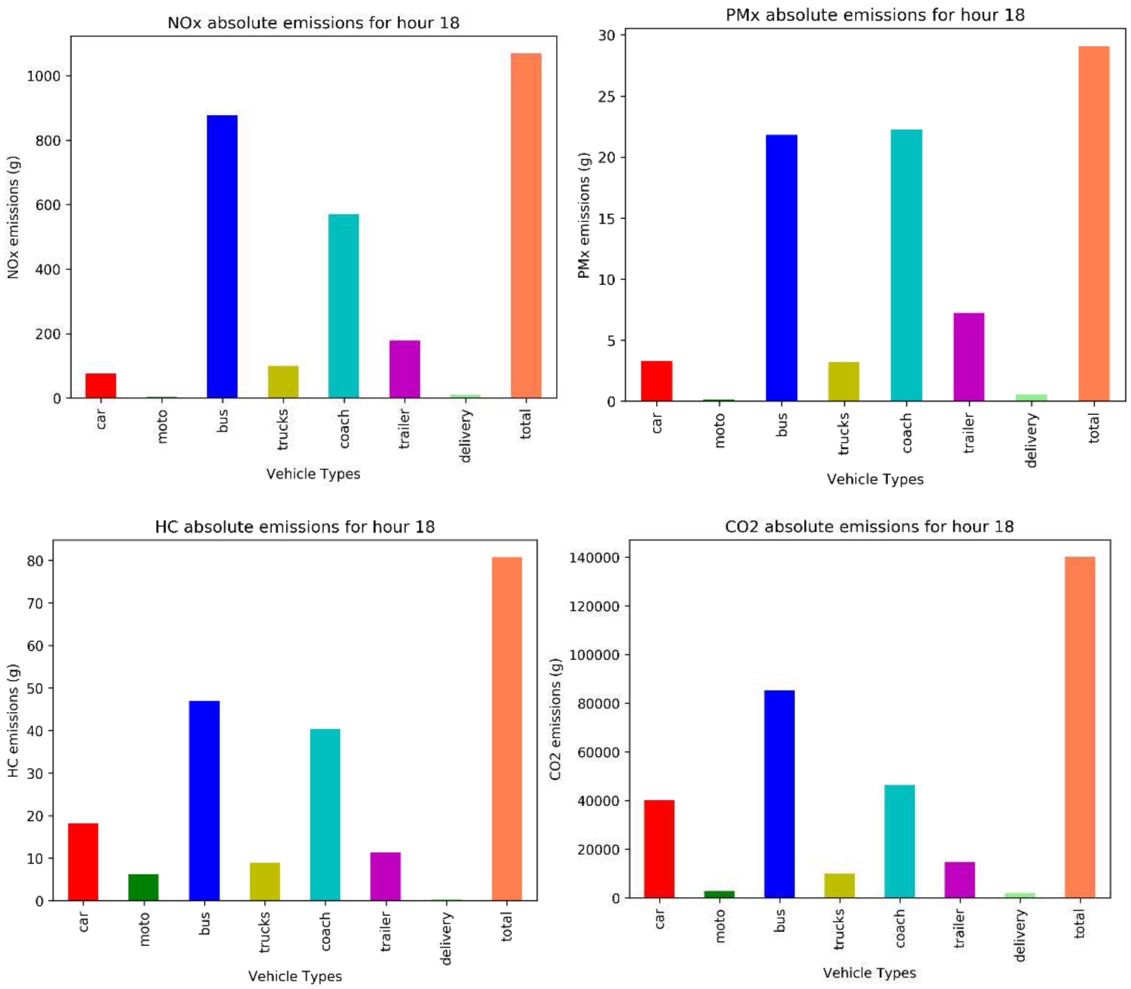



**Figure 2.1.4** Total and per vehicle type pollutant emissions along the pilot zone of Loures for the hour of peak traffic (18:00-19:00) for $NO_x$, PMx, HC and $CO_2$.

Regarding the average normalized hourly pollutant emissions along the main Avenue of Moscavide/ Loures (Figure 2.1.5), a decrease in all pollutants emissions and carbon footprint is presented with respect to the base case.

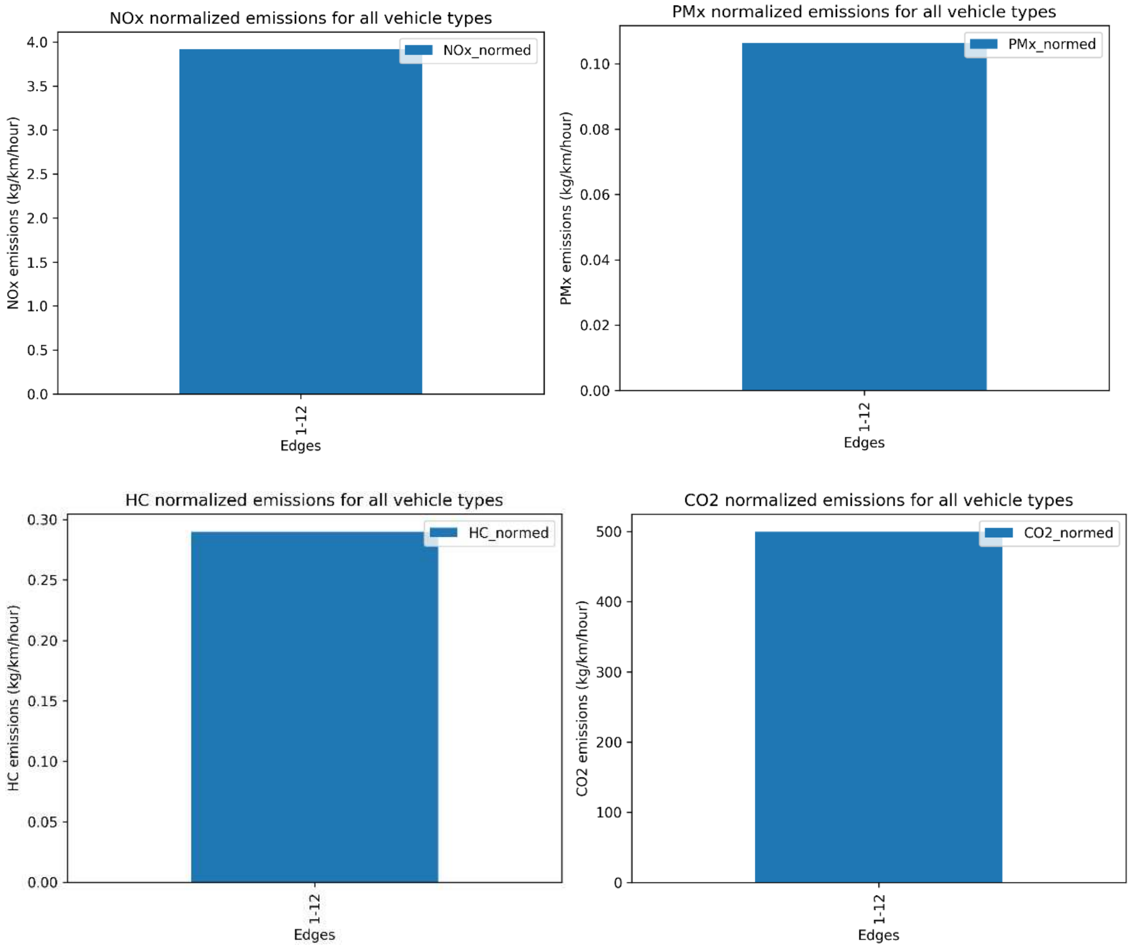



**Figure 2.1.5** Average normalised pollutant emissions in Moscavide (edges 1-12) for $NO_x$, PMx, HC and $CO_2$ (traffic peak hour 18:00-19:00).

Figure 2.1.6 shows the spatial distribution of the normalized pollutant emissions and carbon footprint along the pilot axis of Loures for the traffic peak hour (18:00-19:00) for the requalification.

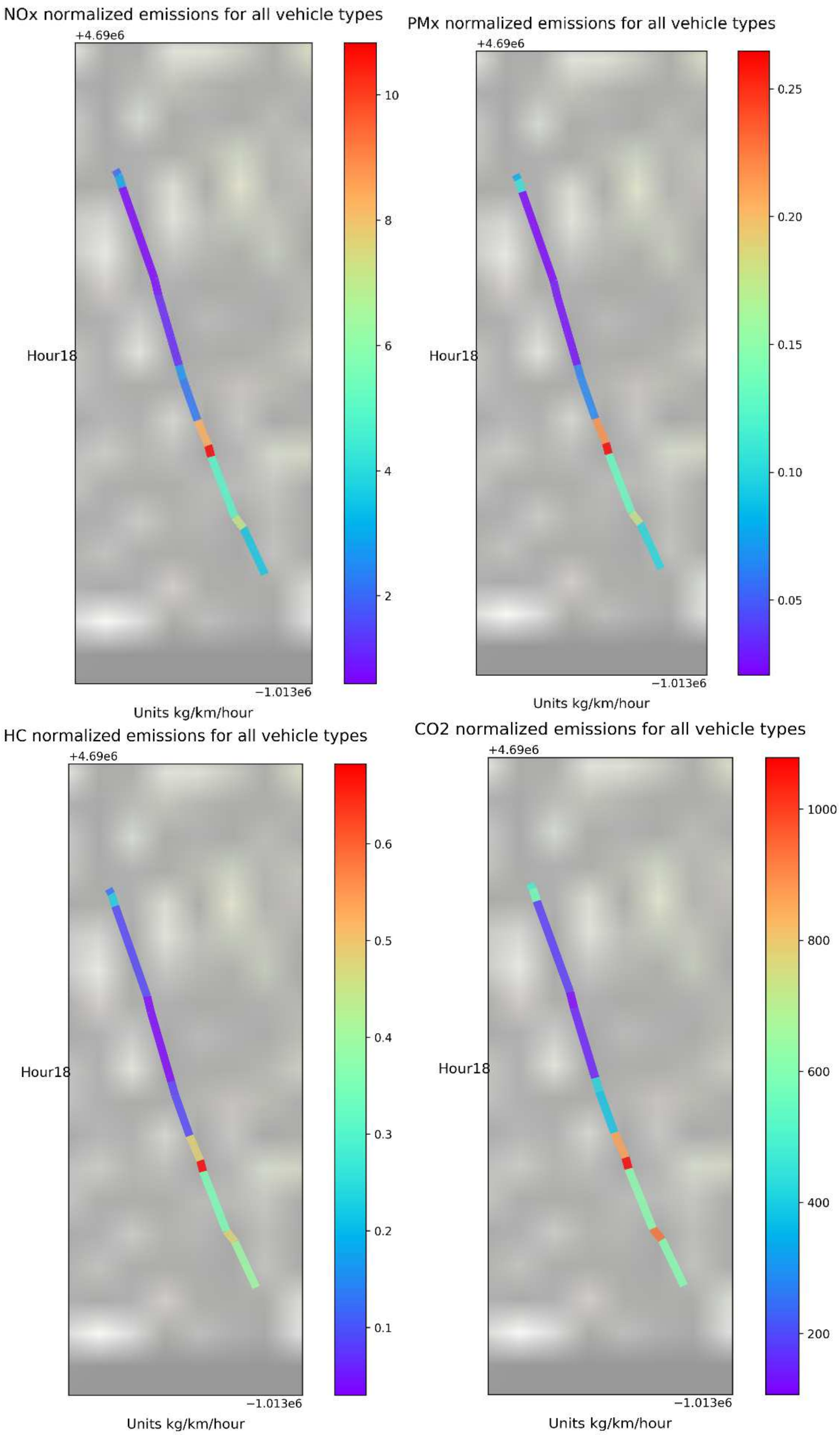



**Figure 2.1.6** Spatial distribution of the normalized pollutant emissions along the pilot axis of Loures for the traffic peak hour (18:00-19:00) for $NO_x$, PMx, HC and $CO_2$.

Table 2.1.4 presents the percentage differences in total hourly pollutant emissions and carbon footprint between the base case and the requalification for the pilot zone of Loures at traffic peak hour (18:00-19:00). Decreases (higher than 28% for all pollutant) have been estimated with the requalification.

**Table 2.1.4** Differences (%) in total hourly pollutant emissions, carbon footprint between the base case and the requalification for the pilot zone of Loures at traffic peak hour (18:00-19:00).

| | CO | CO2 | HC | PMx | NOx |
|---|---|---|---|---|---|
| Diff (%) in total hourly emissions | -31 | -39 | -34 | -28 | -36 |

### 2.1.4 Air pollution dispersion

Figure 2.1.7 displays the percentage differences for NOx, PMx, HC, CO and CO2 concentrations between the base case and the requalification for the pilot zone of Loures. The impact was not uniform for all Moscavide Avenue: the highest reductions were observed for the edges 10, 11 and 12 but for the other edges increases in the concentrations were estimated. The highest reductions were observed for HC (-80%) followed by CO (-50%).

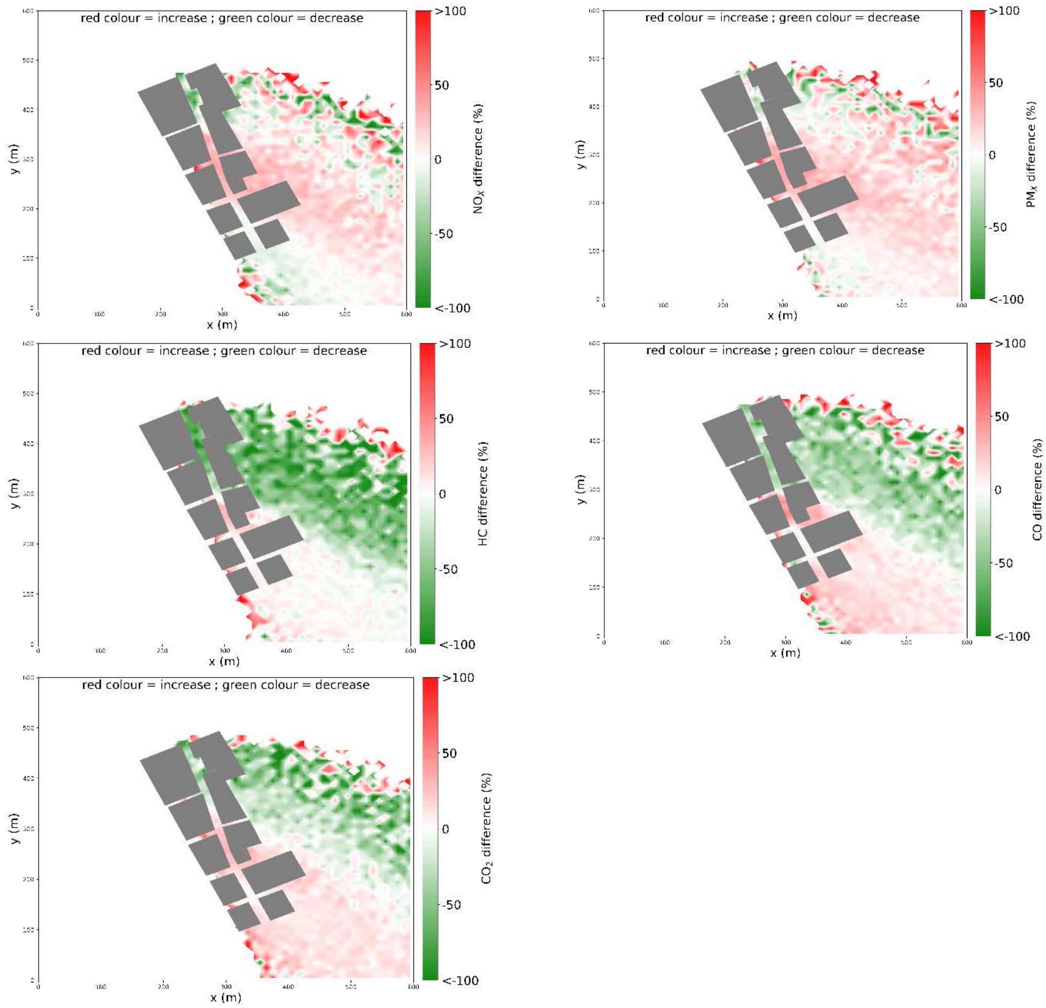



**Figure 2.1.7** Percentage differences for $NO_x$, PMx, HC, CO and $CO_2$ concentrations between the base case and the requalification for the pilot zone of Loures.

**REMEDIO project is co-financed by the European Regional Development Fund**

## 2.2 Split

For the city of Split, IMT was applied taking into account the traffic scenario of reduction of the traffic flows for cars and motorcycles by 4% in the Poljička Road because of the promotion of cycling with the new public bicycle sharing system in Split. IMT was applied for the traffic peak hour (13:00-14:00). The IMT results for the base case are included in REMEDIO Deliverable 3.4.1.

### 2.2.1 Energy

Figure 2.2.1 shows the hourly fuel consumption per vehicle type for the LCMS scenario.

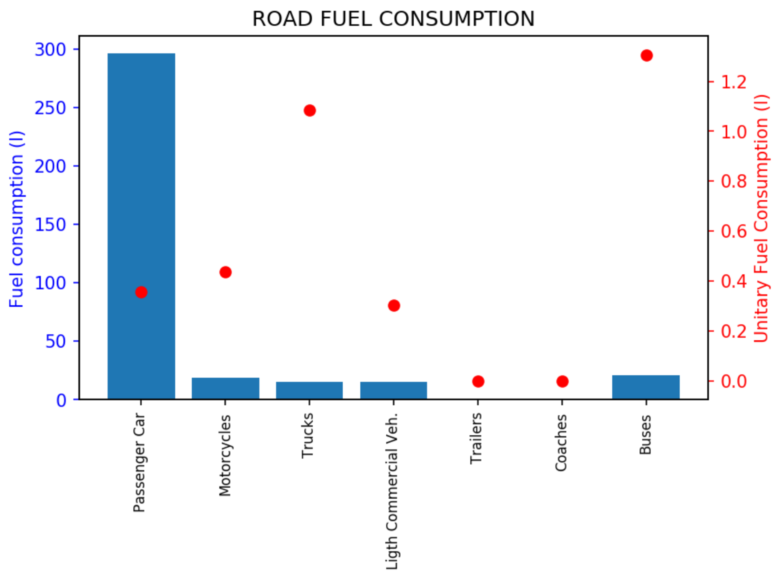



**Figure 2.2.1** Hourly fuel consumption per vehicle type at the hour of peak traffic flow (13:00-14:00) for the LCMS scenario.

### 2.2.2 Noise

Figure 2.2.2 illustrates the total and per vehicle type noise emissions along the pilot zone of Split. Medium heavy vehicles are the type of vehicles producing the highest noise levels.

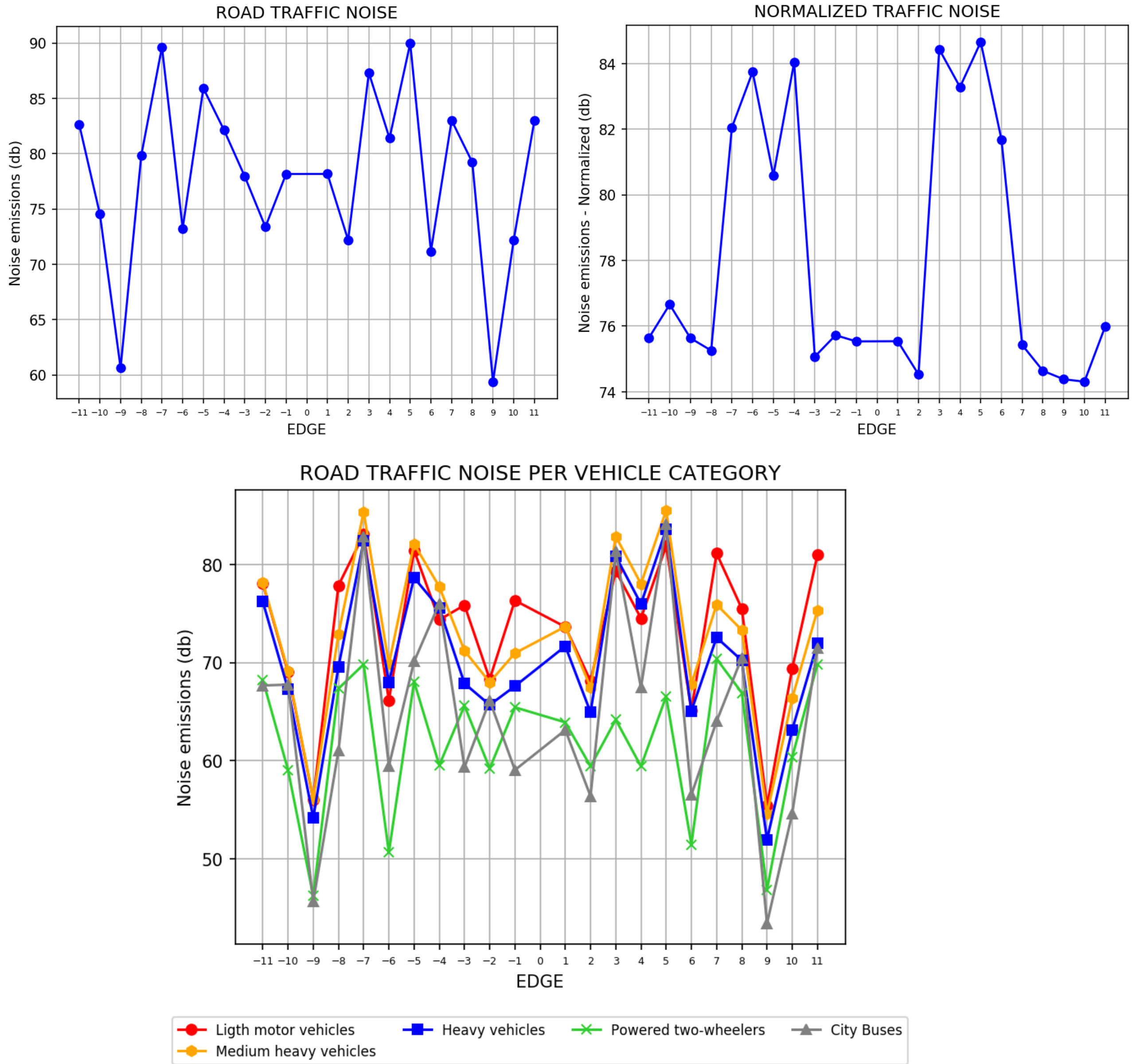



**Figure 2.2.2** Road traffic total and normalized noise (top) and per vehicle type noise (bottom) along the pilot zone of Split at the hour of peak traffic flow (13:00-14:00) for the LCMS scenario.

### 2.2.3 Atmospheric pollution emissions - Carbon footprint

Figures 2.2.3 and 2.2.4 show the absolute and normalized atmospheric pollutant emissions and carbon footprint results, respectively.

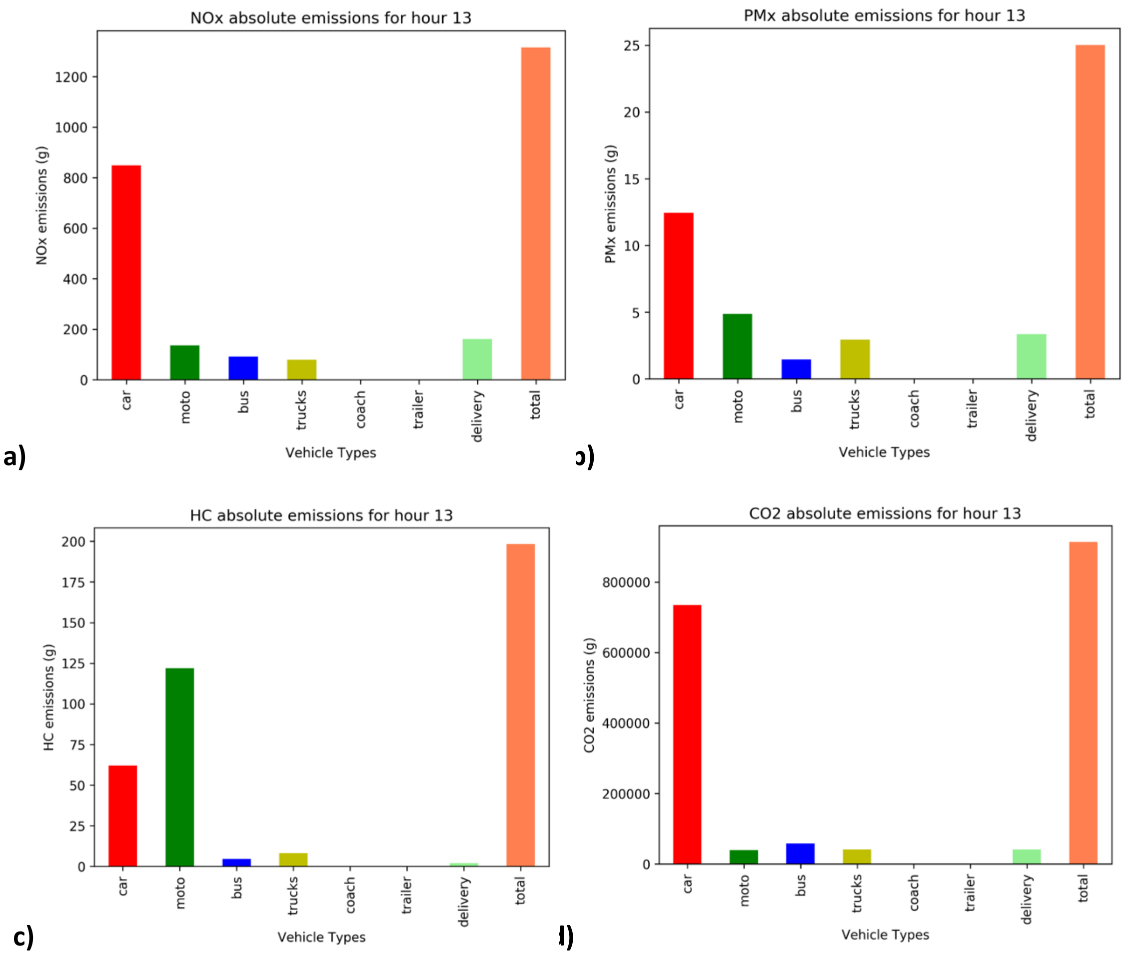



**Figure 2.2.3** Total and per vehicle type pollutant emissions of a) $NO_x$, b) PMx, c) HC and d) $CO_2$ along the pilot zone of Split for the hour of peak traffic (13:00-14:00) for the LCMS scenario.

**REMEDIO project is co-financed by the European Regional Development Fund**

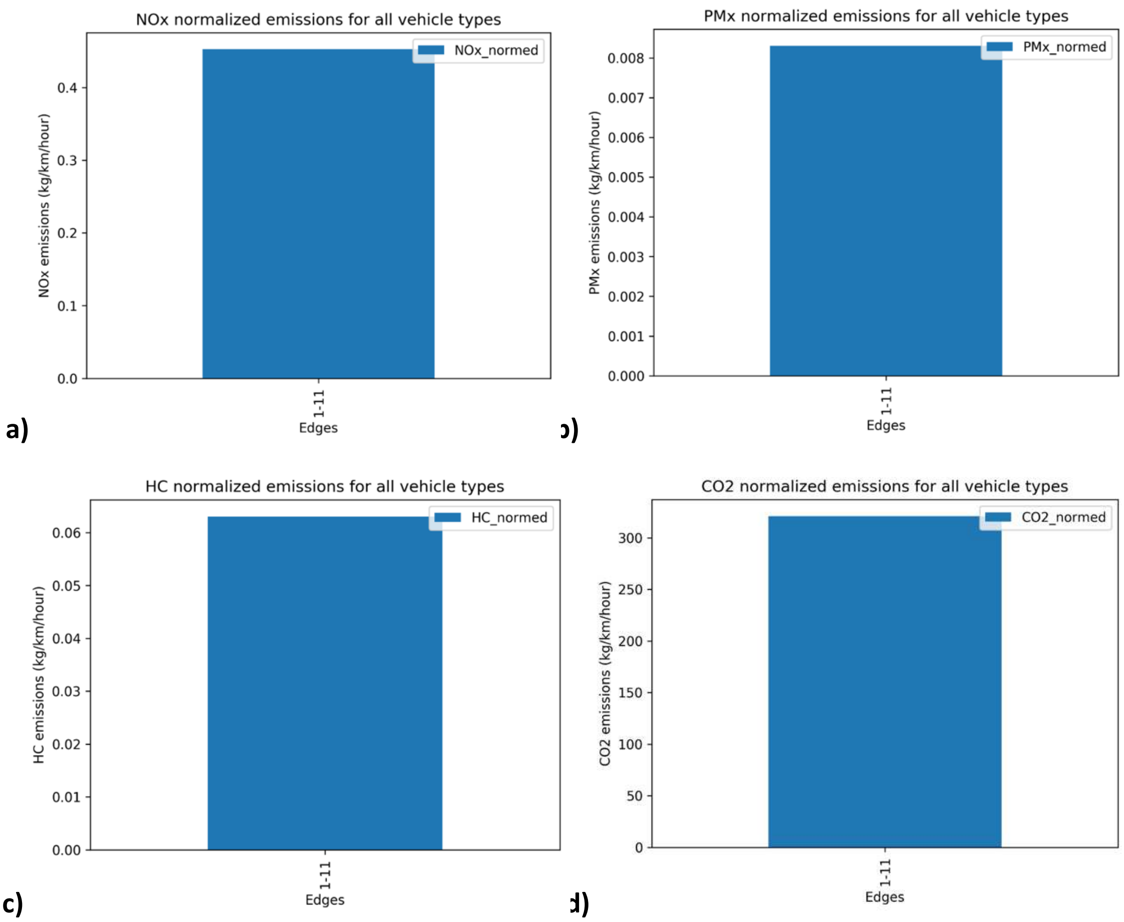



**Figure 2.2.4** Average normalised pollutant emissions of a) $NO_x$, b) PMx, c) HC and d) $CO_2$ along the pilot zone of Split for the hour of peak traffic (13:00-14:00) for the LCMS scenario.

Figure 2.2.5 shows the spatial distribution of the average normalized hourly emissions of pollutants along the pilot area from the passenger cars.

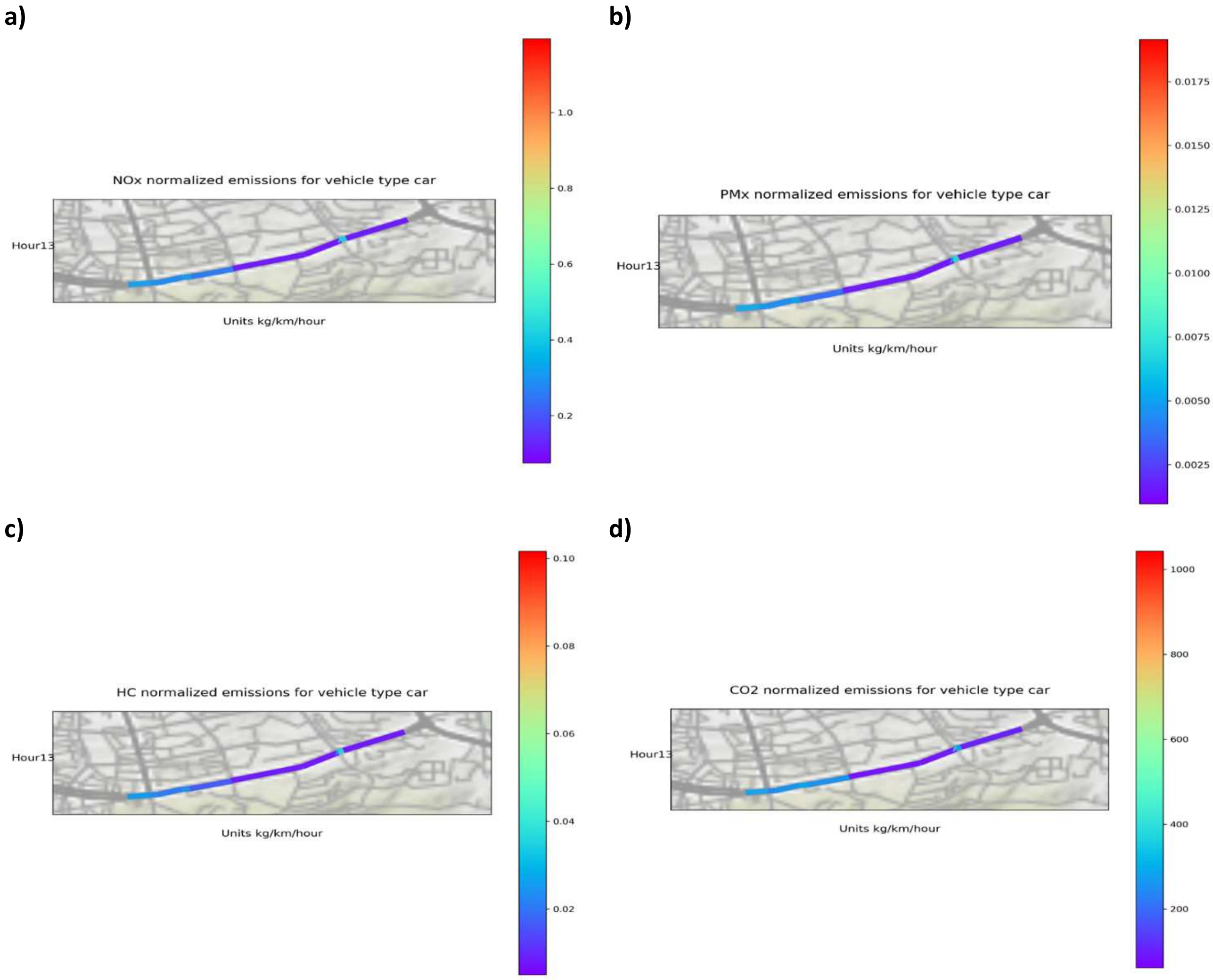



**Figure 2.2.5** Spatial distribution of the normalized pollutant emissions of a) $NO_x$, b) PMx, c) HC and d) $CO_2$ from passenger cars along the pilot axis of Split for the traffic peak hour (13:00-14:00) for the LCMS scenario.

### 2.2.4 Air pollution dispersion

The air pollution dispersion module was applied for the 31st May of 2015 at the hour 13:00-14:00 for the LCMS scenario for the pilot area of Split. IMT was applied with temperature and pressure values of 15 °C and 1 bar, respectively while the wind was blowing from the north. Figure 2.2.6 depicts the air pollutant concentrations over the pilot area of Split.

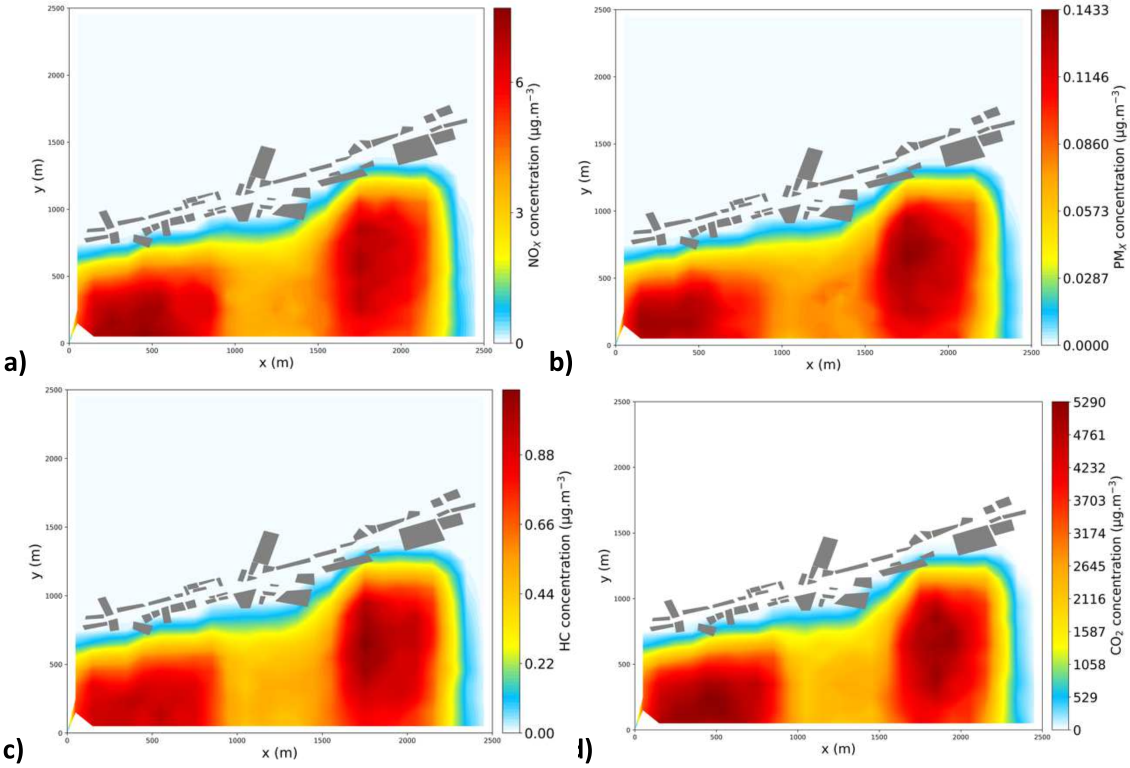



**Figure 2.2.6** Air pollution concentrations of a) $NO_x$, b) PMx, c) HC and d) $CO_2$ along the pilot area of Split for the traffic peak hour (13:00-14:00) for the LCMS scenario.

## 2.3 Thessaloniki

Two low-carbon mobility solutions (LCMS), resulting in three different traffic-related scenarios, have been analyzed for the pilot zone of Thessaloniki. The first low carbon mobility solution include the redesign of the pilot road axis of Thessaloniki and is associated with the following scenarios for the traffic conditions:

- 1st scenario (SCN10): The traffic volume of passenger cars and motorcycles is reduced by 10% with respect to the base case,
- 2nd scenario (SCN20): The traffic volume of passenger cars and motorcycles is reduced by 20% and the average frequency of bus lines through the pilot zone is increased by a factor of 2 with respect to the base case.

The second LCMS concerns the regulated timetable of freight transport and is associated with the scenario of exclusion of the delivery vehicles from the base case traffic volume the hour 10:00-11:00 (SCN-freight).

More details about the description of the pilot road axis, the base case and both LCMS and associated traffic scenarios can be found in Deliverable 3.4.1.

All the modules of IMT were applied for the traffic peak hour (08:00-09:00) in case of the first LCMS and associated traffic scenarios SCN10 and SCN20. In the case of the second LCMS and associated traffic scenario SCN-freight, all the IMT modules were applied for the hour 10:00-11:00. In the following sections, the IMT results for the traffic scenarios SCN10, SCN20 and SCN-freight are presented along with their comparison with the IMT results for the base case (presented in Deliverable 3.4.1).

### 2.3.1 Energy

Figure 2.3.1 depicts the hourly fuel consumption per vehicle type for the three different scenarios (SCN10, SCN20 and SCN-freight) while in Table 2.3.1 the comparison with the base case is presented. For all scenarios examined, passenger cars are the type of vehicle characterized by the largest fuel consumption. The hourly total fuel consumption is decreased by about -18%, -16% and -2.4% in SCN10, SCN20 and SCN-freight, respectively with respect to the base case. In particular, in the case of SCN10, the reduction in total fuel consumption is mostly because of passenger cars fuel consumption reduction by -19.7%. The percentage difference of SCN20 is configured by the decrease of passenger cars fuel consumption by around -33% and the increase for buses by around +48%. Finally, the percentage reduction in total fuel consumption in the case of SCN-freight is small and can be explained by the small fuel consumption of light commercial vehicles with respect to that of other vehicles and by the negligible change in fuel consumption for the rest vehicle categories with respect to the base case scenario.

REMEDIO project is co-financed by the European Regional Development Fund

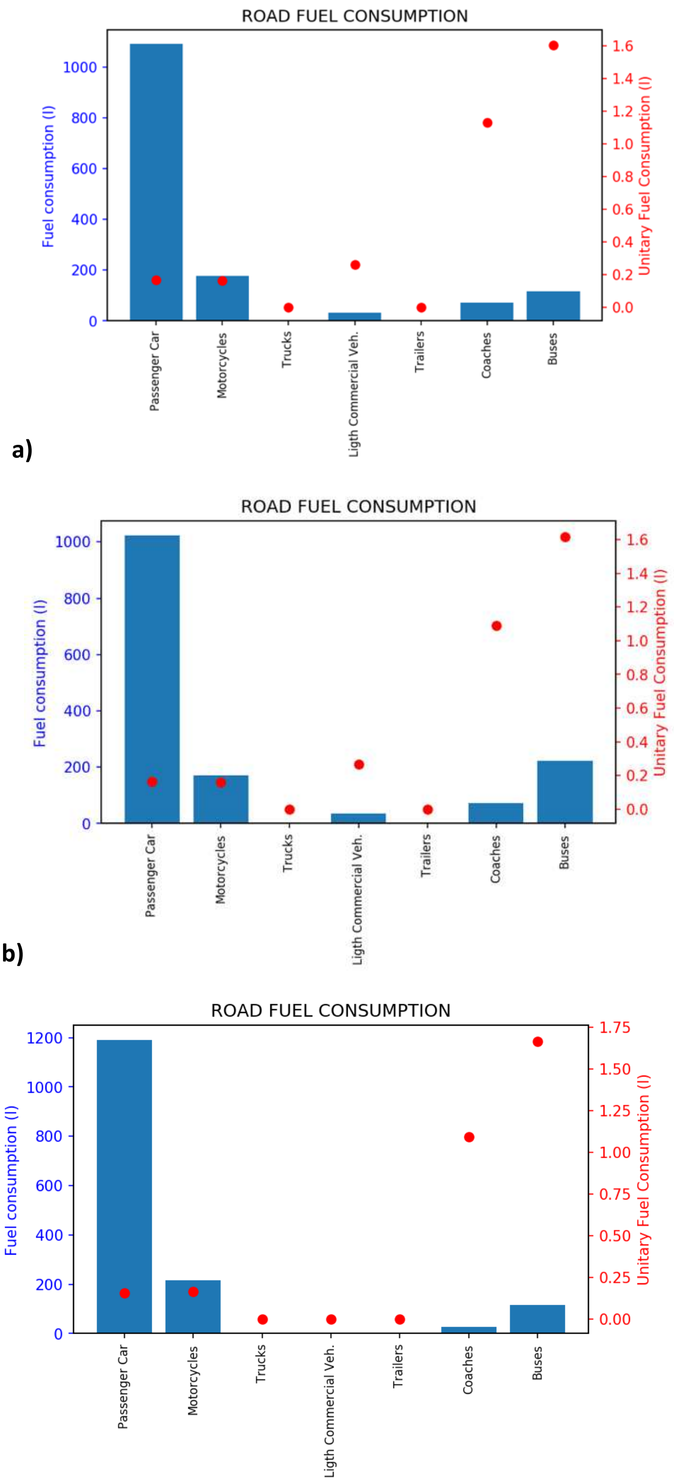



**Figure 2.3.1** Hourly fuel consumption per vehicle type for scenarios: a) SCN10 and b) SCN20 (hour 08:00-09:00) and c) SCN-freight (hour 10:00-11:00).

**Table 2.3.1** Differences (%) in hourly total fuel consumption between the base case and traffic scenarios for the pilot zone of Thessaloniki.

| | SCN10* | SCN20* | SCN-freight* |
|---|---|---|---|
| Diff (%) in Fuel Consumption | -18.19 | -16.23 | -2.40 |

*Hour 08:00-09:00 for SCN10 and SCN20; Hour 10:00-11:00 for SCN-freight

## 2.3.2 Noise

The noise module was applied for the traffic scenarios SCN10 and SCN20 for the hour 08:00-09:00. Figure 2.3.2 illustrates the total and per type noise emissions along the pilot zone of Thessaloniki for SCN10 and SCN20. The spatial patterns of total noise (Figure 2.3.2. a_i and a_ii) are similar with that of the base case (see Deliverable D.3.4.1). The Light motor vehicles are the type of vehicles producing the highest noise levels.

SCN10 and SCN20 result in small reductions of noise levels with respect to the base case in almost all road segments (Figures 2.3.2. and 2.3.3). Figure 2.3.4 depicts the absolute and percentage differences in total noise levels of the two scenarios with respect to the base case. SCN20 results in higher reductions of the base case noise levels along almost the whole pilot axis in comparison to SCN10. These reductions for SCN20 reach up to about -2.3 dB in absolute values and up to -3.4% in relative values.

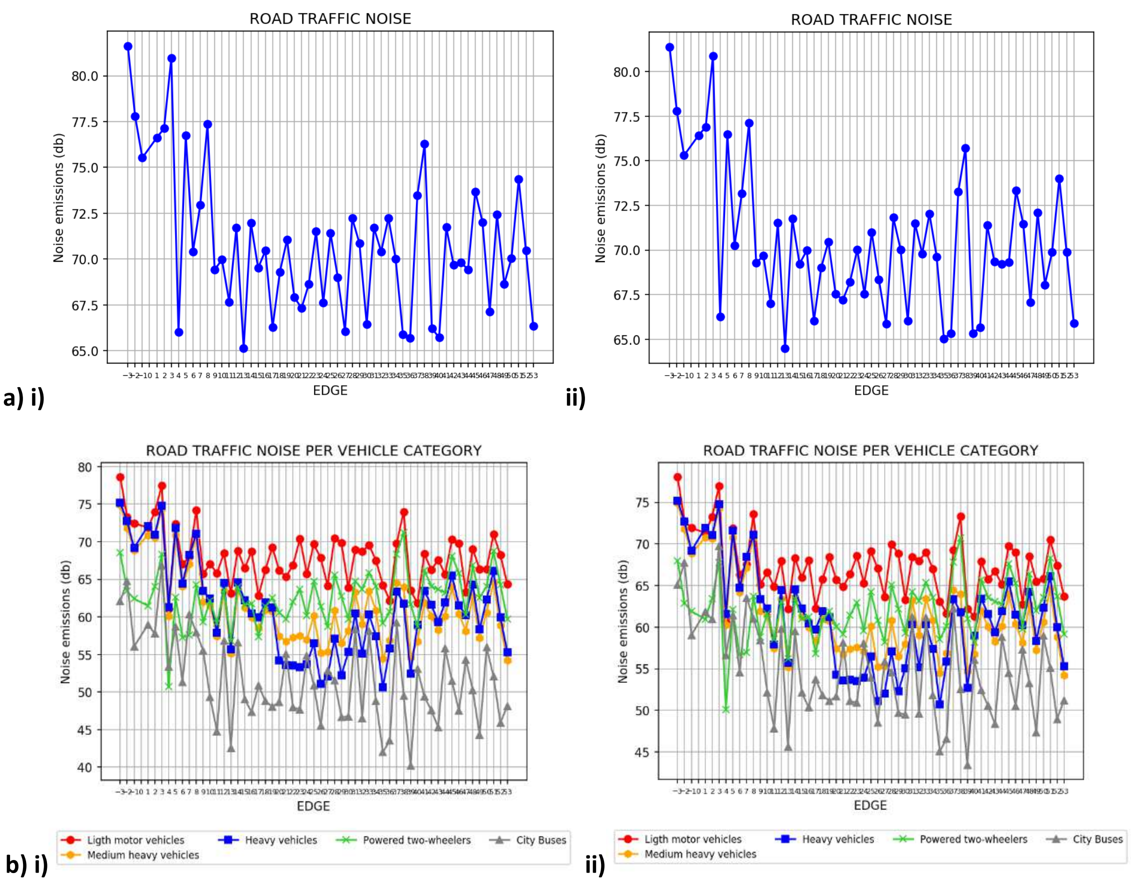



**Figure 2.3.2** Road traffic total noise (a) and per vehicle type noise (b) along the pilot zone of Thessaloniki at the hour of peak traffic flow (08:00-09:00) for i) SCN10 and ii) SCN20.

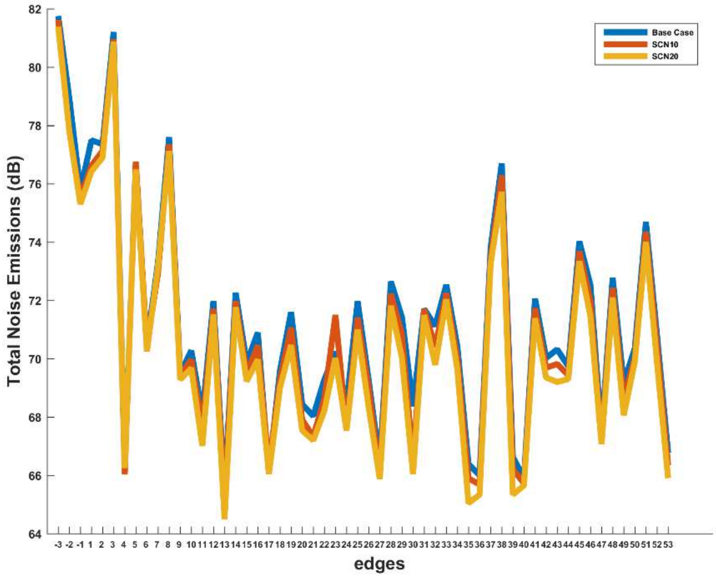



**Figure 2.3.3** Road traffic total noise along the pilot zone of Thessaloniki at the hour of peak traffic flow (08:00-09:00) for the Base Case (blue line), SCN10 (orange line) and SCN20 (yellow line).

**a)** **b)**

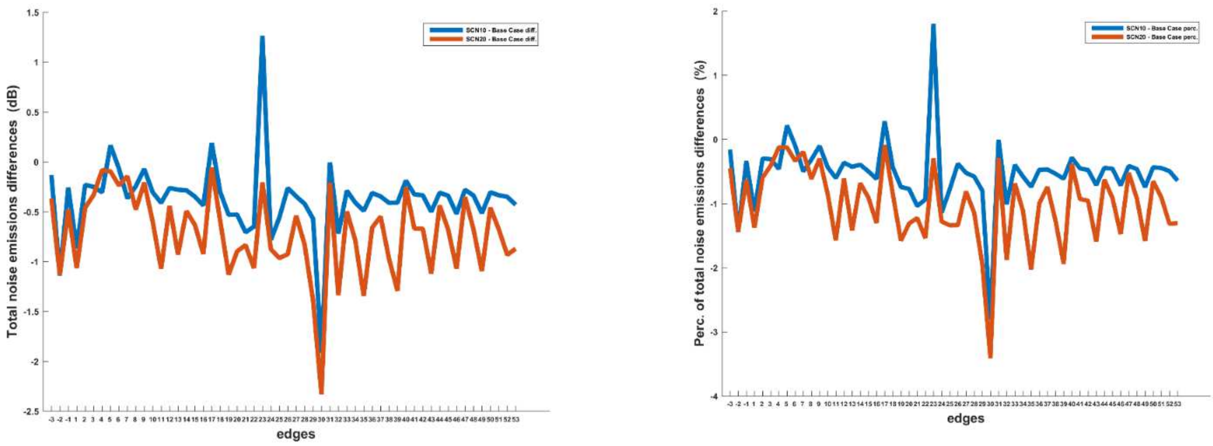



**Figure 2.3.4** Noise emissions differences (a) and percentage differences (b) along the pilot zone of Thessaloniki at the hour of peak traffic (08:00-09:00) between base case and scenarios (SCN10: blue line: SCN20: orange line).

In the following, the IMT results of SCN-freight as well as comparison with the base case results are presented. The IMT was applied for the hour 10:00-11:00. Figure 2.3.5 illustrates the total and per type noise emissions along the pilot zone of Thessaloniki for the base case and SCN-freight. The spatial pattern of the total noise for the SCN-freight is similar with that for the base case. The Light motor vehicles are the type of vehicles producing the highest noise levels.

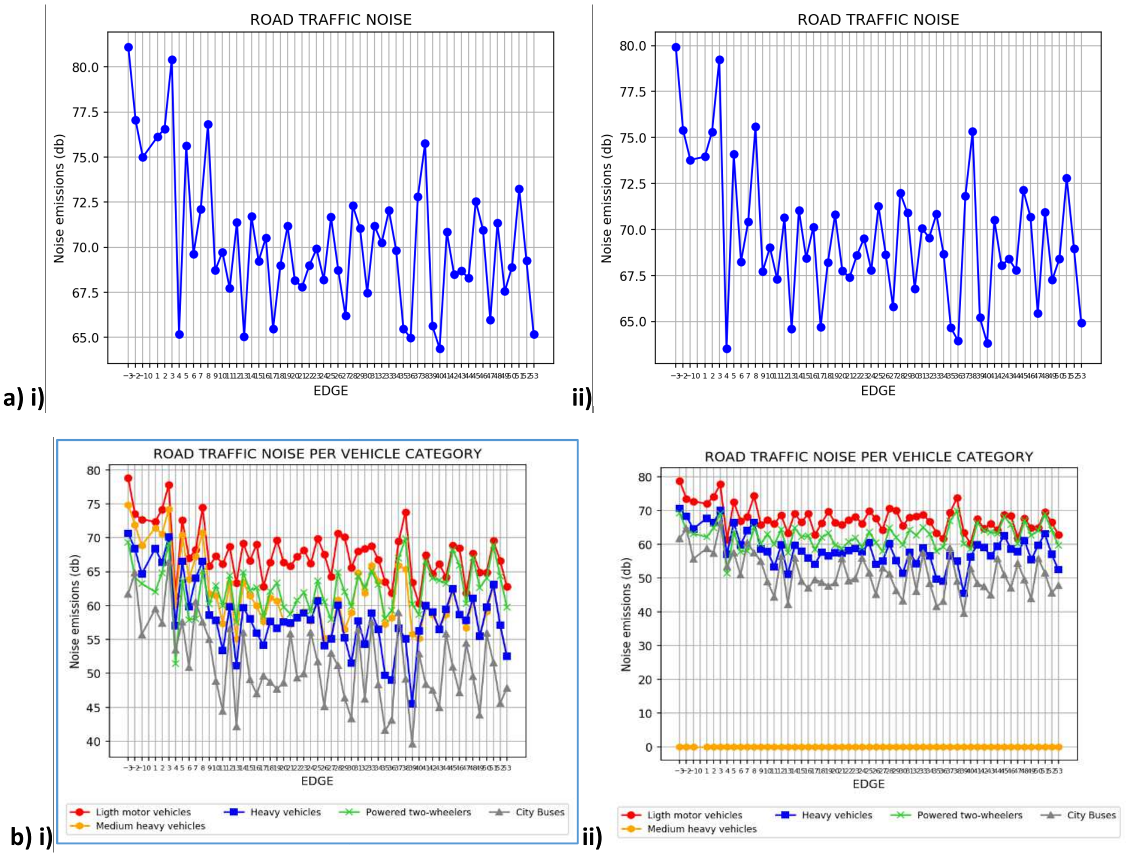



**Figure 2.3.5** Road traffic total noise (a) and per vehicle type noise (b) along the pilot zone of Thessaloniki at the hour 10:00-11:00 for i) the base case and ii) the SCN-freight.

In order to investigate the impact of SCN-freight, the noise emissions differences between base case and SCN-freight were calculated (Figure 2.3.6). Across the pilot road axis, the absolute differences range from -0.08 dB down to -2.16 dB. The largest reductions are found in Ethnikis Antistaseos Street (edges -3 to 9) being on average -1.43 dB in absolute values and -2% in percentage values. Along the rest part of the road axis, the reductions are lower being on average -0.54 dB in absolute values and -0.78% in percentage values.

a) b)

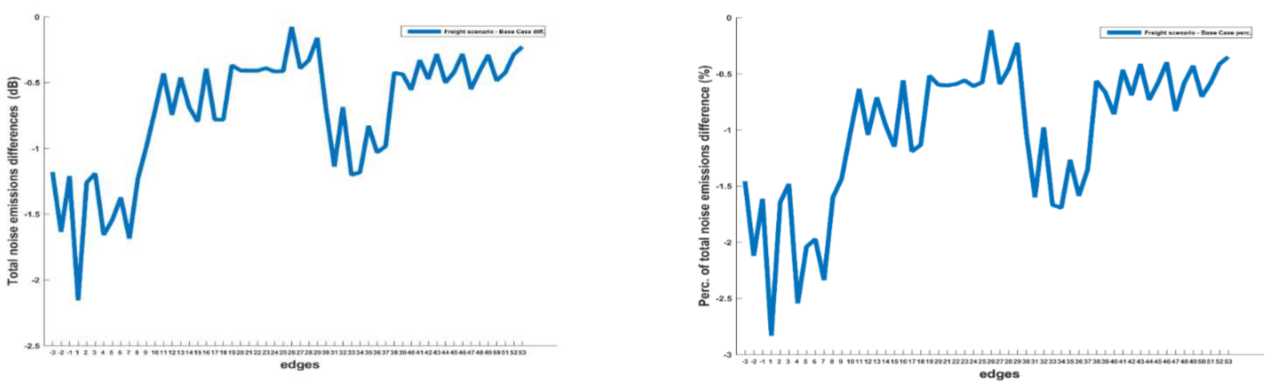



**Figure 2.3.6** Noise emissions differences (a) and percentage differences (b) along the pilot zone of Thessaloniki at the hour 10:00-11:00 between base case and SCN-freight.

REMEDIO project is co-financed by the European Regional Development Fund

Table 2.3.2 summarizes the differences in the total noise emissions averaged along the road axis and the road-wide maximum reductions in total noise emissions between the base case and all the traffic scenarios for the pilot zone of Thessaloniki. The mean noise emission reductions with respect to base case are -0.37 dB, -0.72 dB and -0.73 dB respectively for SCN10, SCN20 and SCN-freight corresponding to -0.52%, -1.01% and -1.03% percentage values.

**Table 2.3.2** Absolute and percentage differences in total noise emissions between the base case and traffic scenarios for the pilot zone of Thessaloniki.

| | **SCN10*** | **SCN20*** | **SCN-freight*** |
|---|---|---|---|
| Diff** in Mean Noise Values (dB) | -0.37 | -0.72 | -0.73 |
| Diff** (%) in Mean Noise Values | -0.52 | -1.01 | -1.03 |
| Maximum Diff** in Noise Values (dB) | -1.92 | -2.33 | -2.16 |
| Maximum Diff** (%) in Noise Values | -2.80 | -3.41 | -2.83 |

*Hour 08:00-09:00 for SCN10 and SCN20; Hour 10:00-11:00 for SCN-freight

**Reductions

### 2.3.3 Atmospheric pollution emissions - Carbon footprint

The atmospheric pollution emissions and carbon footprint (i.e. CO2 emissions) module was applied for the first LCMS for the hour 08:00-09:00. Figure 2.3.7 depicts the total and per vehicle type hourly pollutant emissions and carbon footprint for the two different traffic scenarios (SCN10 and SCN20) associated with the first LCMS. The ranking of vehicle types in terms of contribution to pollutant emissions and carbon footprint for SCN10 is similar with that for the base case (see Deliverable 3.4.1). On the other hand, there are differences between the base case and SCN20 attributed to the increase of the number of buses circulating in the pilot axis of Thessaloniki. Thus, according to SCN20, the buses become the vehicle type with the highest share to $NO_x$ emissions and the second in the rank contributor to PMx and $CO_2$ emissions.

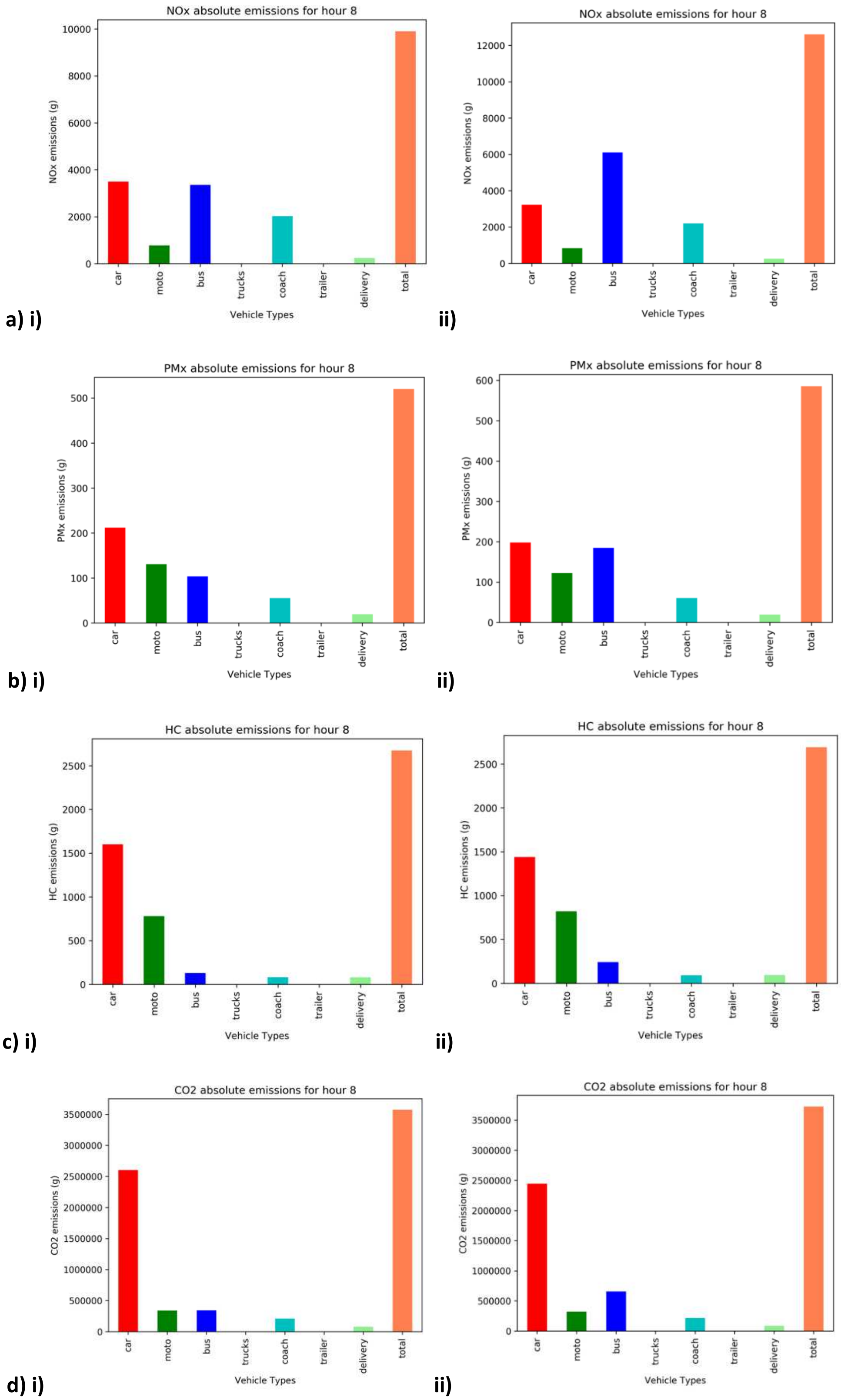



**Figure 2.3.7** Total and per vehicle type pollutant emissions along the pilot zone of Thessaloniki for the hour of peak traffic (08:00-09:00): a) $NO_x$, b) PMx, c) HC and d) $CO_2$ for i) SCN10 and ii) SCN20.

Regarding the average normalized hourly pollutant emissions along the four main streets of the pilot axis of Thessaloniki (Figure 2.3.8), a decrease in all pollutants emissions and carbon footprint is presented for both scenarios with respect to the base case, except for $NO_x$

emissions in SCN20 for which an increase has been estimated due to the increase of buses flows.

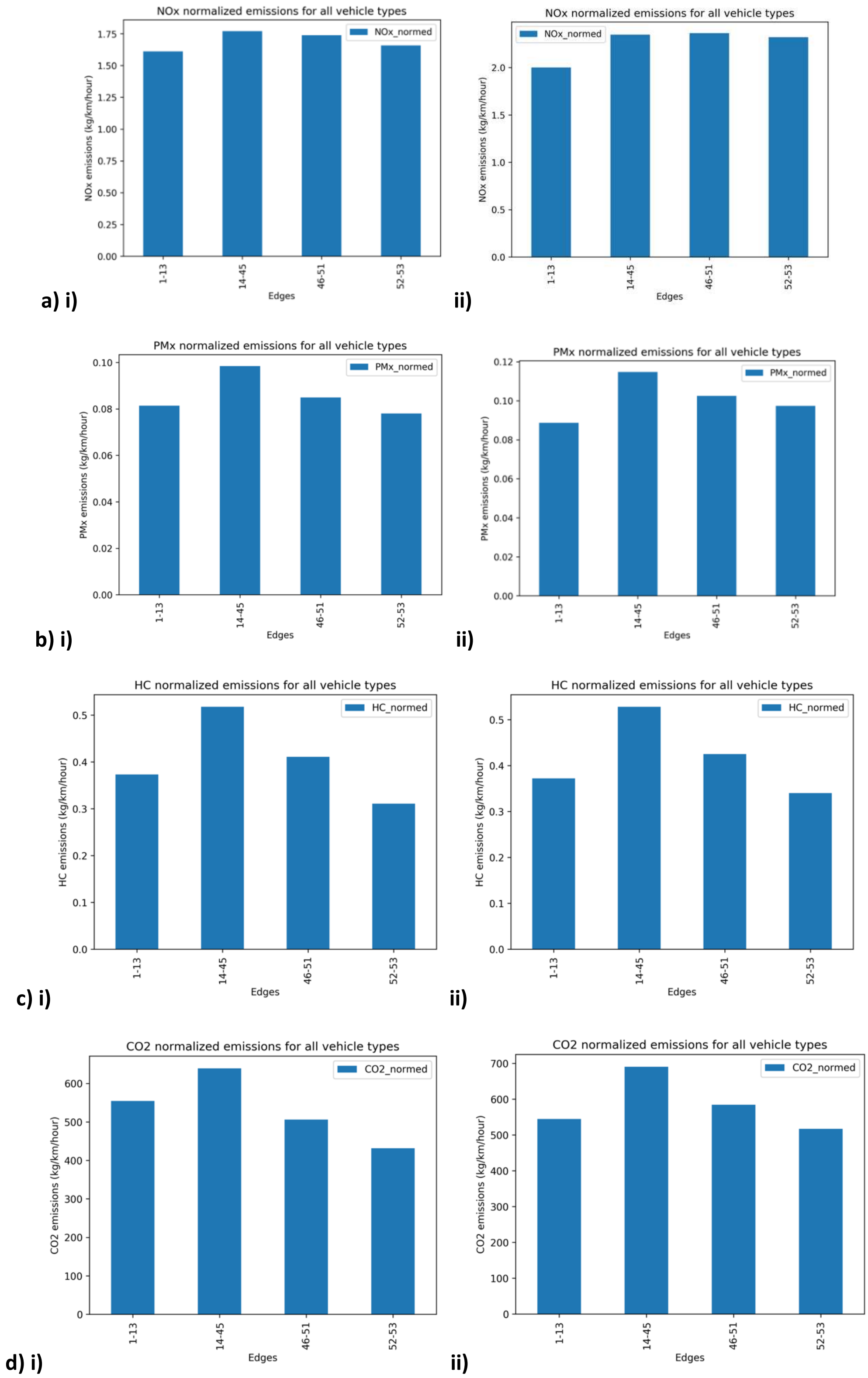
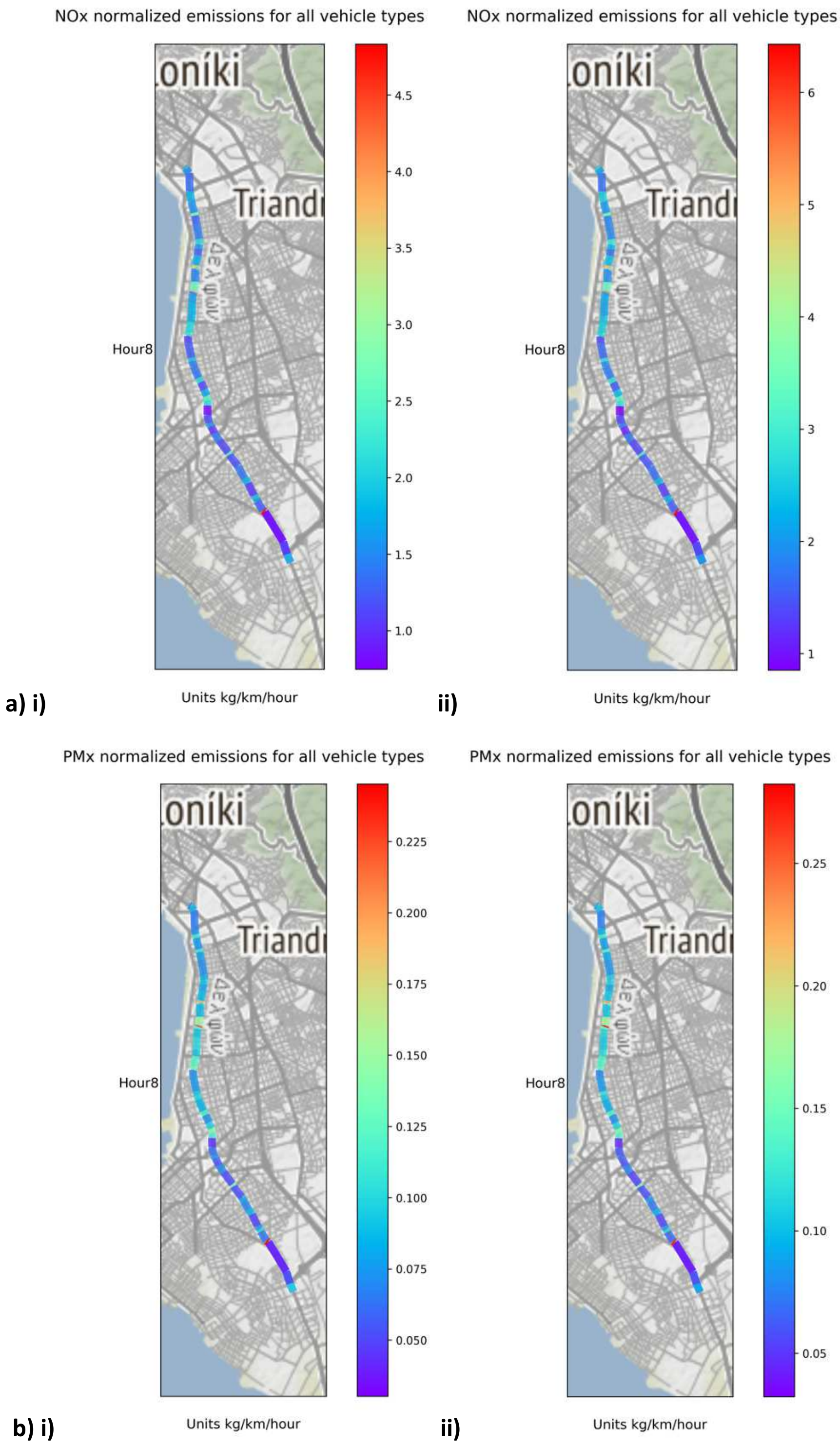
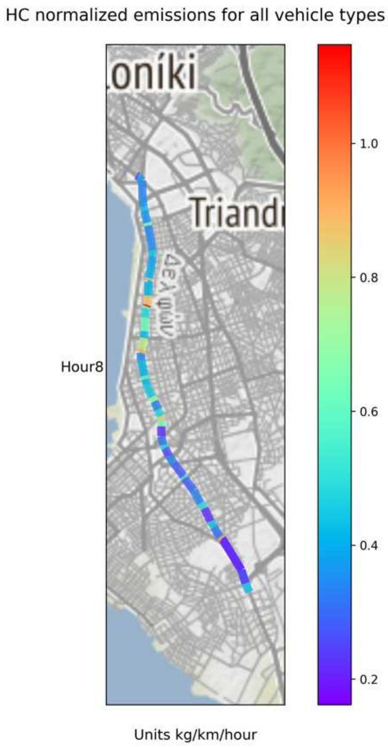



**Figure 2.3.8** Average normalised pollutant emissions in Ethnikis Antistaseos (edges 1-13), Vas. Olgas (edges 14-45), Vas. Georgiou (edges 46-51) and Man. Andronikou (edges 52-53): a) $NO_x$, b) PMx, c) HC and d) $CO_2$ (traffic peak hour 08:00-09:00) for i) SCN10 and ii) SCN20.

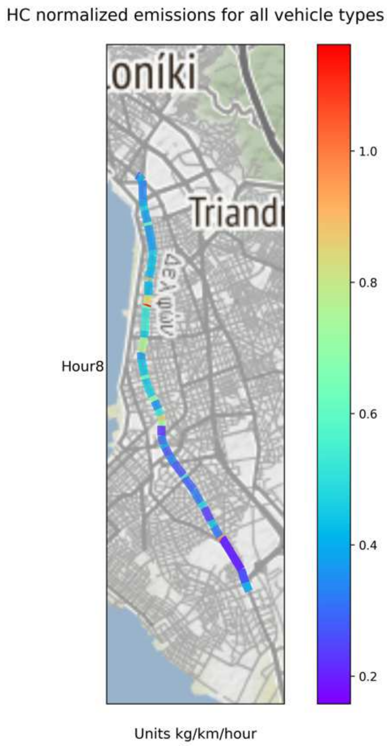
REMEDIO project is co-financed by the European Regional Development Fund

Figure 2.3.9 shows the spatial distribution of the normalized pollutant emissions and carbon footprint along the pilot axis of Thessaloniki for the traffic peak hour (08:00-09:00) for the traffic scenarios SCN10 and SCN20.

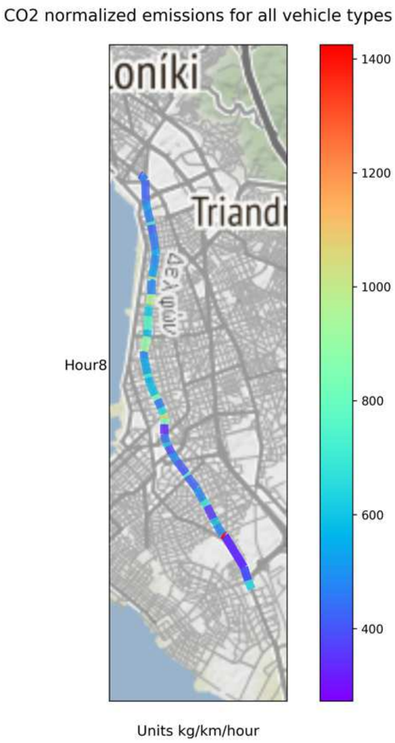




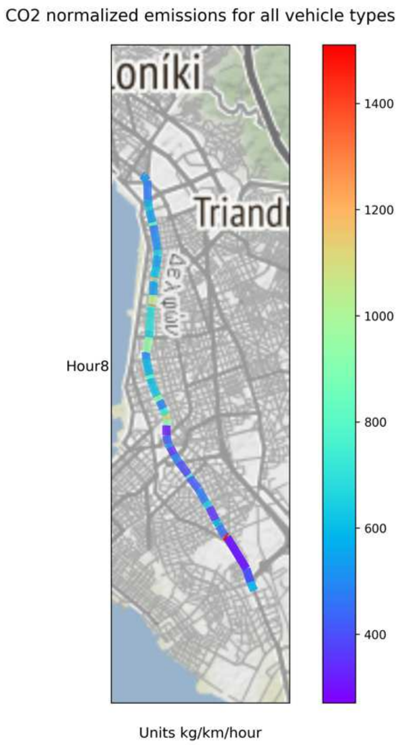

c) i)




ii)




d) i)




ii)

**Figure 2.3.9** Spatial distribution of the normalized pollutant emissions along the pilot axis of Thessaloniki for the traffic peak hour (08:00-09:00): a) $NO_x$, b) PMx, c) HC and d) $CO_2$ for i) SCN10 and ii) SCN20.

In Figure 2.3.10, the percentage differences in total hourly pollutant emissions and carbon footprint between the base case and traffic scenarios SCN10/SCN20 are presented for the pilot zone of Thessaloniki at traffic peak hour (08:00-09:00). More particularly, decreases in all pollutant base case emissions and carbon footprint have been estimated due to SCN10, ranging from -10% to approximately -20%. SCN20 results in smaller decreases in base case PMx, HC and CO2 emissions, comparing to SCN10, and in base case $NO_x$ emissions increase by around +14% due to the increase of buses flows. These results are indicative of the necessity for the use of “clean vehicles” for public transportation.

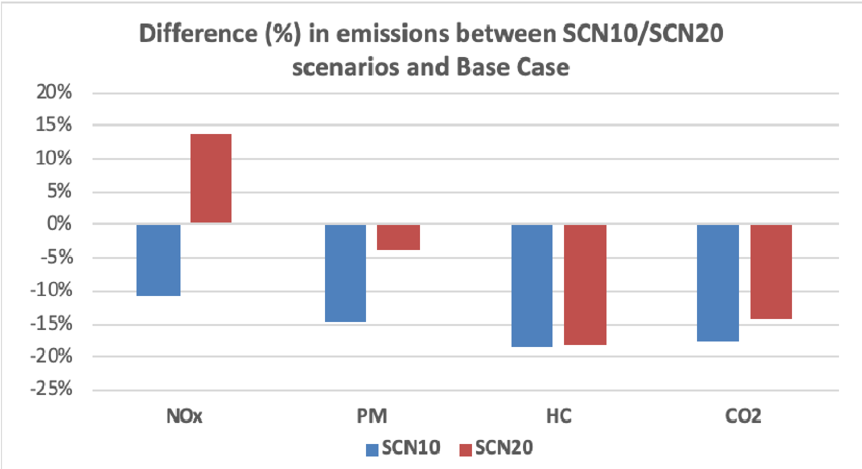



**Figure 2.3.10** Differences (%) in total hourly pollutant emissions, carbon footprint between the base case and traffic scenarios SCN10/SCN20 for the pilot zone of Thessaloniki at traffic peak hour (08:00-09:00).

In the following, the results of the SCN-freight as well as its comparison with the base case are presented. IMT was applied for the hour 10:00-11:00. Figure 2.3.11 shows the total and per vehicle type pollutant emissions and carbon footprint along the pilot zone of Thessaloniki for the SCN-freight. According to the base case, the delivery vehicles have a low share to the total pollutant emissions and carbon footprint (up to ~5%). Consequently, SCN-freight result in per vehicle type and total emissions that remain almost the same as those of the base case (Figure 2.3.11).

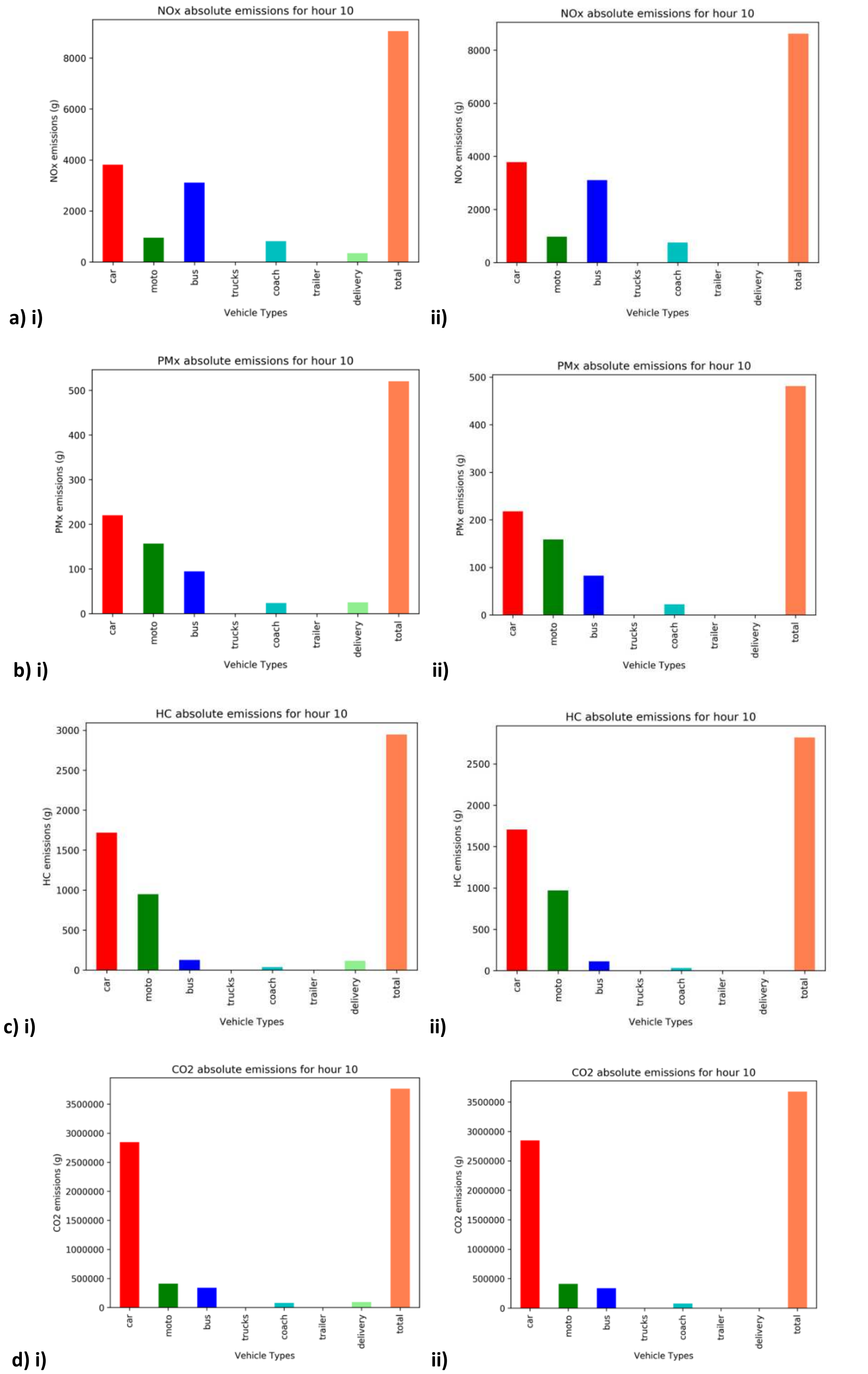



**Figure 2.3.11** Total and per vehicle type pollutant emissions along the pilot zone of Thessaloniki for the hour 10:00-11:00: a) CO, b) $NO_x$, c) PMx, d) HC and e) $CO_2$ for i) base case and ii) SCN-freight.

The average normalized hourly pollutant emissions along the four main streets of the pilot axis for the freight scenario are lower with respect to the base case (Figure 2.3.12), presenting a spatial pattern similar with the base case (not shown here).

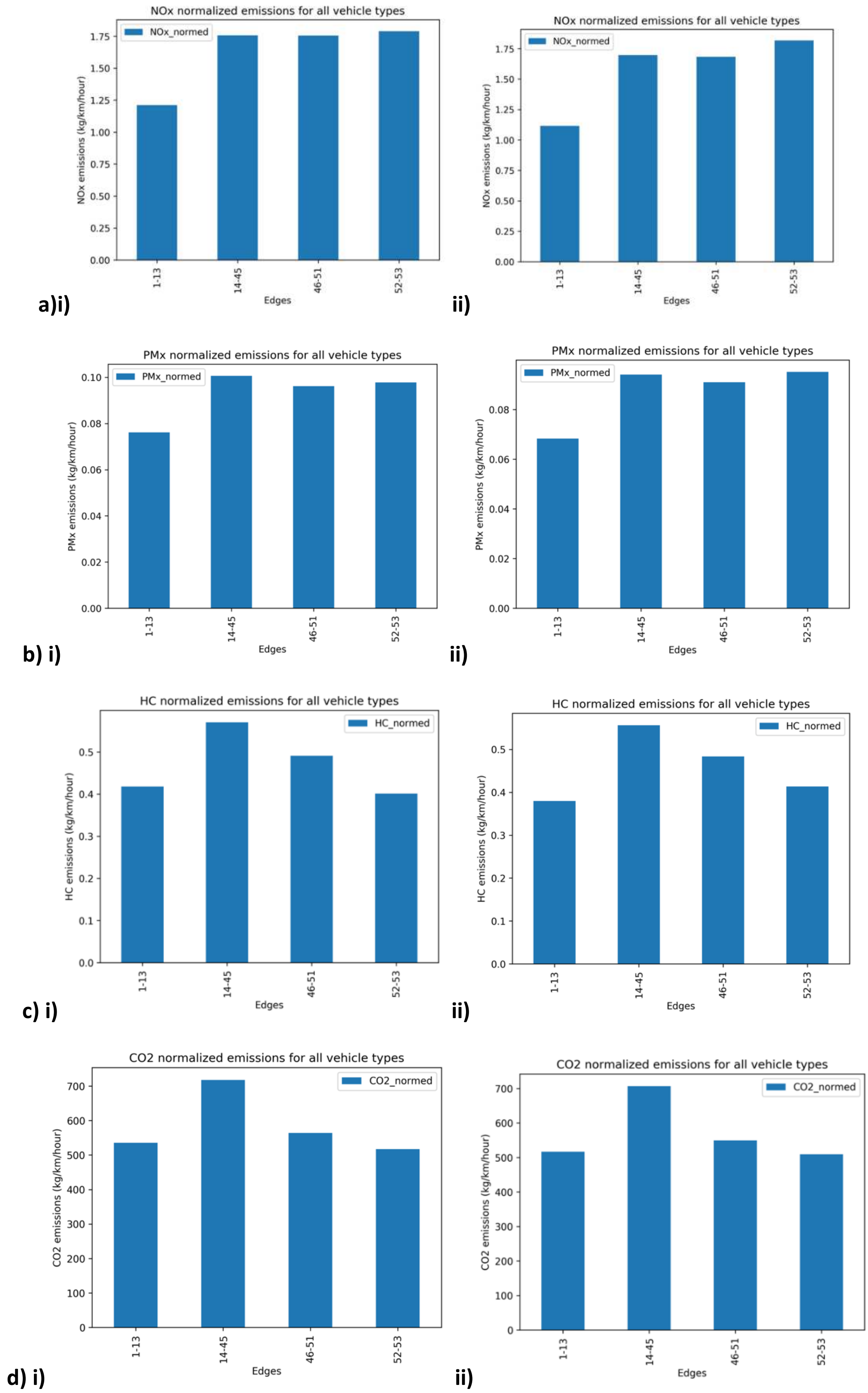



**Figure 2.3.12** Average normalized pollutant emissions in Ethnikis Antistaseos (edges 1-13), Vas. Olgas (edges 14-45), Vas. Georgiou (edges 46-51) and Man. Andronikou (edges 52-53): a) $NO_x$, b) PMx, c) HC and d) $CO_2$) (hour 10:00-11:00) for i) base case and ii) SCN-freight

In Figure 2.3.13, the percentage differences in total hourly pollutant emissions and carbon footprint between the base case and SCN-freight are presented for the pilot zone of Thessaloniki at hour 10:00-11:00. The SCN-freight results in small reductions in all pollutant base case emissions and carbon footprint. The highest reduction is estimated for PMx (-7.5%) followed by NOx (-4.8%), HC (-4.3%) and CO2 (-2.4%) (Figure2.3.13).

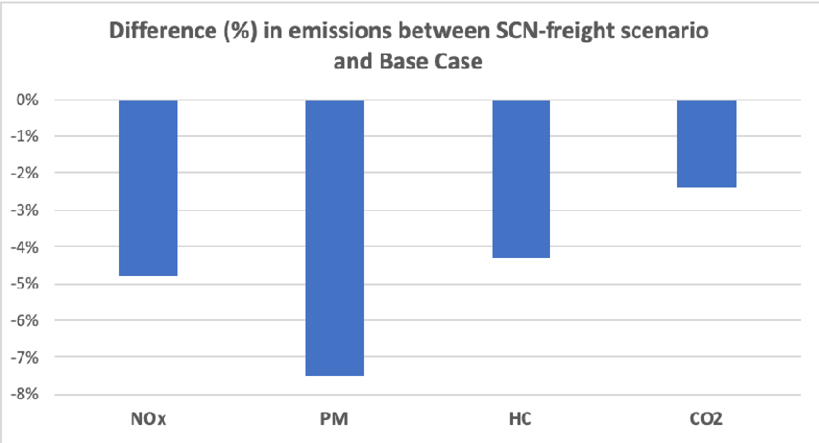



**Figure 2.3.13** Differences (%) in total hourly pollutant emissions and carbon footprint between the base case and SCN-freight for the pilot zone of Thessaloniki at hour 10:00-11:00.

### 2.3.4 Air pollution dispersion

The dispersion module was applied accounting for the traffic related emissions for the first LCMS with associated mobility scenarios the SCN10 and SCN20. The module was applied the hour 08:00-09:00 for a part of the Thessaloniki pilot axis comprised of 4 nodes (36-39) and therefore 3 edges (36-38) similarly to the base case (see Deliverable 3.4.1). The road part is located at Vasilissis Olgas Street and was selected for the IMT dispersion module simulations since it presented the highest traffic flows and PMx and NOx normalized emissions (more specifically at edge 36). Figure 2.3.14 depicts the NOx and PMx concentrations for SCN10 and SCN20.

In both scenarios, the highest concentrations are presented in edge 36, similarly to the base case scenario. For SCN10, the highest NOx and PMx concentration levels show a reduction of -9% and -12%, respectively, compared to the base case scenario. The corresponding reductions of NOx and PMx emissions in edge 36 are -6% and -17% respectively.

For SCN20, the highest NOx and PMx concentration levels increase by around +23% and +9%, respectively, compared to the base case scenario. The corresponding increases of NOx and PMx emissions in edge 36 are +34% and +3.5% respectively.

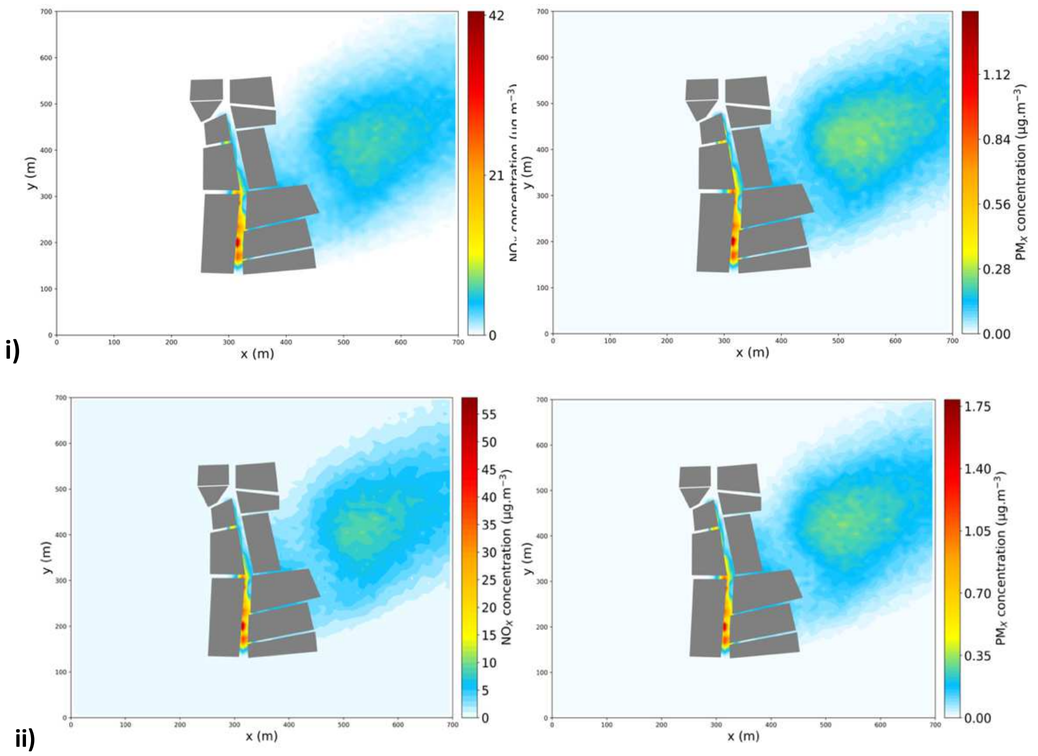



**Figure 2.3.14** Traffic related concentrations of NOx (left) and PMx (right) for the traffic peak hour (08:00-09:00) for i) SCN10 and ii) SCN20.

The dispersion module was also applied accounting for traffic related emissions of the second LCMS (associated mobility scenario is the SCN- freight). The module was applied the hour 10:00-11:00 for the road edges 36-38 of the Thessaloniki pilot axis. In hour 10:00, the highest PMx and NOx normalized emissions are presented in edge 37. Figure 2.3.15 depicts the spatial distribution of NOx and PMx concentrations for both the base case and SCN- freight the hour 10:00-11:00.

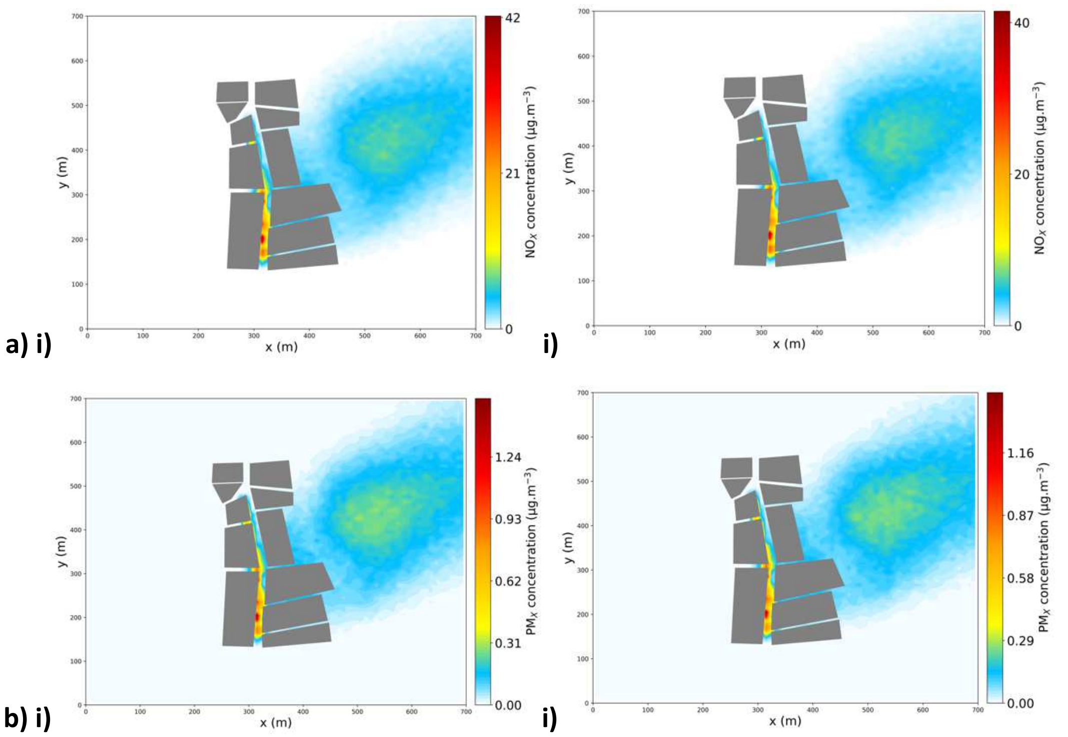



**Figure 2.3.15** Traffic related concentrations of a) NOx and b) PMx for the hour 10:00-11:00 for i) base case and ii) SCN-freight.

The highest NOx and PMx concentrations levels are reduced by around -2% and -6%, respectively, compared to base case scenario. The corresponding reductions of the highest NOx and PMx normalized emissions in edge 37 are -3% and -8%, respectively.

### 2.3.5 Health and Costs

The health and costs module was applied taking into account the daily concentrations of PM10, PM2.5 and $NO_2$ as well as daily meteorological data (i.e. air pressure, temperature) the period 19 - 30 September 2017. The data were based on measurements from a monitoring station located along the pilot axis (at the City Hall of Thessaloniki, Vas. Georgiou 1 Street) and operated by the City of Thessaloniki (Directorate of Urban Environment Management, Department of Environmental Actions) and on simulation results from the application of the meteorological model Weather Research and Forecasting model (WRF) and the photochemical model Comprehensive Air Quality Model with Extensions (CAMx).

A -10% reduction in daily concentrations of PM10, PM2.5 and $NO_2$ was assumed as a result of mobility measures/solutions to reduce traffic congestion and promote sustainable urban mobility. The presented IMT results take into account the "daily cumulative estimation" scenario, which considers that every day was affected by the previous one. The results from the application of the health and costs module indicate the following reductions of the health outcomes (hospitalizations and deaths) and the cost outcomes (hospitalizations) with respect to the base case:

For the health outcomes:

- -0.3% reduction (median value) in cardiac hospitalizations and in cardiac deaths,

- -0.5% and -1.5% reductions (median values) in respiratory hospitalizations and in respiratory deaths respectively.

For the health related cost outcomes:

- -0.4% and -0.5% reductions (median values) in cardiac hospitalizations and in respiratory hospitalizations respectively.

These results should be considered with cautiousness given the quite wide confidence intervals for some of the health outcomes and the generally high uncertainties in the estimation of the impacts that the environment and the environmental measures may have on human health.

## 2.4 Treviso

Two contrasting scenarios were analyzed by means of the IMT application along the axis road under study, namely the West Road in Treviso.

The baseline scenario (the actual state of the road) is characterised by the main following features:

- a two-ways road of 5,5 km length,
- 2 bus lines with 8 stops,
- 6 traffic lights,
- 1 roundabout,
- an average traffic load of about 24,000 vehicles/day as measured by the monitoring campaign deployed from 17 October 2017 to 15 November 2017, at a specific spot along the West Road considered enough representative of at least some part of the axis road (long=12.2410998, lat= 45.6805365, EPSG: 4326).

In Figure 2.4.1 is depicted the hourly variation of traffic modal split for the average day of the monitoring campaign from 17th October to 15th November 2017.

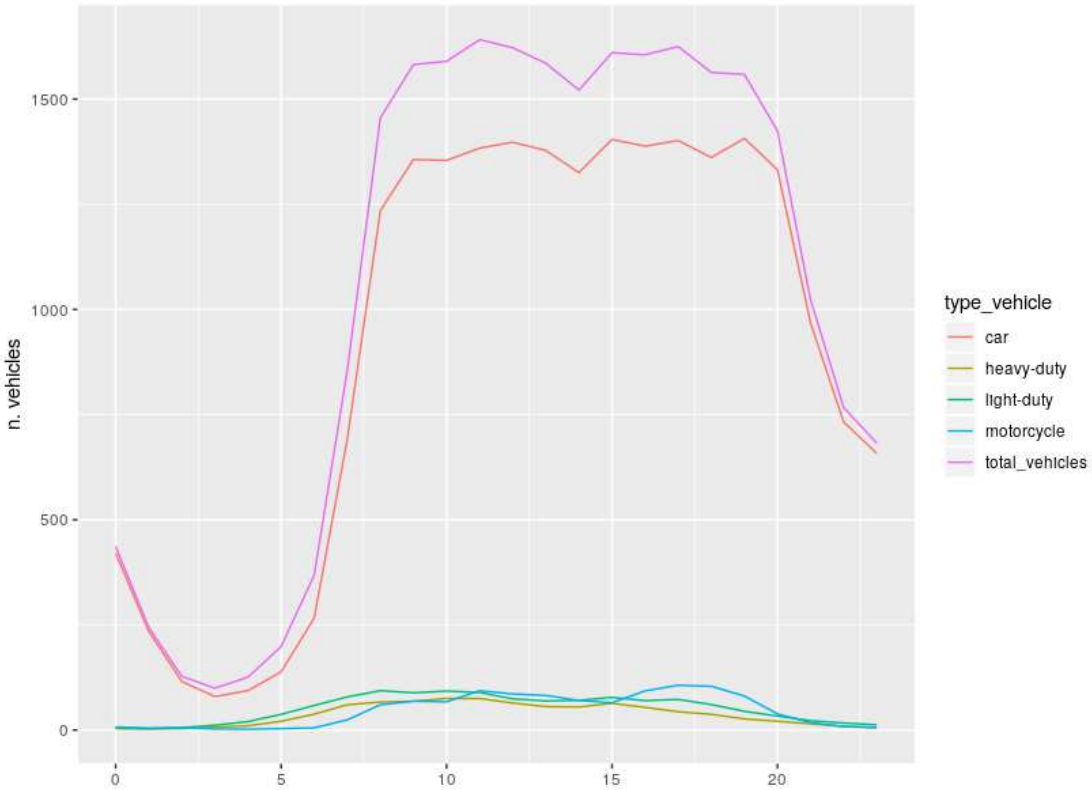



**Figure 2.4.1** Modal split of traffic flows along the monitoring site (long=12.2410998, lat= 45.6805365, EPSG: 4326 ) in the West Road during the campaign from 17th October to 15th November 2017.

More details about the description of the pilot axis road and the baseline traffic scenario can be found in Deliverable 3.4.1.

Given the above mentioned 'state of the art' of the road under study, the roundabout scenario (a benchmark alternative) was foreseen by leaving all baseline features 'as is' except for the replacement of the 6 traffic lights with some roundabouts. The aim was the evaluation of the corresponding effects in terms of possible pollution reductions.

All IMT modules were applied for the traffic peak hour (10:00-11:00). In the following sections, a comparison of the IMT results for the two contrasting traffic scenarios ('baseline' vs. 'roundabout') are presented for each evaluation module (energy, noise, emissions and concentrations of atmospheric pollutants, health and costs).

Where possible the comparison of environmental effects was performed by means of the estimation of the absolute Difference (Diff) and/or percentage Difference (Diff (%)) between the two scenarios.

### 2.4.1 Energy

Figure 2.4.2 shows the hourly fuel consumption per vehicle type for the two contrasting scenarios: 'baseline' (on the left) vs. 'roundabout' (on the right).

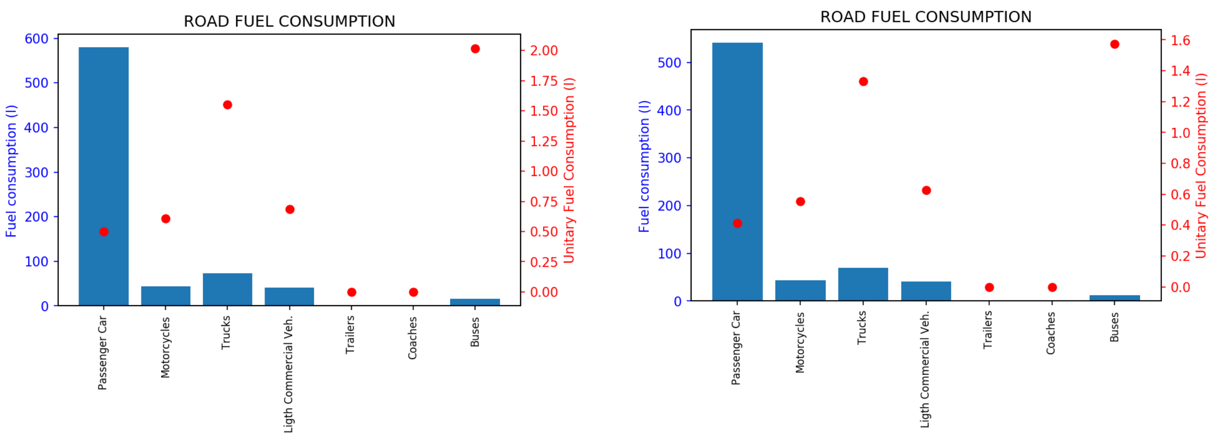



**Figure 2.4.2** Road fuel consumption by vehicle categories for the peak traffic hour (11 am) at the West Road: the 'baseline scenario' (on the left) vs. the 'roundabout scenario' (on the right).

For both scenarios, passenger cars were the type of vehicles characterized by the largest fuel consumption. Hourly total fuel consumption was reduced by less than 5% in the 'roundabout' scenario compared to the 'baseline'.

### 2.4.2 Noise

Figure 2.4.3 shows the total and per vehicle type noise emissions along the different edges (sections) of the West road for the two contrasting scenarios: 'baseline' vs. 'roundabout'.

Some sections of the roads (edges) experienced an increase of noise emissions in the 'roundabout' scenario because of the benchmark removal of the 6 traffic lights and the corresponding increase of average traffic speed.

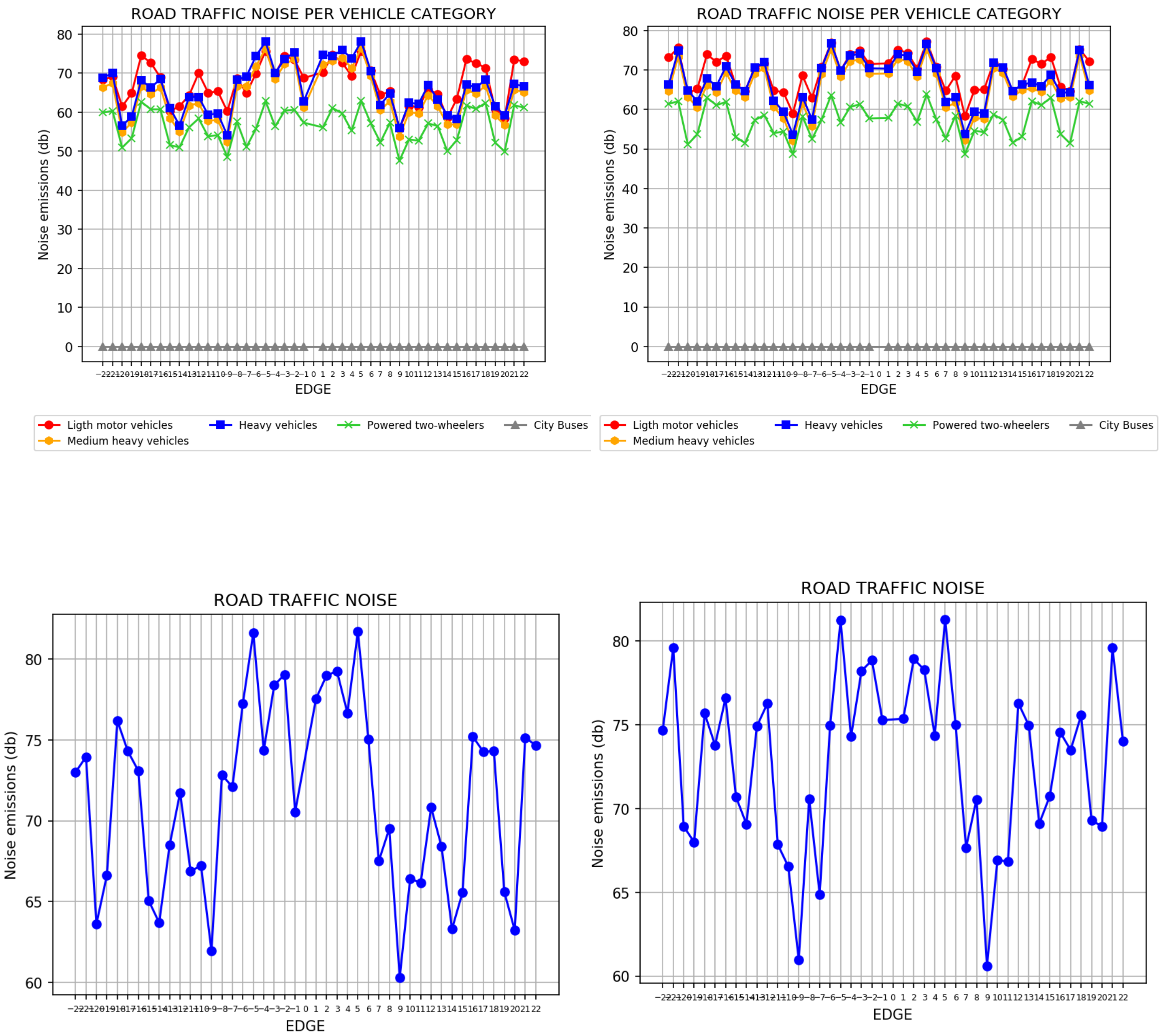



**Figure 2.4.3** Noise emissions for each section (edge) of the West Road in the peak traffic hour (11 am): the ‘baseline scenario’ (on the left) vs. the ‘roundabout scenario’ (on the right)**.**

## 2.4.3 Atmospheric pollution emissions - Carbon footprint

The atmospheric pollutant emissions and carbon footprint (i.e. $CO_2$ emissions) module was applied in the peak traffic hour (11 am) for both the ‘baseline’ and the ‘roundabout’ scenarios.

From Figure 2.4.4 to Figure 2.4.8, the total and per vehicle type hourly carbon footprint ($CO_2$) and pollutant emissions (CO, HC, $NO_x$, $PM_x$) are depicted respectively.

The comparison of the results from the two contrasting scenarios showed a substantial reduction for the ‘roundabout’ case: namely, about 10% of total emissions for $CO_2$, CO, $PM_x$, about 20% of $NO_x$ total emission, and up to 30% for HC total emissions.

REMEDIO project is co-financed by the European Regional Development Fund

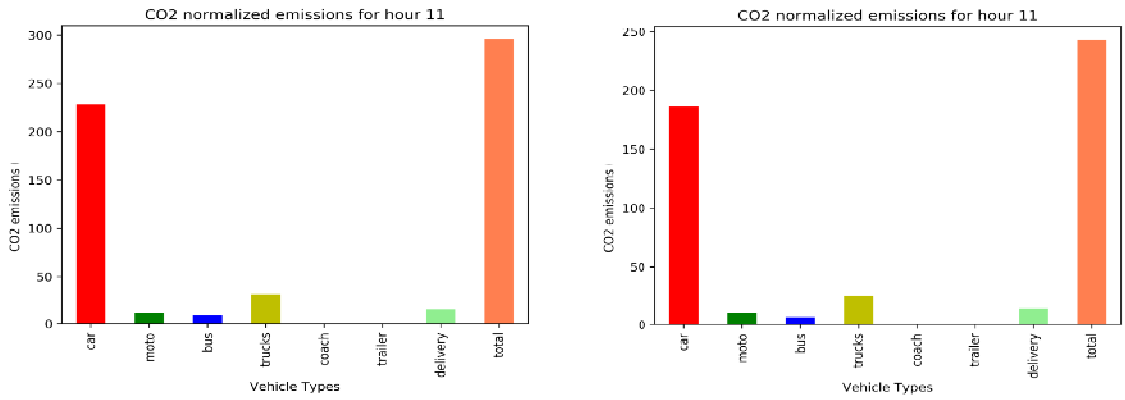



**Figure 2.4.4** CO2 emissions (kg/km/hour) by vehicle categories for the peak traffic hour (11 am) at the West Road: the 'baseline scenario' (on the left) vs. the 'roundabout scenario' (on the right).

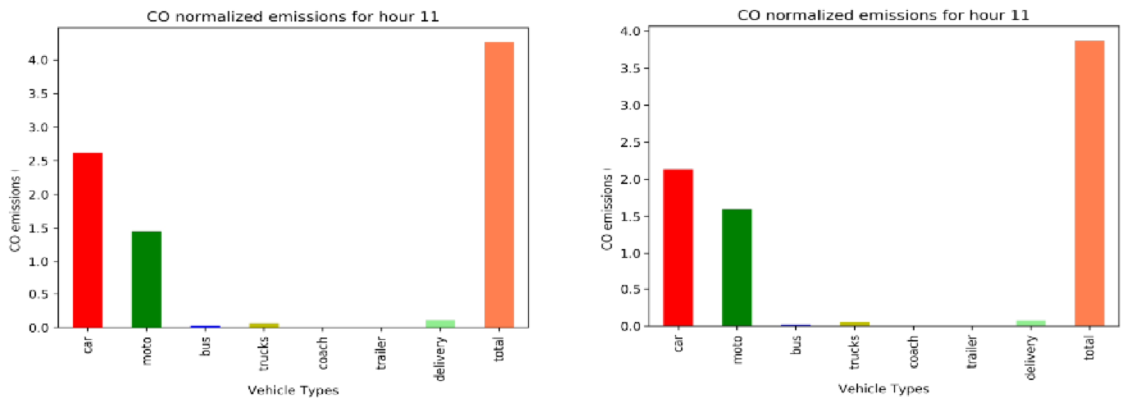



**Figure 2.4.5** CO emissions (kg/km/hour) by vehicle categories for the peak traffic hour (11 am) at the West Road: the 'baseline scenario' (on the left) vs. the 'roundabout scenario' (on the right).

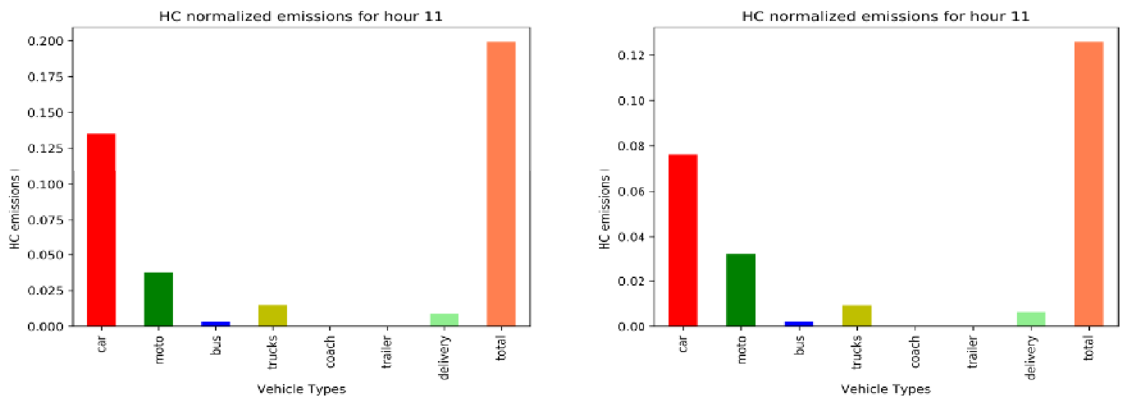



**Figure 2.4.6** HC emissions (kg/km/hour) by vehicle categories for the peak traffic hour (11 am) at the West Road: the 'baseline scenario' (on the left) vs. the 'roundabout scenario' (on the right).

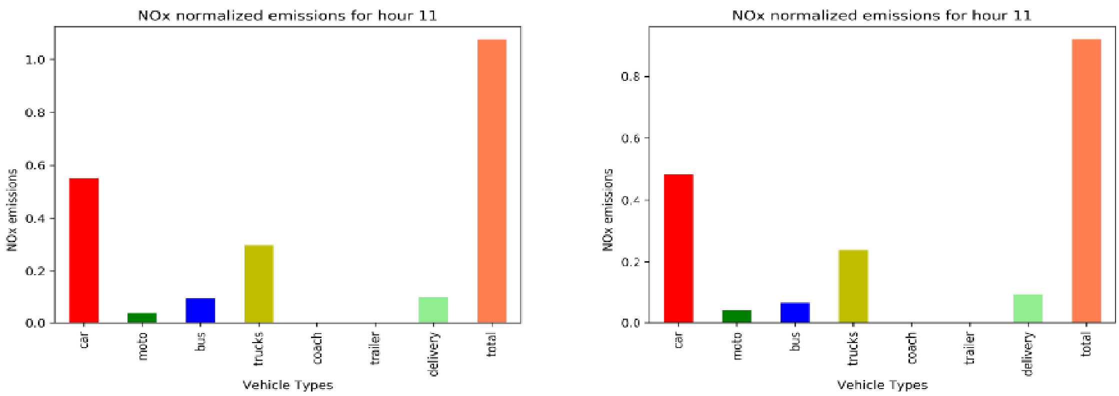



**Figure 2.4.7** NOx emissions (kg/km/hour) by vehicle categories for the peak traffic hour (11 am) at the West Road: the 'baseline scenario' (on the left) vs. the 'roundabout scenario' (on the right).

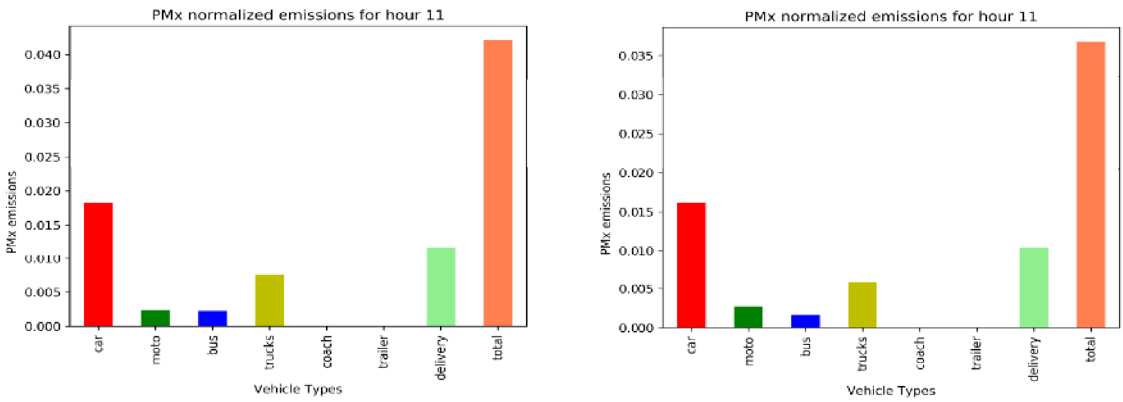



**Figure 2.4.8** PMx emissions (kg/km/hour) by vehicle categories for the peak traffic hour (11 am) at the West Road: the 'baseline scenario' (on the left) vs. the 'roundabout scenario' (on the right).

From Figure 2.4.9 to Figure 2.4.12, the very same pollutants are rendered in form of maps by highlighting the spatial distribution of emissions along the different sections (edges) of the road axis under study. By spatial comparing the two emission scenarios under study a clear reduction was evident in the pollutant emissions located in correspondence to the edges (sections) where the traffic light were substituted by the roundabouts.

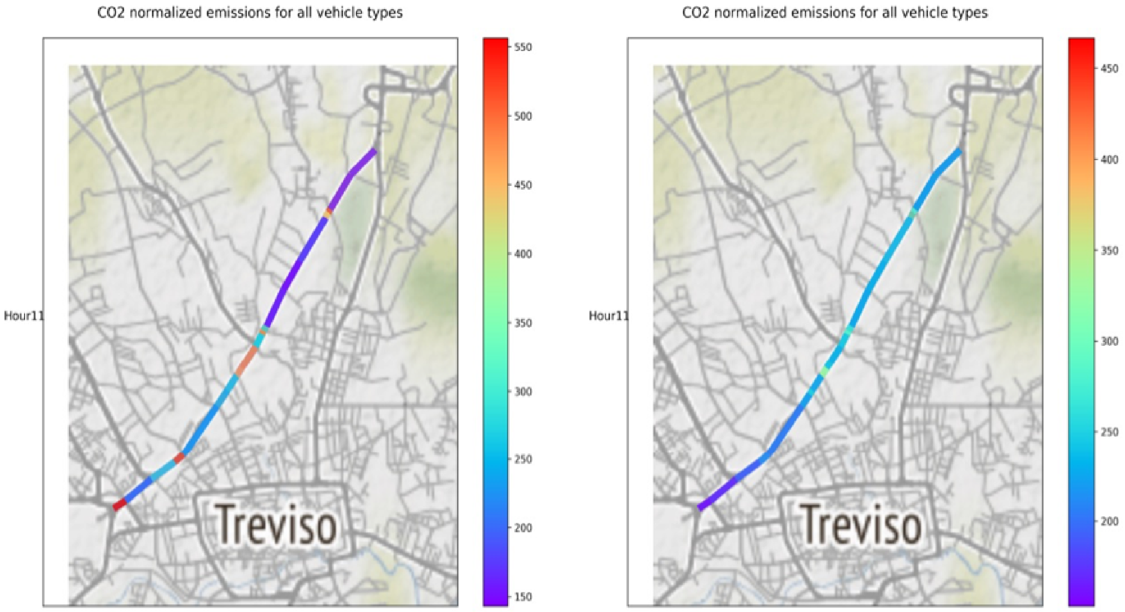



**Figure 2.4.9** Spatial rendering of CO2 emissions (kg/km/hour) for the peak traffic hour (11 am) along the West Road for the 'baseline scenario' (on the left) vs. the 'roundabout scenario' (on the right).

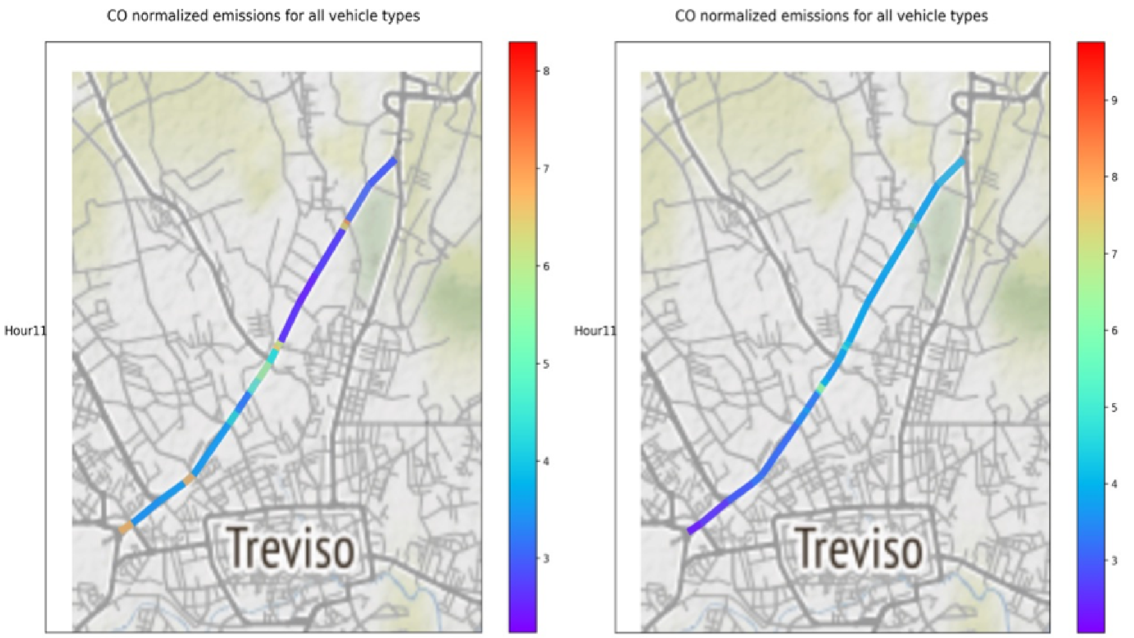



**Figure 2.4.10** Spatial rendering of CO emissions (kg/km/hour) for the peak traffic hour (11 am) along the West Road for the 'baseline scenario' (on the left) vs. the 'roundabout scenario' (on the right).

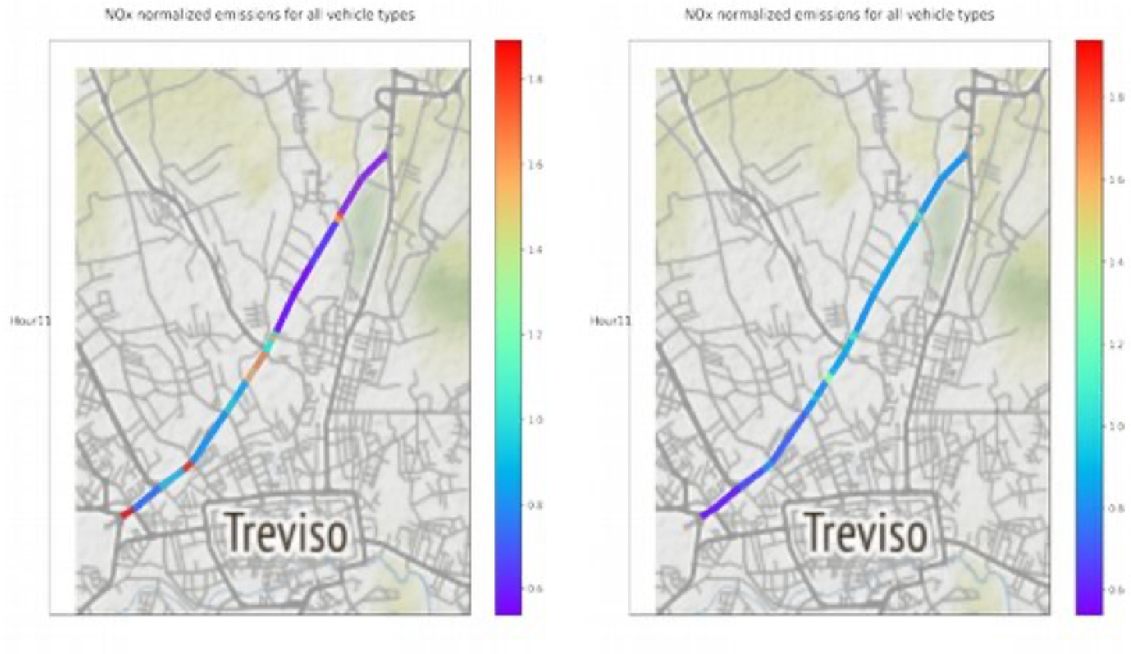



**Figure 2.4.11** Spatial rendering of NOx emissions (kg/km/hour) for the peak traffic hour (11 am) along the West Road for the 'baseline scenario' (on the left) vs. the 'roundabout scenario' (on the right).

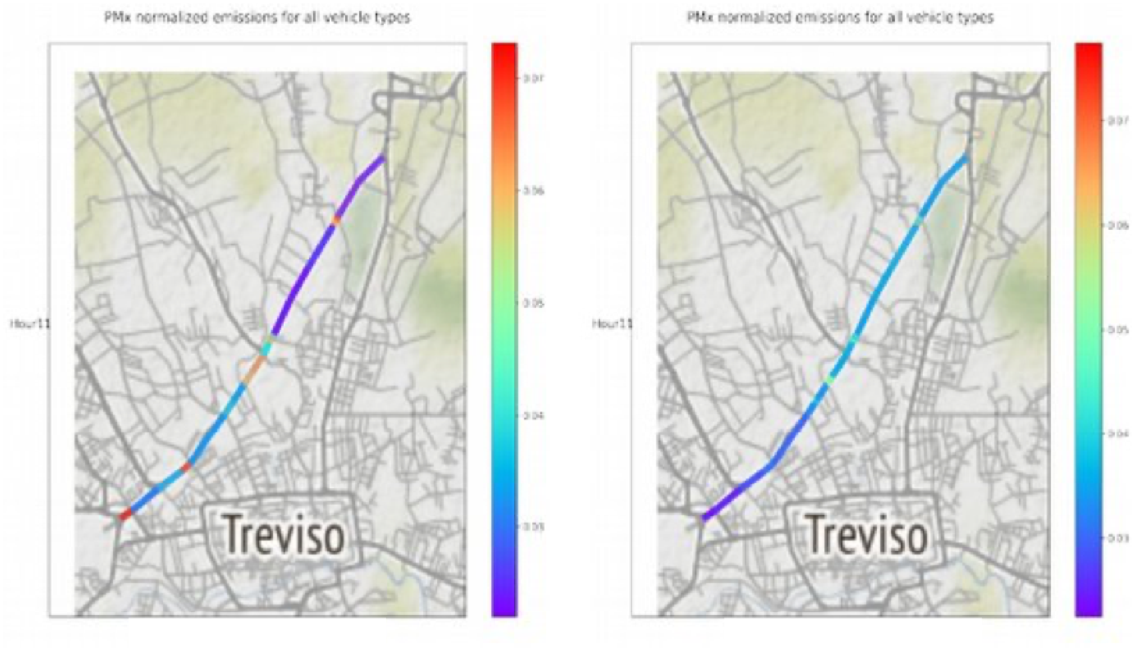



**Figure 2.4.12** Spatial rendering of PMx emissions (kg/km/hour) for the peak traffic hour (11 am) along the West Road for the 'baseline scenario' (on the left) vs. the 'roundabout scenario' (on the right).

### 2.4.4 Air pollution dispersion

Maps showing the pollutant concentrations of CO, HC, NOx, PMx estimated by the dispersion module along the West Road are presented for both the 'baseline' and the 'roundabout' scenario (from Figure 2.4.13 to 2.4.16).

Again, as for the spatial distribution of emissions, the benchmark implementation of the roundabouts, in substitution of existing the traffic lights at the main crossroads, showed the elimination of the typical hot spot concentrations for all pollutants (left side on the pictures) and consequently a dilution along the road (attention must be paid to the different scales of the figures).

The implementation of the 'roundabout' scenario showed a reduction in the maximum concentration of pollutants equal to 33% for CO, 17% for PMx, 8% for NOx, and 57% for HC. To be noted that these reductions are referred to a single computational cell where the maximum of domain occurred.

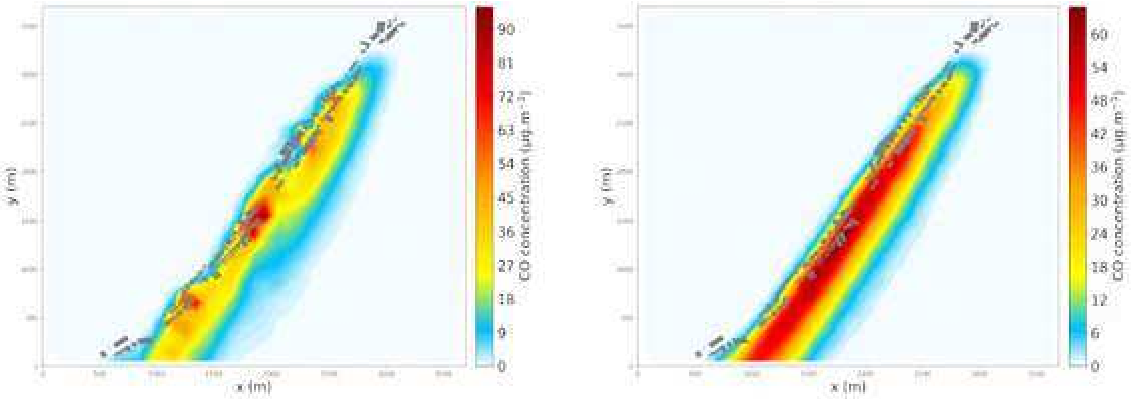



**Figure 2.4.13** Map of CO concentrations (ug/m3) estimated by the dispersion module for the peak traffic hour (11 am) along the West Road for the 'baseline scenario' (on the left) vs. the 'roundabout scenario' (on the right).

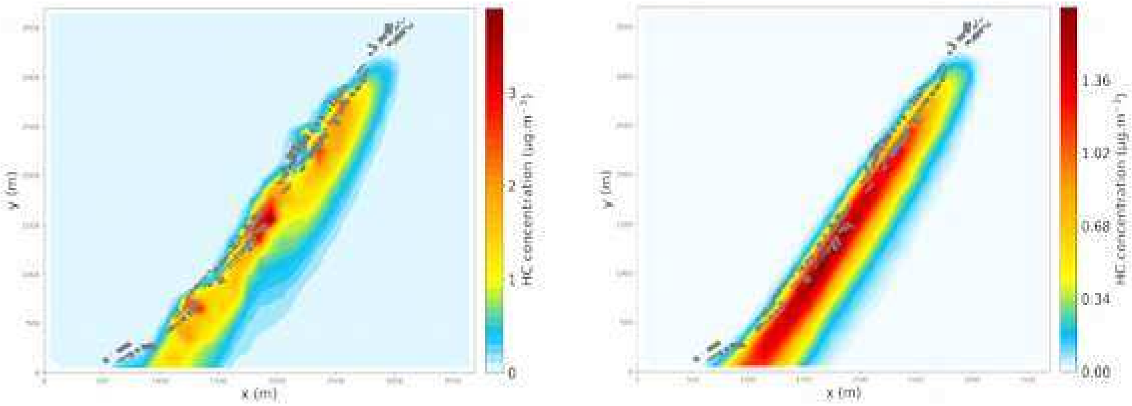



**Figure 2.4.14** Map of HC concentrations (ug/m3) estimated by the dispersion module for the peak traffic hour (11 am) along the West Road for the 'baseline scenario' (on the left) vs. the 'roundabout scenario' (on the right).

REMEDIO project is co-financed by the European Regional Development Fund

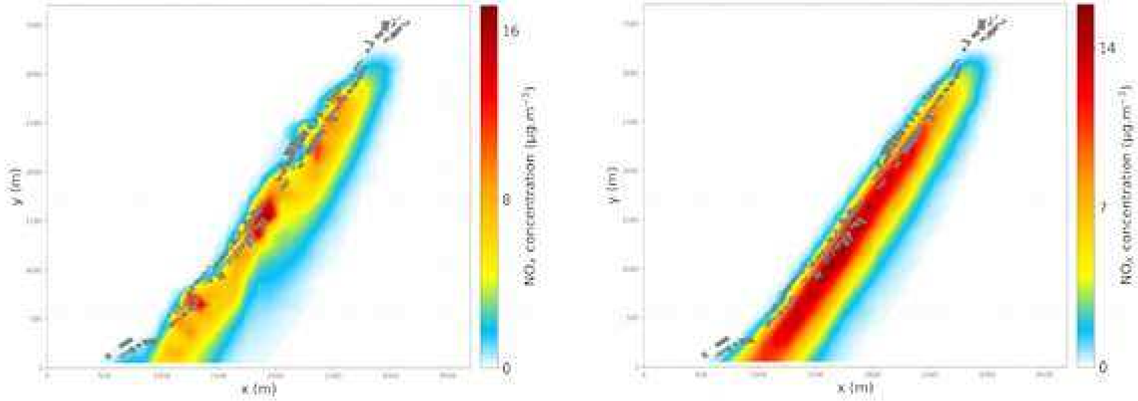



**Figure 2.4.15** Map of NOx concentrations (ug/m3) estimated by the dispersion module for the peak traffic hour (11 am) along the West Road for the 'baseline scenario' (on the left) vs. the 'roundabout scenario' (on the right).

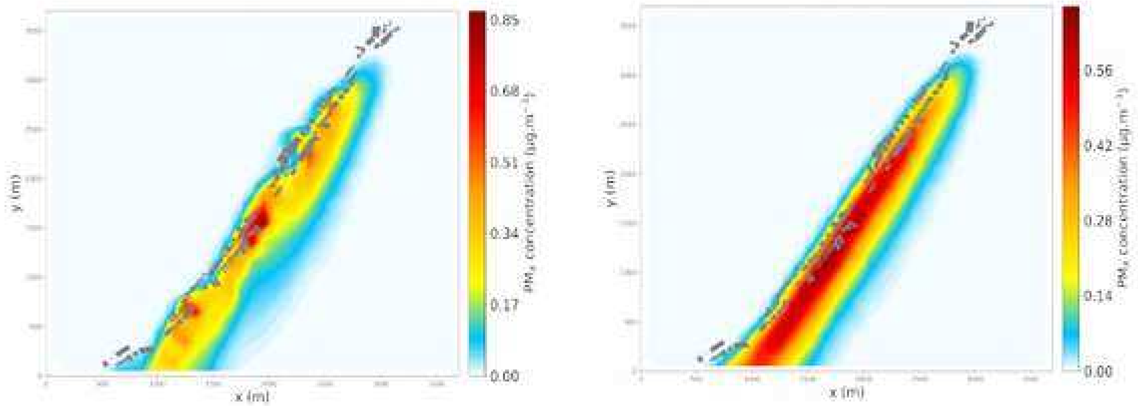



**Figure 2.4.16** Map of PMx concentrations (ug/m3) estimated by the dispersion module for the peak traffic hour (11 am) along the West Road for the 'baseline scenario' (on the left) vs. the 'roundabout scenario' (on the right).

### 2.4.5 Health and costs

The aim of the IMT health and costs module is to provide estimations of the mean expected number of some health outcomes (deaths and hospitalizations for specific and all causes) and the corresponding expenditures (costs). Therefore, the module can be used for the assessment of the impacts that some environmental interventions (mitigation measures) can have in term of health events and related costs. The health outcomes (daily number) estimated by the module are deaths for cardiac, respiratory, cerebrovascular causes only and deaths for any causes, along with hospitalizations for cardiac, respiratory and cerebrovascular causes only.

Through the IMT health and costs module applied for the Treviso case study, we tested what happened in terms of the health outcomes and related costs by imagining to reduce of a flat 10% daily concentrations of NO2, PM10, PM2.5 for the whole study period in which the ambient air concentrations were monitored by mean of a monitoring station deployed along the West Road.

The health outcomes estimated for the Treviso case study are always expressed in relative terms (i.e. not absolute numbers of deaths or hospitalizations) with reference to the 'baseline' scenario. To be noted here that the 'daily baseline' scenario was defined in relation to the effective air ambient levels of some specific pollutants (PM2.5, PM10, NO2) monitored from 23rd October to 13th November 2017 by the air quality station deployed along the West Road (long=12.2410998, lat= 45.6805365, EPSG: 4326). Consequently, the reduction scenario (hereafter called 'daily cumulative') was defined on the benchmark assumption of a flat 10% reduction of daily PM2.5, PM10, NO2 concentrations applied for the whole period under study (4 weeks).

Figure 2.4.17 shows the boxplot of the reduction ratio (daily baseline over daily cumulative) of the health outcomes (hospitalizations and deaths) estimated as an aftermath of the reduction of pollutant concentration by a flat 10% on a daily basis. To be noted about 0.5% reduction in the median of hospitalization for respiratory causes, about 1.7% reduction in the median of mortality from all causes, and about 1.7% reduction in the median of mortality for respiratory causes. It must be clearly stressed once again that the variation of health outcomes (reduction in hospitalization and deaths) was presented as a ratio (daily baseline over daily cumulative) and not in absolute number of cases because the module was trained with default data not directly referring to the population living in the area under study (the West Road).

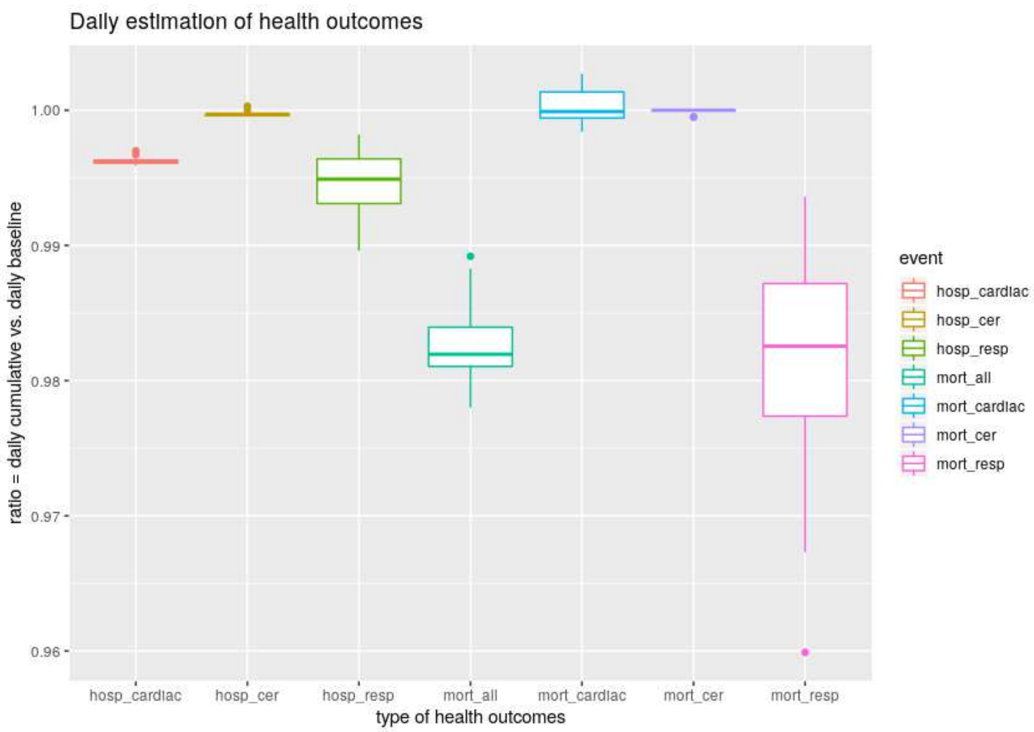



**Figure 2.4.17** Boxplot of hospitalization and deaths for different causes estimated as a consequence of a flat 10% reduction in the ambient air concentration of pollutants for the period under study.

In Figure 2.4.18 and Figure 2.4.19 are presented the time evolution of the ratio of health outcomes (hospitalizations and deaths) for the period under study (4 weeks in the period Oct-Nov 2017). To be noted that the day considered in terms of health outcomes matters (i.e. not all the days were the same). In fact, from the previous charts clearly results how the amount of variability for the health outcomes was depending also by the specific day being considered in the simulation.

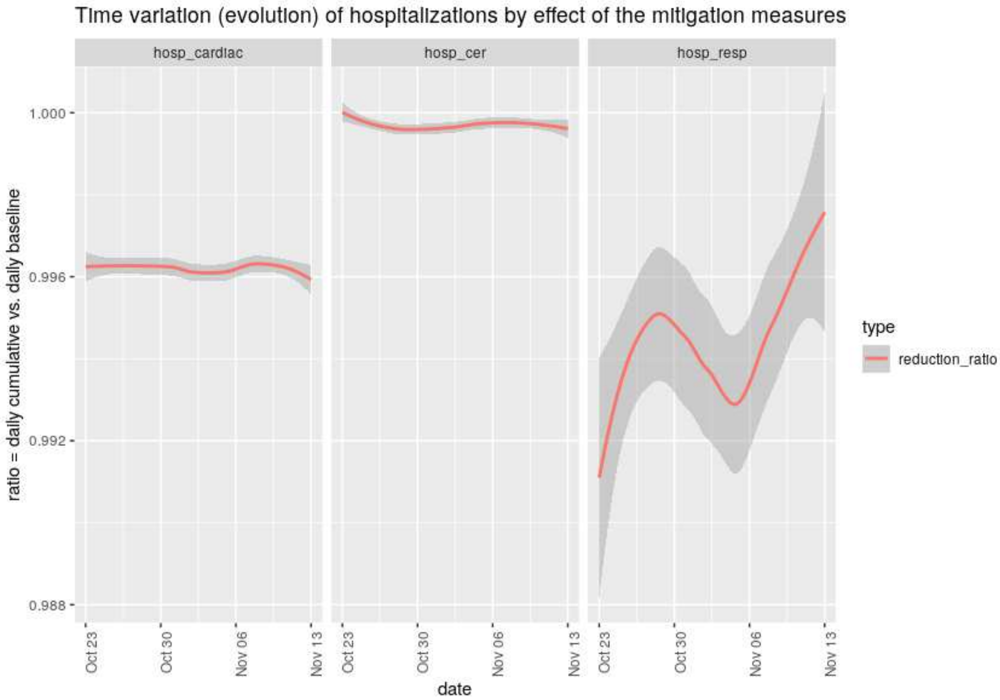



**Figure 2.4.18** Time evolution of hospitalizations by cause estimated in relation of a 10% reduction of atmospheric pollutant concentrations compared to the actual ambient levels monitored in the 4 weeks period from October to November 2017.

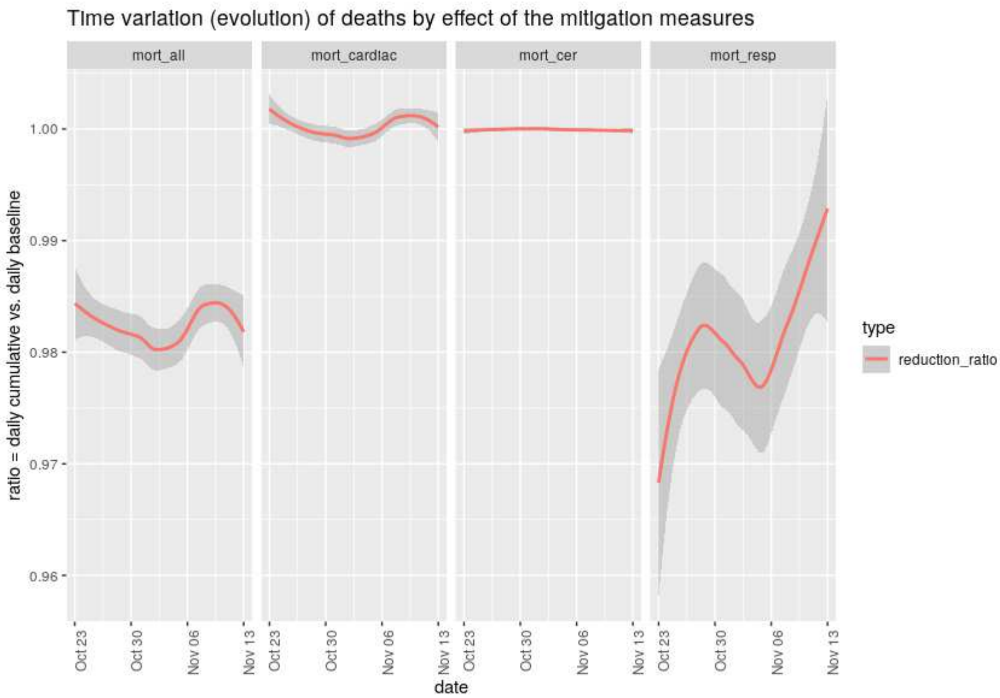



**Figure 2.4.19** Time evolution of deaths by cause estimated in relation of a 10% reduction of atmospheric pollutant concentrations compared to the actual ambient levels monitored in the 4 weeks period from October to November 2017.

**REMEDIO project is co-financed by the European Regional Development Fund**

REMEDIO project is co-financed by the European Regional Development Fund

Default unitary costs were used for the simulation of the West Road. Default costs correspond to that associated with stroke occurrences and congenital heart diseases for cardiac events and to chronic obstructive pulmonary diseases for respiratory events provided by the Medical Expenditure Panel Survey (MEPS) of the U.S. Agency for Healthcare Research and Quality costs.

As shown in Figure 2.4.20, a reduction in the median of the hospitalization costs of about 0.05% for respiratory causes and less than 0.04% for cardiac causes were estimated for the present case study.

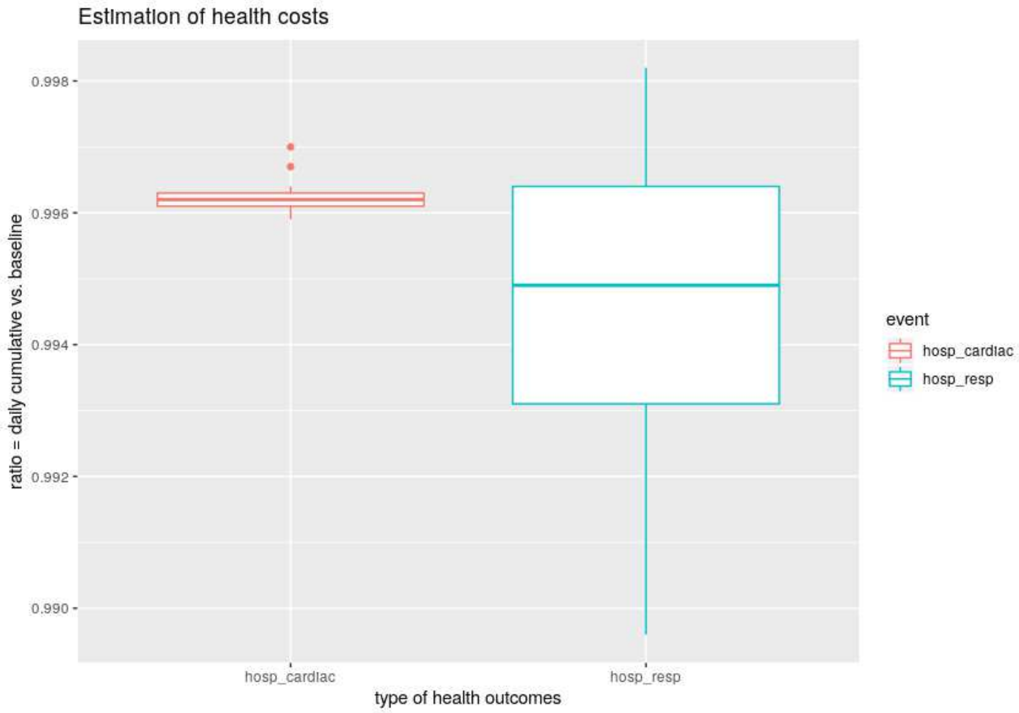



**Figure 2.4.20** Boxplot of costs for the health events estimated as a consequence of a flat 10% reduction in the ambient air concentration of pollutants for the period under study.

REMEDIO project is co-financed by the European Regional Development Fund

# 3 Environmental Benefits of Low Carbon Mobility Solutions

Significant are the environmental improvements at street level induced by the low carbon mobility solutions implemented or planned in the pilot areas of REMEDIO project. The environmental benefits are associated with:

- Promotion and infrastructures for soft mobility (i.e. cycling),
- Infrastructures for improved walkability and high quality of living (e.g. renewal and redesign of road axis),
- Improved traffic conditions (e.g. replacement of traffic lights with roundabouts),
- Promotion of public transportation to reduce the use of private cars,
- Use of clean vehicles for public transportation,
- Improved material and constructions to reduce traffic noise.

The maximum levels of environmental improvements assessed at street level as a result of the low carbon mobility solutions to reduce traffic congestion studied within REMEDIO are summarized below:

- ✓ Reductions in fuel consumption up to -43%,
- ✓ Reductions in noise mean levels up to -1% (a rather small environmental saving as a consequence of the increase in vehicle speed values resulting from the decrease of number of vehicles or the improved traffic conditions),
- ✓ Reductions in carbon footprint up to -39%,
- ✓ Reductions in PMx and NOx emissions up to -28% and -36% respectively,
- ✓ Reductions of a few tens percent in the maximum concentrations of atmospheric pollutants (e.g. PMx and NOx).

Assuming a flat -10% reduction in pollutants daily concentrations then a small benefit (reductions up to a few percent as median values) has been estimated for the health events (hospitalizations and deaths) and the health-related costs for hospitalizations. However, these results would require more evidence and should be considered with cautiousness given the quite wide confidence intervals for some of the health outcomes and the generally high uncertainties in the estimation of the impacts that the environment and the environmental measures may have on human health.

REMEDIO addresses a common problem of many cities and towns in the Mediterranean area proposing for their mixed-used high-congested roads a new approach that is very effective in improving the quality of life of many citizens. The positive assessment results support that the REMEDIO methodology, applied in many road axes of the Mediterranean cities, can result in cumulative effects that allow the compliance with the EU legislation on Air Quality (with the decrease of pollutant emissions and the reduction of people exposure to air pollution) while at the same time will support the EU strategic vision for climate neutral economy by 2050 (with the reduction of the greenhouse gases emissions and the increase of energy efficiency). This is more obvious when considering that the operational path of the project is aligned with the urban scale concept of Sustainable Urban Mobility Planning and can reach urban communities not yet involved in such a process or even if involved, they still lack low carbon transport systems in similar with REMEDIO urban deprived areas. The improvement of urban mobility of such areas could act as incentive not only for environmental improvements but also as incentive to increase competitiveness in urban scale (e.g. through increase of the real estate values and reduction of social exclusion). The REMEDIO mobility solutions, modelling approach and participatory governance pathway are flexible and applicable tools in different geographical contexts and wider scales, requiring though some adaptation depending on the territorial framework, the stakeholders and the public profile.