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Environmental analysis in traffic-congested roads using an Integrated Modelling Tool

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INTRODUCTION

In the framework of the REMEDIO project, a novel Integrated Modelling Tool (IMT) has been developed composed of individual modules that assess the main impacts of traffic on **pollutant emissions, air pollution dispersion, carbon footprint, energy efficiency, noise, cost and health effects**.

The aim of this study is the presentation of the IMT as well as its application on a main road axis of Thessaloniki. The air pollutant emissions and carbon footprint results are presented along with a validation through the comparison of IMT with the emission model COPERT Street level. Furthermore, a comparison between the present-time traffic conditions scenario and future scenarios, when a mobility solution (i.e. redesign of the road axis) will be implemented, is shown.

IMT MODULES

The Integrated Modeling Tool (Figure 1) is linking the :

- Traffic model 'Simulation of Urban Mobility' (SUMO),
- Emission model 'Passenger Car and Heavy Duty Emission Model (Light)' (PHEMLight),
- 'Pollutant dispersion in the atmosphere under variable wind conditions' (VADIS) model (coupling a boundary layer flow module with a Lagrangian dispersion module),
- Noise module based on the EU 'Common Noise Assessment Methods' methodology (CNOSSOS-EU),
- Health and Cost modules based on statistical modeling.

IMT MODELING

User can simulate with each one of the IMT individual modules the main effects caused by traffic in congested-road from **a common platform**, within a step by step process divided in 5 steps:

- **Steps 1-2**: Zone and traffic definition.
- **Step 3:** Traffic calculations using the open-source software SUMO (Simulation of Urban MObility).
- **Step 4**: Execution of each one of the IMT modules with results presented as graphics, figures or tables.
- **Step 5**: Simulation of new traffic conditions because of mobility soft actions implementation to compare different mobility solutions to reduce the impact of traffic.

IMT APPLICATION – THESSALONIKI CASE STUDY

ROAD AXIS MAIN CHARACTERISTICS (Figure 2)

- **connecting the city entrance from the airport with the city center**
- **crossing through the compact mixed-use inner part of the city** including areas with important commercial activity and dense residential ones.

MODELLING SYSTEM APPLICATION

- **Simulation Period**: 19 September 2017 on hourly basis.
- **Main Input Data**: a) **Measurements of traffic volume** at different sites along the axis (passenger cars, light commercial vehicles, heavy duty trucks, buses, motorcycles) (Figure 3), b) **Vehicle categorization** according to **technology** (gasoline, diesel etc) and **emission standard** (EURO 0 to EURO 6), c) **Network characteristics** (links, nodes, traffic lights, signs, pedestrian crossings, road slope etc), d) **meteorological and air quality data** and e) **health data** (hospitalizations and deaths).
- **3 Scenarios** :
  - **1st : Present-time traffic conditions (Base Case scenario (BC))** (example emission map in Figure 4),
  - **Road axis redesign actions for sustainable urban mobility → Reduction of traffic lanes from 3 to 2, upgrade of the bus lane**
  - **2nd : Reduction of number of passenger cars and motorcycles by -10% (Scenario-10 (SCN10)),**
  - **3rd : Reduction of number of passenger cars and motorcycles by -20% with increase by a factor of 2 of bus circulation frequency (Scenario-20 (SCN20)).**

RESULTS – CONCLUSIONS

Base Case Scenario (BC) (24hours analysis)

- **Traffic load** along the axis is configured by the **major contribution of passenger cars** (about 80%) and that of motorcycles (15%) (Figure 5).
- The diurnal variation of pollutant emissions and carbon footprint (CO_2 emissions) is configured by the diurnal pattern of the traffic load. The **emission values** are **maximum the hours 7:00 am to 10:00 am. Increased amounts of pollutants**, presenting small hourly variability, are emitted **from 10:00 am until 9:00 pm** (Figure 6). Similar is the trend for the fuel consumption (not shown here).
- CO_2 emissions are the highest. NOx emissions are higher than those of HC and PM mostly during daytime (Figure 6).
- **NOx, PM and HC are emitted mostly by the passenger cars**. The **second** most polluting **emission source for PM and HC** is the **Motorcycles** while **for NOx are the Buses**. Passenger cars are the major CO_2 emission source (Figure 7).

Comparison between COPERT Street Level (SL) and air pollutant emissions and carbon footprint module of IMT

- both models present a similar hourly distribution of NOx, PM, HC/VOC and **carbon footprint** emissions (CO2 shown in Figure 8)
- the **correlation** between the daily emission values of the two models is very high (**0**.9) indicating a **good model performance**

Scenario-10 (SCN10) (Analysis for the traffic peak hour: 8 am – 9 am)

- Decrease of passenger cars pollutant emissions by about -18%, carbon footprint and fuel consumption by about -20% (Table 1).
- Decrease of motorcycles pollutant and CO_2 emissions by about -22% (Table 1).
- **Reduction of all vehicle types pollutant emissions ranging from -10% to approximately -20%.** (Figure 9).
- **Reduction of fuel consumption by about -18 %** (Figure 9).

Scenario-20 (SCN20) (Analysis for the traffic peak hour: 8 am – 9 am)

- Higher reductions compared to SCN10 of **passenger cars** and motorcycles pollutant emissions, CO_2 emissions and fuel consumption **ranging from -22% to -25%** (Table 1).
- Buses pollutant emissions, CO_2 emissions are almost doubled with respect to BC scenario. Fuel consumption increases by ~47% compared to BC (Table 1).
- **More pronounced reductions in fuel consumption and in CO_2 and HC emissions** with respect to SCN10 except for PM emissions (Figure 9).
- **NOx emissions are higher than those of the BC scenario** (Figure 9) due to the increase in bus circulation.

➢ **The reduced use of private cars in SCN20, being 2 times more than that of SCM10, would result in more clear benefits for the atmospheric environment in the case of enhancement of the local public transportation with the use of clean vehicles in the city buses fleet.**

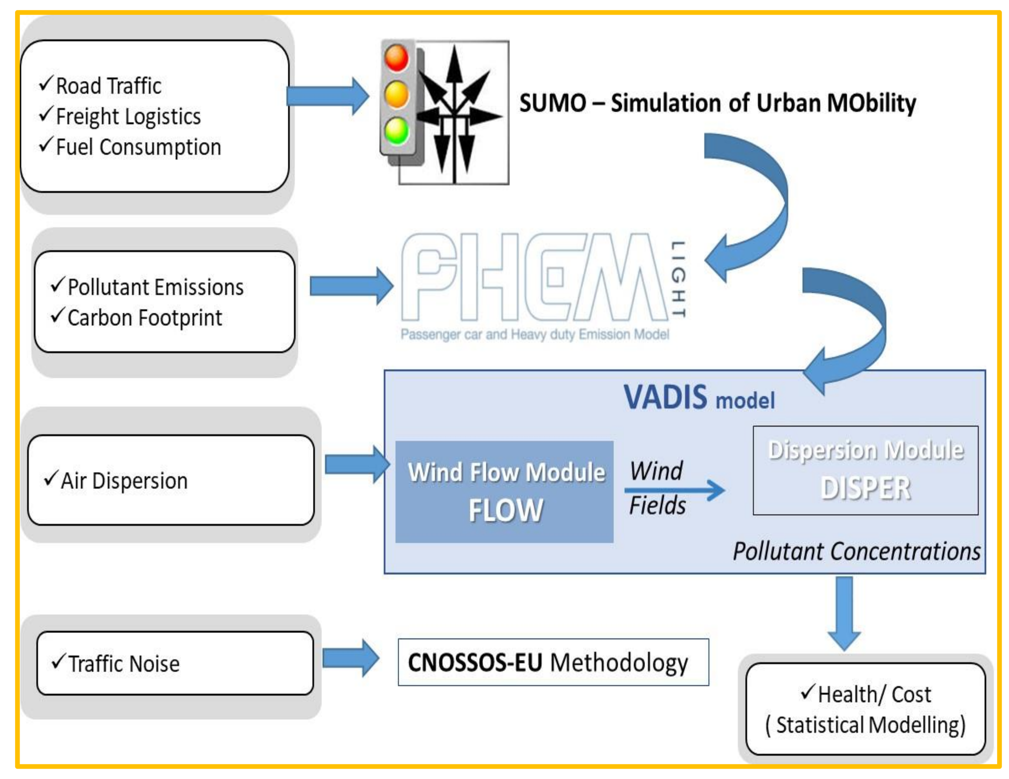

Figure 1. Integrated Modeling Tool.

Figure 2. Thessaloniki road axis for modelling simulations.

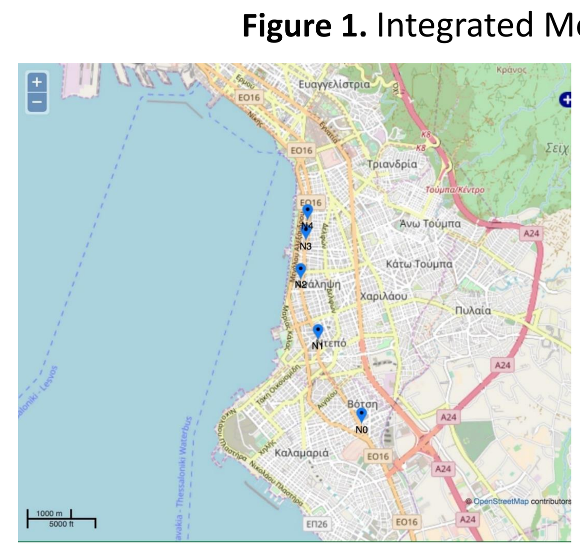

Figure 3. Monitoring sites of traffic volume the period 18 to 22 September 2017.

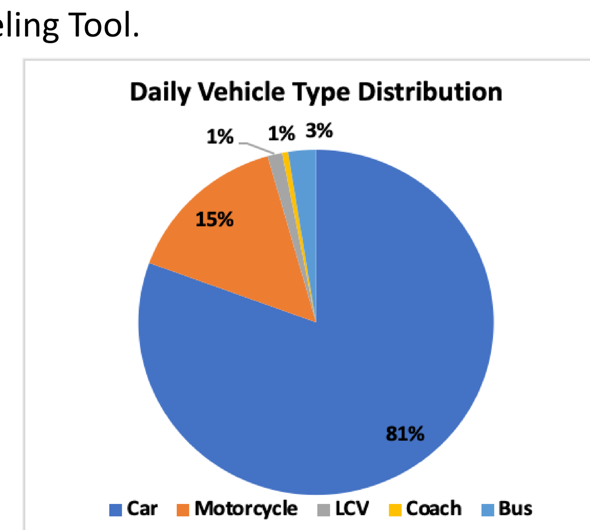

Figure 5. Distribution of vehicles circulating along the axis by type.

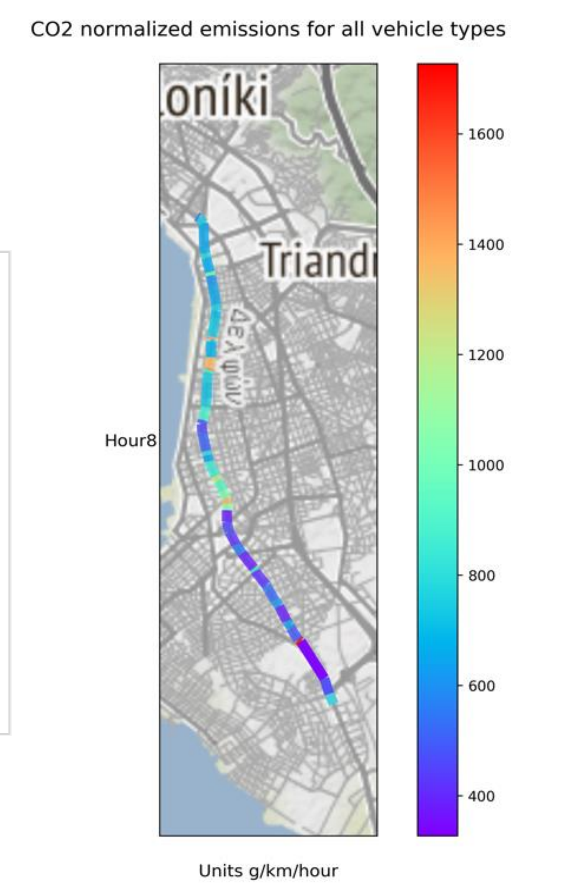

Figure 4. Map of CO_2 emissions (g/km/hour) at traffic peak hour.

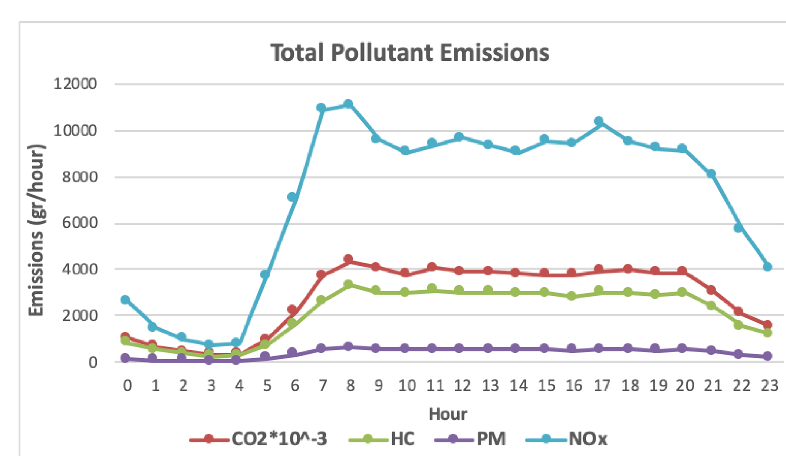

Figure 6. Diurnal variation of pollutant emissions and carbon footprint.

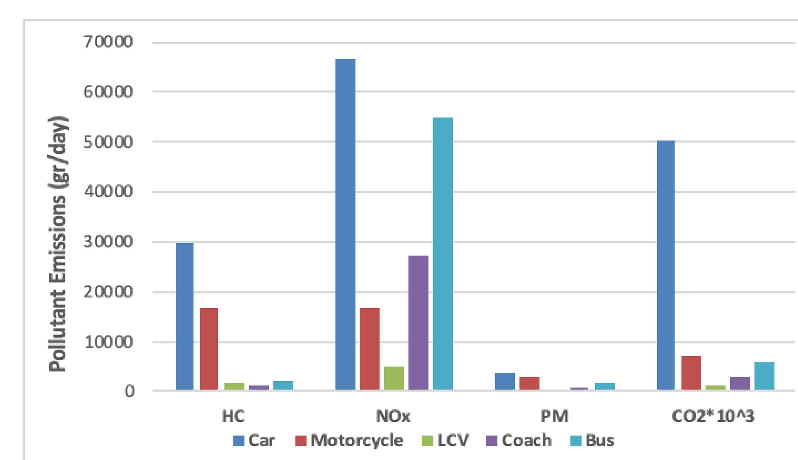

Figure 7. Daily pollutant emissions and carbon footprint per vehicle type.

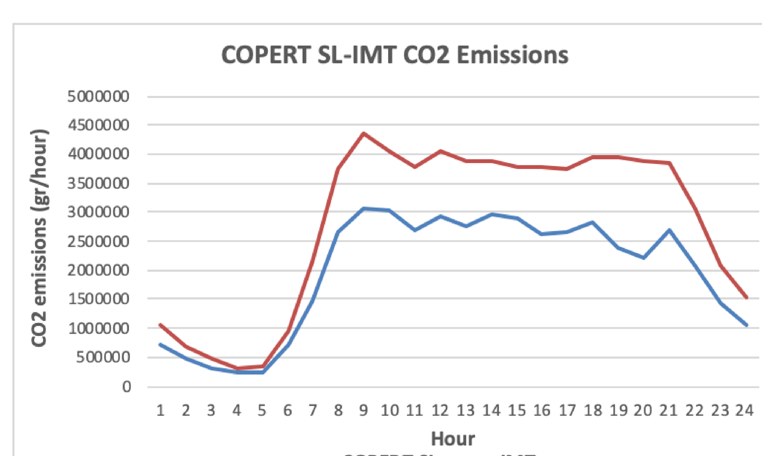

Figure 8. Diurnal variation of COPERT SL and IMT carbon footprint.

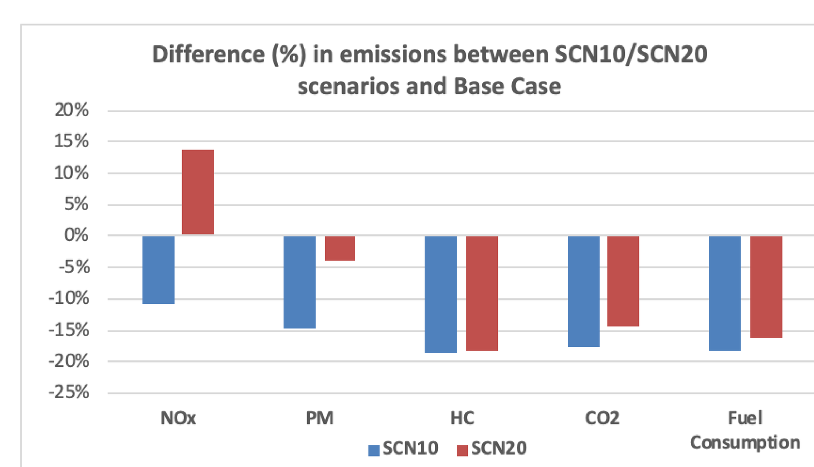

Figure 9. Total % differences in traffic-related variables because of traffic scenarios.

Table 1. % Differences* in pollutant emissions, carbon footprint and fuel consumption per vehicle type because of traffic scenarios.

	Scenario-10 (SCN10)					Scenario-20 (SCN20)				
	CO_2	HC	PM	NOx	Fuel Consumption	CO_2	HC	PM	NOx	Fuel Consumption
Car	-19.83%	-17.37%	-16.65%	-18.28%	-19.71%	-24.73%	-25.61%	-22.11%	-24.72%	-32.89%
Motorcycle	-22.37%	-22.50%	-21.76%	-22.94%	-22.52%	-26.10%	-18.45%	-26.38%	-17.17%	-34.50%
Bus	+0.29%	-2.40%	+3.75%	+2.61%	-0.36%	+92.00%	+82.51%	+85.39%	+86.75%	+47.69%

$$* \ \% \ \text{Difference} = \frac{(SCN - BC)}{BC} \%$$

Acknowledgements

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