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Environmental assessment of low carbon mobility solutions with the use of an Integrated Modeling Tool

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INTRODUCTION

A **novel Integrated Modelling Tool** 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 use of the Integrated Modeling Tool to assess the impact on the atmospheric environment of the redesign of a main road axis of Thessaloniki with the objective to promote sustainable modes of transport and to upgrade the bus transport along it. The assessment focuses on possible **environmental benefits** including **reductions in traffic-related pollutants' emissions and carbon footprint** in addition to **improvements in energy efficiency** between the **present-time traffic conditions scenario** and **future scenarios**, when the mobility solution (i.e. redesign of the road axis) will be implemented.

ROAD AXIS MAIN CHARACTERISTICS

- Road axis **connecting the city entrance from the airport with the city center** (Figure 1),
- Road axis **crossing through the compact mixed-use inner part of the city** including areas with important commercial activity and dense residential ones.

ROAD AXIS REDESIGN ACTIONS FOR SUSTAINABLE URBAN MOBILITY

- **Reduction of traffic lanes from 3 to 2,**
- **Upgrade of the existing on the right-hand side of the road bus lane to a 2nd generation separated bus lane,**
- **Construction of a Bicycle Lane on the road left-hand side** (Figure 2)

MODELLING SYSTEM APPLICATION

- The **Integrated Modeling Tool** (Figure 3) 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**.
- **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 4), b) **Vehicle categorization** according to **technology** (gasoline, diesel etc) and **emission standard** (EURO 0 to EURO 6), c) **Network characteristics** (links, nodes, **t**raffic lights, signs, pedestrian crossings, road slope etc), d) **meteorological and air quality data** and e) **health data** (hospitalizations and deaths).
- **3 Scenarios for Traffic Conditions**:

  1st : Present-time traffic conditions (Base Case scenario (BC)) (example emission map in Figure 5),
  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)).

Figure 1. Thessaloniki road axis for modelling simulations.

Figure 2. Redesign of the road axis.

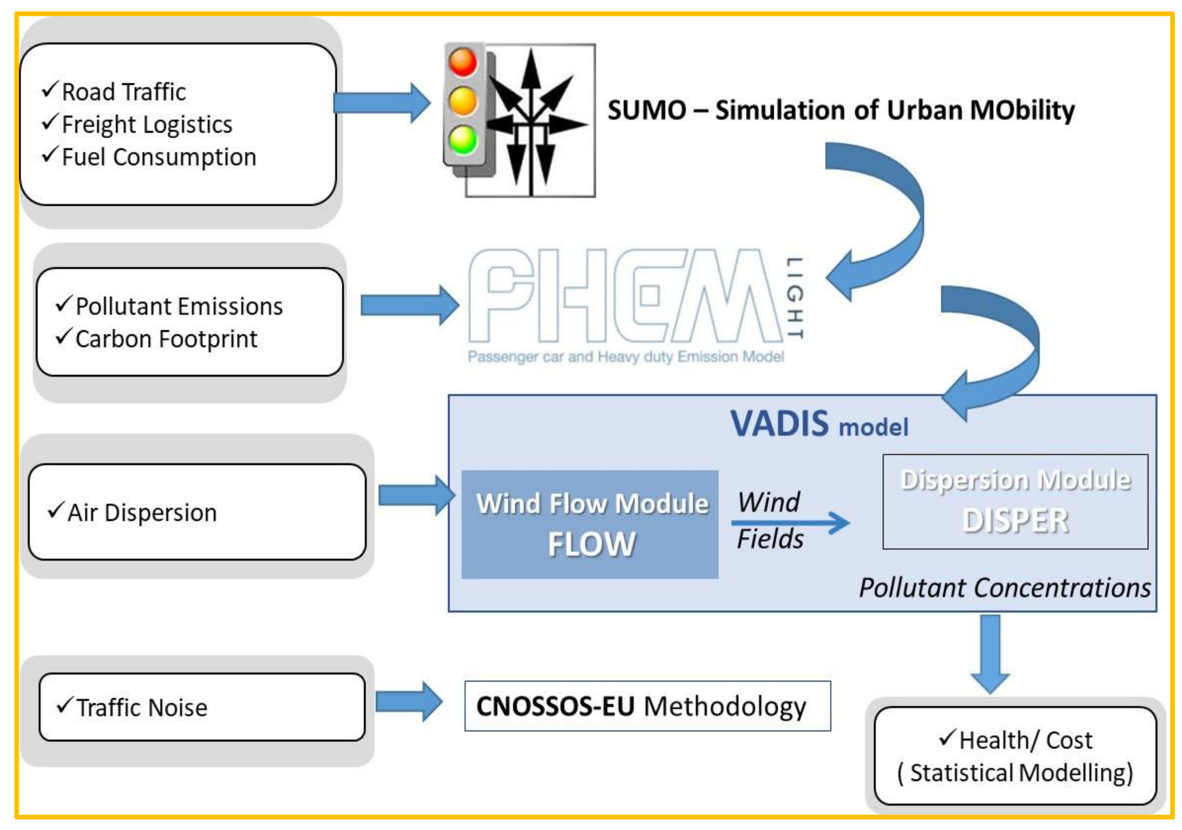

Figure 3. Integrated Modeling Tool.

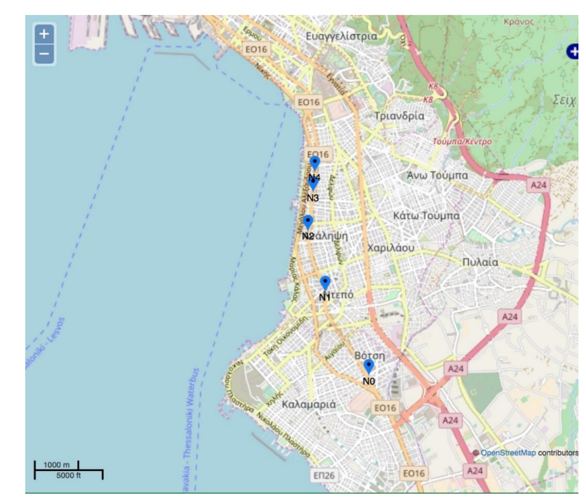

Figure 4. Monitoring sites of traffic volume the period 18 to 22 September 2017.

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 6).
- 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 7). Similar is the diurnal pattern 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 7).
- **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 8).

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

- Decrease of passenger cars pollutant emissions by about -18%, carbon footprint by about -15% and fuel consumption (Table 1).
- Decrease of motorcycles pollutant and CO_2 emissions ranging between -7% and -12% and fuel consumption (Table 1).
- **Reduction of all vehicle types pollutant emissions up to about -15%** (Figure 9).
- **Reduction of fuel consumption by about -15 %** (Figure 9).
- **The average vehicle speed is increased by +2.5% resulting in reduction of travel time by -8%** (Figure 9).

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

- Important reductions of passenger cars and motorcycles pollutant emissions, CO_2 emissions and fuel consumption being 1.5 to 3 times higher than those for SCN10 (Table 1).
- Buses pollutant emissions, CO_2 emissions and fuel consumption are almost doubled with respect to BC scenario (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).
- **Small further increase in average vehicle speed and decrease in travel time with respect to SCN10** (Figure 9).

- **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.**

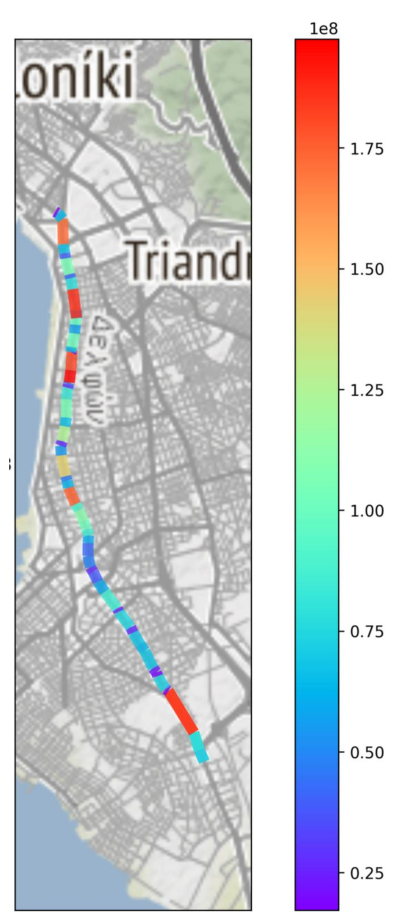

Figure 5. Map of CO_2 emissions (mg/hour) at traffic peak hour.

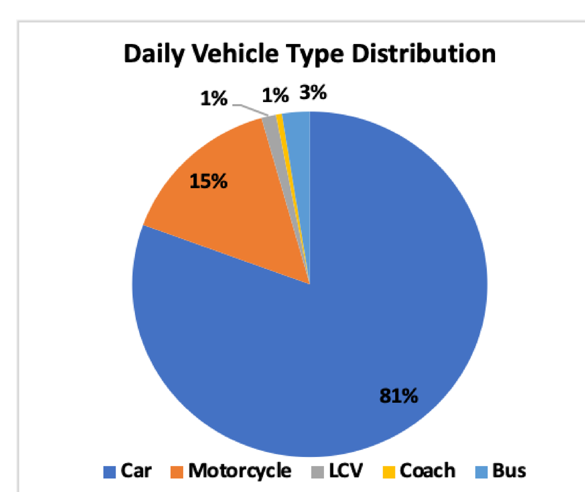

Figure 6. Distribution of vehicles circulating along the axis by type.

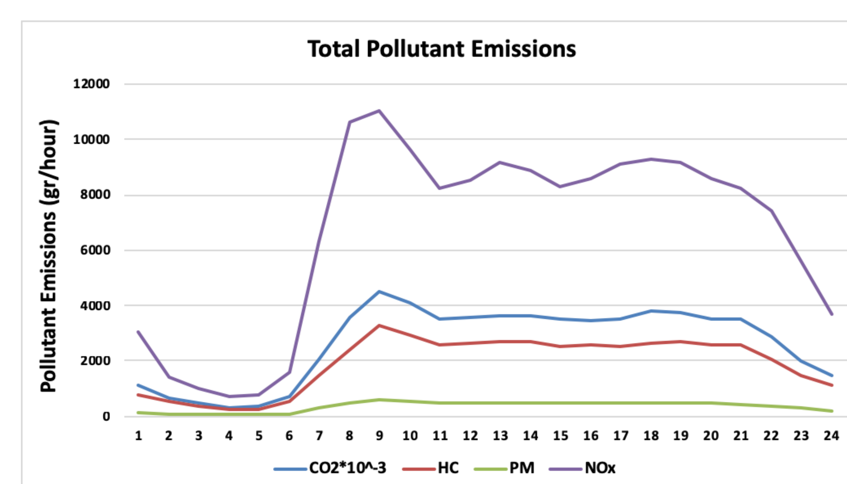

Figure 7. Diurnal variation of pollutant emissions and carbon footprint.

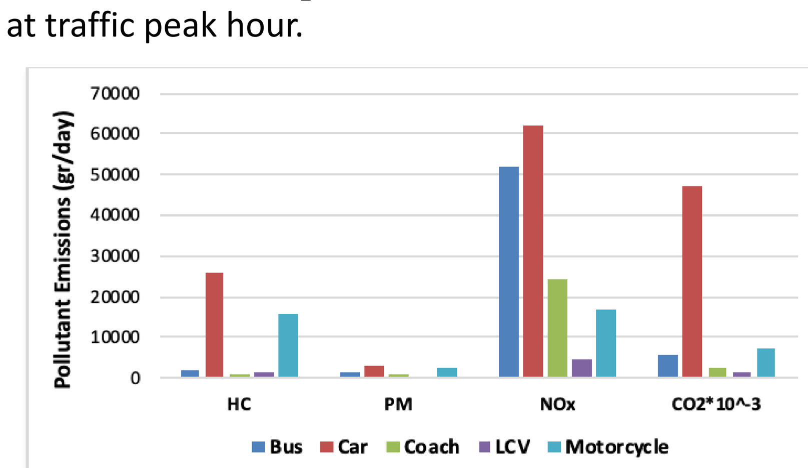

Figure 8. Daily pollutant emissions and carbon footprint per vehicle type.

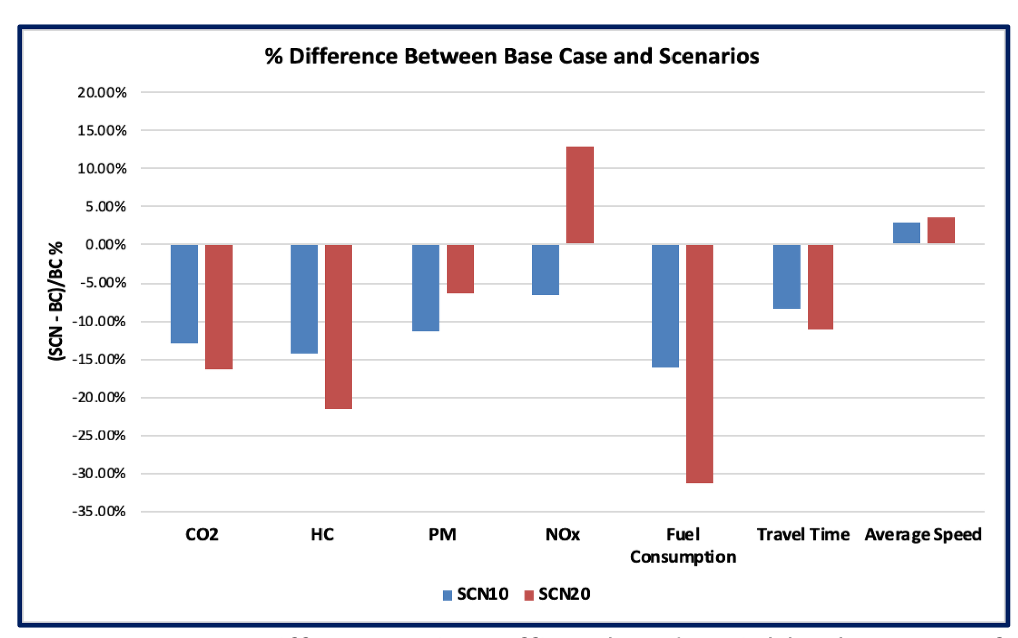

Figure 9. Total % differences in traffic-related variables because of traffic scenarios.

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	-15.40%	-19.48%	-18.14%	-17.46%	-16.85%	-27.17%	-30.01%	-30.68%	-27.33%	-34.30%
Motorcycle	-11.71%	-7.20%	-11.58%	-6.74%	-11.20%	-22.77%	-20.62%	-23.77%	-18.36%	-22.70%
Bus	+0.38%	-2.87%	-3.42%	+2.83%	+0.39%	+92.91%	+88.20%	+96.44%	+96.16%	+92.92%

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

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