



Project co-financed by the European
Regional Development Fund

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

Fine-tuning of the IMT (Activity 3.3)

Deliverable 3.3.1

Integrated Modelling Tool for low carbon mobility solutions

Date: 30/10/2019

Dissemination Level: Public

Document Status: Working Document

Document details

FILE NAME	VERSION
L3.3.1_Integrated_Modelling_Tool_for_low_carbon_mobility_solutions_final	final

Document history

VERSION	DATE	AUTHOR	DESCRIPTION
v1_USE	21.03.2018	Elisa López, José Antonio Becerra, Ricardo Chacartegui, Nabil Mohamed Amghar, Carlos Ortiz, Jesús Lizana, Pilar Orihuela.	First full version
v1_USE_A UTH	10.05.2018	Natalia Liora, Serafeim Kontos, Anastasia Poupkou, Christos Giannaros, Dafni Parliari, Spyridon Dimopoulos, Efrosini Giama, Charikleia Meleti, Dimitrios Melas	Description of the emission module and Emissions module validation included
v1_USE_fl	11.05.2018	Francesca Liguori	Full revision
v1_USE_ UAVR	14.05.18	Joana Ferreira	Description of the dispersion module
v2_USE	15.05.18	Elisa López, José Antonio Becerra, Ricardo Chacartegui, Nabil Mohamed Amghar, Carlos Ortiz, Jesús Lizana, Pilar Orihuela.	Second full version
final	30.10.2019	Francesca Liguori	Minor corrections for final delivering and publication

Executive Summary

A novel Integrated Modelling Tool (IMT) has been developed as a tool for mobility decision making within the REMEDIO. The IMT is composed by 8 individual modules that cover the main impacts of traffic on the city and its inhabitants, namely, energy efficiency, noise, atmospheric pollution emission, carbon footprint, air pollution dispersion, freight streamlining, cost and health impact. The IMT provides to users (i.e. technician responsible for traffic management) the possibility of analyze the main effects of traffics over congested roads in the current situation, as well as analyzing the effects of apply potential soft-actions to mitigate the road-congestion problems.

This document summarizes all the work done during the development of the IMT that corresponds to activity 3.3 within the REMEDIO project. First, the conceptual modelling approach is described through the main points developed from an IMT user perspective. Later on, each individual module development is summarized, from theoretical concepts to model implementation. Then, the IMT platform, which houses the integration of all single modules and allows the user to make the simulations, is explained. Moreover, a step-by-step user guide is included. The IMT validation is carry out in the municipality of Treviso. Finally, the document introduces the conceptual modeling approach to simulate soft mobility actions by means of the IMT.

Table of contents

Executive Summary	2
1 Introduction.....	8
2 IMT conceptual modelling approach	9
2.1 Brief overview	9
2.2 Traffic simulation.....	10
3 Energy module	13
3.1 Resume.....	13
3.2 Methodology.....	13
3.2.1 Theoretical model	13
3.2.2 Model calculations	15
4 Noise module.....	20
4.1 Resume.....	20
4.2 Methodology.....	21
4.3 Noise model within the IMT.....	23
4.3.1 Objective Modelling variable	23
4.3.2 Theoretical model	23
4.3.3 Implementation of the model – Procedure for codifying	26
4.3.4 Comparison with SUMO traffic results.....	34
4.4 Noise modules results	40
5 Atmospheric pollution emission & carbon footprint module.....	43
5.1 Introduction	43
5.2 Methodology.....	43
5.3 Input/Output xml files.....	45
6 Freight Streamlining Module	48
6.1 Summary	48
6.2 Model description	48
6.3 Freight module interaction within the IMT.....	49
7 Air pollution dispersion module.....	50
7.1 Resume.....	50
7.2 Model description	50

7.3	VADIS model within the IMT	52
8	Health and Cost module. Health	53
8.1	Introduction	53
8.2	Modules setup and assumptions	53
8.3	XML input/output definition	54
8.4	Core functions description	54
8.5	Executable usage and options	57
9	Health and Cost module. Cost	59
9.1	Introduction	59
9.2	Core functions description	60
9.3	Executable usage and options	61
9.4	Future new feature	61
9.5	Software	61
9.6	References	61
10	IMT Platform	64
10.1	IMT platform development.....	64
10.1.1	Platform programming.....	64
10.1.2	Integrating the energy and noise modules. An example for the rest of modules	66
10.1.3	Traffic patterns.....	68
10.2	Platform description	72
10.2.1	Characterization and simulation of traffic	74
10.2.2	Modules execution.....	80
10.3	Legal notice and disclaimer:.....	82
10.4	User manual	83
10.4.1	Logging	83
10.4.2	Step-by-step process.....	84
10.4.3	Upload-files process.....	100
10.4.4	Modules execution.....	107
10.5	Traffic files description.....	133
11	Validation in the test city of Treviso	155
11.1	Inputs from Treviso	155
11.2	Noise module validation	160

11.3	Atmospheric Pollution Emission & carbon footprint module validation	163
12	Soft actions	169
12.1	Introduction	169
12.2	Actions 1: Add a bus lane	171
12.2.1	Pre-defined values.....	171
12.2.2	Specific simulation procedure.....	171

1 Introduction

A novel Integrated Modelling Tool (IMT) has been developed as a tool for mobility decision making within the REMEDIO project (REgenerating mixed-use MED urban communities congested by traffic through Innovative low carbon mobility sOLutions), co-founded by the MED Programme. The IMT is composed by 7 individual modules that cover the main impacts of traffic on the city and its inhabitants, namely, energy efficiency, noise, atmospheric pollution emission and carbon footprint, air pollution dispersion, freight streamlining, cost and health impact.

The IMT provide to users (i.e. technician responsible for traffic management) the possibility of analyze the main effects of traffics over congested road in the current situation, as well as analyzing the effects of apply potential soft-actions to mitigate the road-congestion problems.

User can access the IMT platform following the next link: <http://remedio-imt.eu>. Before access the platform, user must carry out a registration process. Data will be treated confidentially as notified in the legal message.

REMEDIO scientific partners have worked together in the development of the different modules which compose the IMT. Thus, the modules development has been as follows:

- USE: energy efficiency noise modules
- AUTH: atmospheric pollution emission & carbon footprint module
- IST: air pollution dispersion & freight streamlining modules
- University of Padoa (on behalf of ARPAV): cost & health impact modules

After individual modules development, the USE team has been in charge of the integration of each one within the final REMEDIO IMT. As result, user can simulate the main effects (each one of the individual modules) caused by traffic in congested-road from a common platform, which is developed to facilitate the user interaction with the core models within a step by step process.

Once the IMT is developed, the tool is tested and validated on the Treviso study-area. For that, results from a campaign test developed between 18/10/17 and 14/11/17 are taken. During the test campaign along Road West pilot zone meteorological parameters, traffic flows noise and pollutants concentrations were measured. Data was recorded every minute.

Traffic flow data (classified for length of the vehicle) are used as input of the energy, noise and air pollutant emissions modules and so feeding the following modules of dispersion, cost and health. Noise measurements and air pollutant concentrations measured during the test campaign are useful for comparing IMT outputs with real data measurements.

2 IMT conceptual modelling approach

The following section presents a general description of the modelling process followed during the development of the IMT. For this, the description is carried out going through the main points developed from an IMT user perspective. It means, the process is described from the data introduced by the user to make the simulation until the analysis of the results provided by each one of the different modules.

2.1 Brief overview

Figure 1 shows a global resume of IMT conceptual model. The tool is implemented within a FIWARE platform that allows users (i.e. technician responsible for traffic management from a certain city), to calculate by means of several modules the traffic effects on emissions, fuel consumption, noise, air pollutant concentrations, health effects and costs from the information of the area to simulate.

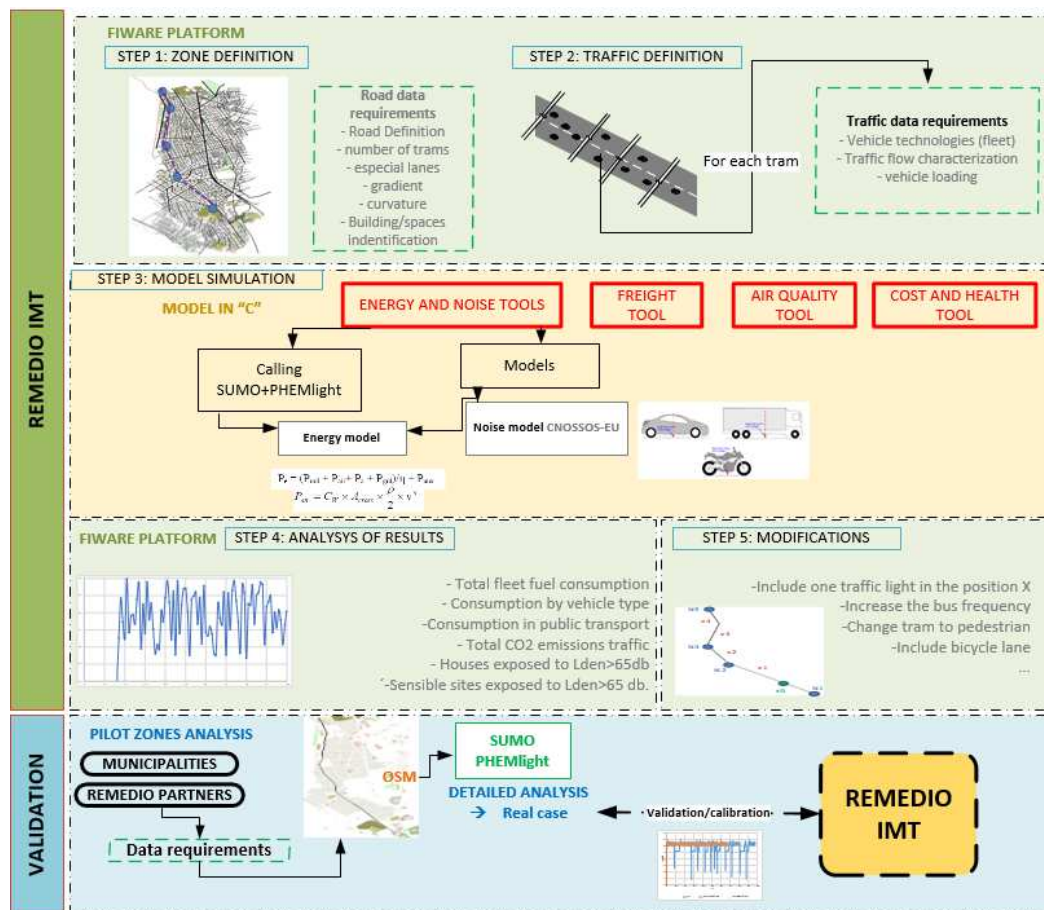


Figure 1: Overall conceptual modelling approach

The process is divided in 5 steps. Firstly, the user is asking to define the zone of study. The two first steps consist of the zone and traffic definition. A complete zone definition requires data about road length, number of edges and lanes, coordinates of traffic lights, stop signals and pedestrian crossing, specification of special lanes (i.e. bus lanes, bike lanes),

slope, road surface material. In the step 2, vehicles technologies and traffic flows are introduced by the user.

Traffic calculations within the IMT are carried out using the open-source software SUMO (Simulation of Urban MObility)¹. SUMO is developed in C++; it uses only portable libraries; it allows microscopic and multimodal traffic simulation and no artificial limitations in network size and number of simulated vehicles. A more detailed explanation of traffic simulation by using SUMO is showed in the following section.

After traffic calculations, the platform has the inputs needed for run each one of the IMT modules. Each individual module is programmed within the REMEDIO project by using open-source software (i.e. Python). For the pollutant emissions estimation, specific models are used as: i) the emission model 'Passenger Car and Heavy Duty Emission Model (Light)' (PHEMLight) and ii) the model 'Pollutant dispersion in the atmosphere under variable wind conditions' (VADIS) (coupling a boundary layer flow module with a Lagrangian dispersion module). The use of PHEMLight licence is exclusive for the work development within the REMEDIO project. After REMEDIO project, the use of the tool in open access would require the replacement of emission models from PHEMLight for open-access databases (HFEBA) as well as specifically-designed correlations to simulate the vehicles driving cycle.

After simulation, results of each module are presented as graphics, figure or tables and the users can simulate a new situation by implementing soft actions to compare different solutions to reduce the impact of traffic effects.

2.2 Traffic simulation

Traffic calculations within the IMT are carried out using the open-source software SUMO (Simulation of Urban MObility). Some of simulation features included in SUMO¹ are:

- space-continuous and time-discrete vehicle movement
- Different vehicle types
- Multi-lane streets with lane changing
- Different right-of-way rules, traffic lights
- A fast openGL graphical user interface
- Manages networks with several 10.000 edges
- Fast execution speed
- Network-wide, edge-based, vehicle-based and detector-based outputs.

As can be seen in Figure 1, the zone definition requires road data about road definition, number of edges and lanes, special lanes, slope, road surface. These inputs are introduced by the user in the IMT platform. Data is collected automatically as shown in Figure 2.

¹ http://www.dlr.de/ts/en/desktopdefault.aspx/tabid-9883/16931_read-41000/

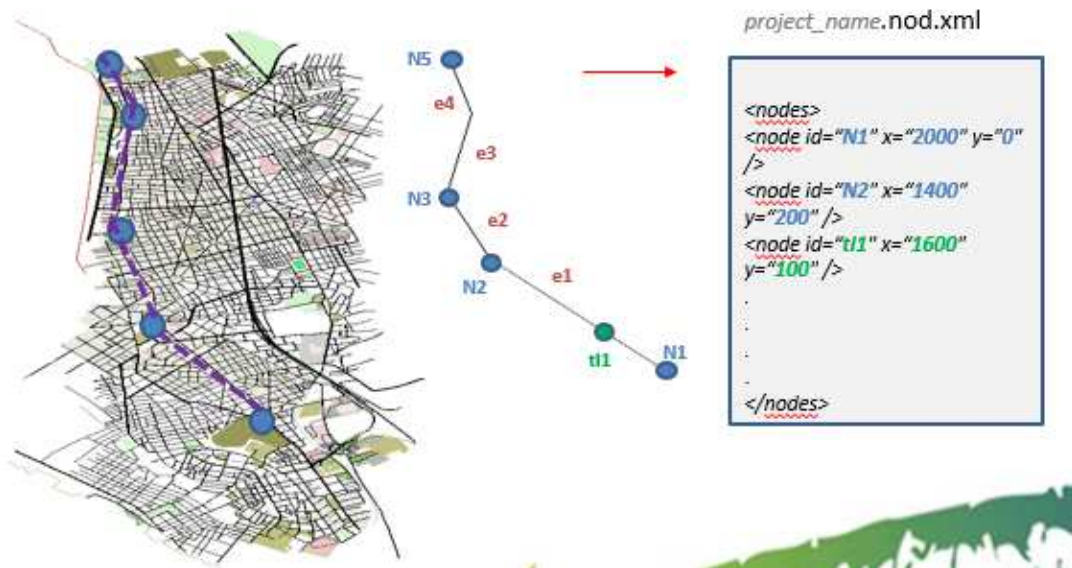


Figure 2: Schematics of data handling for road definition within the IMT

Traffic flow and fleet definition are also defined within the platform and data is collected in a route file. Firstly, the vehicle technologies are defined based on parameters appear in Table 1.

Table 1. Vehicle type definition

Attribute name	Default	Description
id	-	The name of the vehicle type
probability	1.00	probability for emitting a vehicle class with this emission class
vClass	"passenger"	Vehicle class
emissionClass	"PC_G_EU4"	Emission class

In the second part, traffic flow is defined using the attributes collected in Table 2.

Table 2. Vehicle flow definition

Attribute name	Description
id	The name of the vehicle
type	The id of the vehicle type to use for this vehicle.
line	A string specifying the id of a public transport line
begin	first vehicle departure time
end	end of departure interval

vehsPerHour	number of vehicles per hour, equally spaced (not together with period or probability)
period	insert equally spaced vehicles at that period (not together with vehsPerHour or probability)

Figure 3 shows the conceptual scheme of how is traded internally the data introduced by the user in order to carry out the traffic simulation.

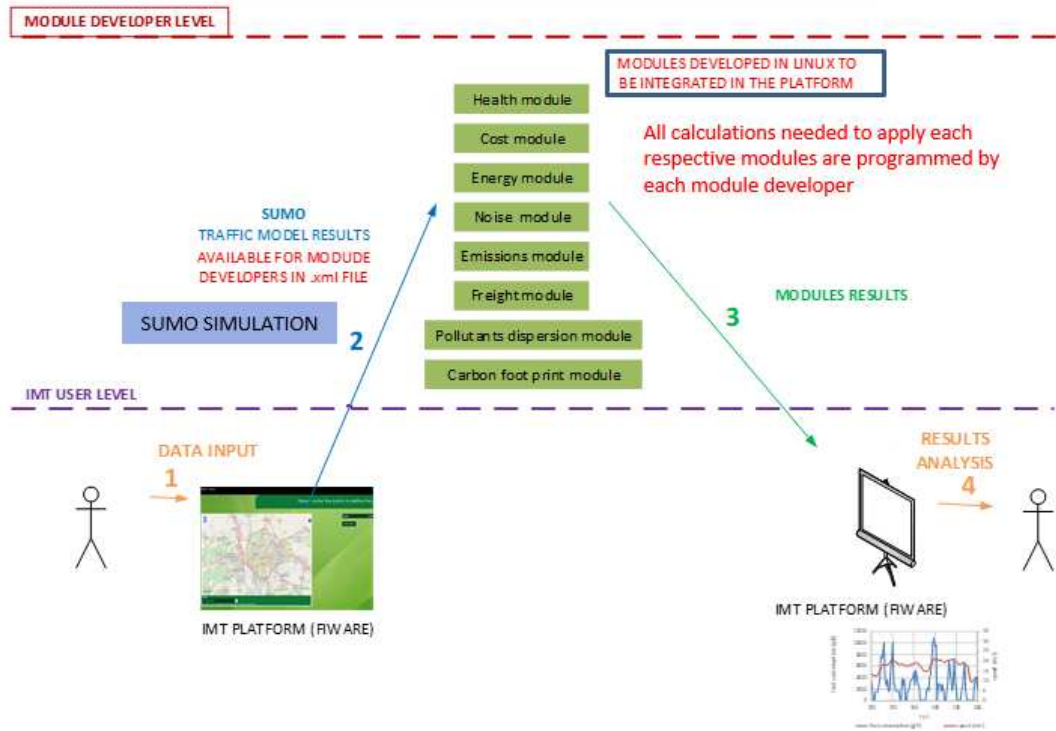


Figure 3. Road file created internally from the data introduced by the user

3 Energy module

3.1 Resume

The energy module is an application created by using Python programming language, which takes the traffic results as inputs. The aim of the module is to calculate the fuel consumption and emissions caused by traffic. Energy model results have been validated considering literature models for driving cycles calculations.

3.2 Methodology

3.2.1 Theoretical model

A theoretical model based on PHEM within the COLOMBO project² has been used to analyse the necessary engine power output for the actual second for a driving cycle. The emissions are then interpolated from emission curves in the normalised format according to the current engine power output by using PHEMlight database.

The most important parts of driving power calculation (P_e) are rolling and air resistance, acceleration and road gradient, transmission losses as well as power demand of auxiliaries, as can be seen in equation (3-1):

$$P_e = \frac{(P_{roll} + P_{air} + P_a + P_{grad})}{\eta} + P_{aux} \quad (3-1)$$

where η represent the drive train efficiency and takes the value 0.9 for all vehicle classes excluded HDC_CB ($\eta = 0.8$).

The meaning and calculation of the individual parts of power is described as follows:

P_{roll} : power to overcome rolling resistance (W)

$$P_{roll} = (m_{vehicle} + m_{load}) \cdot g \cdot (Fr_0 + Fr_1 \cdot v + Fr_4 \cdot v^4) \cdot v \quad (3-2)$$

where:

$m_{vehicle}$: vehicle curb weight (kg)

m_{load} : mas of the payload or passengers (kg)

g : acceleration of gravity (m/s^2)

$Fr_0...Fr_4$: rolling resistance coefficients

v : vehicle speed (m/s)

² S. Hausberger and D. Krajewicz, "Cooperative Self-Organizing System for low Carbon Mobility at low Penetration Rates COLOMBO : Deliverable 4.1 Scenario Specifications and Required Modifications to Simulation Tools," pp. 1–55, 2014.

P_{air} : power to overcome air resistance (W)

$$P_{air} = C_w \cdot A_{cross} \cdot \frac{1}{2} \cdot v^3 \quad (3-3)$$

where:

C_w : drag coefficient

A_{cross} : cross-sectional area of the vehicle (m²)

v : vehicle speed (m/s)

P_a : acceleration power (W)

$$P_a = (m_{vehicle} \cdot \Lambda_v \cdot m_{rot,wheels} \cdot m_{load}) \cdot a \cdot v \quad (3-4)$$

where:

$m_{vehicle}$: vehicle curb weight (kg)

$m_{rot,wheels}$: wheels equivalent rotational inertia (kg)

a : acceleration of the vehicle (m/s²)

Λ_v : rotating mass factor calculated by linear interpolation from a polygon

v : vehicle speed (m/s)

The masses of vehicles and payloads are accelerated translationally and all rotating components of the vehicle (tires, etc.) are accelerated rotationally. The rotationally accelerated masses are categorised in three groups. Each of these has a different transmission ratio and thus goes through different angular acceleration. The rotational acceleration power output for these three component groups is converted into translational acceleration.

Calculation of equivalent rotational masses: The equivalent rotational masses are interpolated from curves specified in the vehicle file dependent of the vehicle speed. The curves are generated for each possible gear number and vehicle class. The speed curve comes from the average velocity for each gear in the ERMES cycle. The rotating mass factor (Λ_v) curve was calculated over the average values for each gear from a full load acceleration.

$$\Lambda_{v,i} = \frac{\frac{P_{a,max} \cdot 1000}{a_{max} \cdot v} - m_{load} - m_{rot,wheels}}{m_{vehicle}} \quad (3-5)$$

where $P_{a,max}$ represent the maximum power available for acceleration and is calculated by equation (6).

$$P_{a,max} = P_{rated} \cdot P_{max,norm} - P_{aux} - P_{trans} - P_{roll} - P_{air} - P_{grd} \quad (3-6)$$

where:

P_{rated} : rated engine power (kW)

$P_{\text{max,norm}}$: available share of rated power calculated by linear interpolation from a polygon

P_{aux} : power demand from auxiliary units (kW)

P_{trans} : transmission losses (kW)

P_{roll} : power demand from rolling resistance (kW)

P_{air} : power demand from air drag (kW)

P_{grd} : power demand from road gradient (kW)

3.2.2 Model calculations

An alternative way to calculate the energy consumption is by using a SUMO-PHEMlight integration. Thus, energy results are directly calculated as the traffic is simulated. This involves a lower time-consumption simulation, which allows a better operation of the IMT than in the case of using the theoretical modelling code in an external Python application. As a positive issue, the implementation of the new Python application allows the use of the tool outside the environment of PHEMlight, which would allow the configuration of other databases.

In order to compare the theoretical model described above with SUMO energy results, equations have been particularized for a vehicle typology PC_G_EU4 which represent an usual emissions vehicle type in European countries. Vehicle typology PC_G_EU4 consist of a passenger car with gasoline engine European 6. Also, the procedure to determine fuel consumption through this theoretical model is explained:

Figure 4 shows available data for PC_G_EU4 is presented below.

Vehicle			Engine		
Vehicle category	PC		Engine rotational inertia	0,5	kg*m2
Fueltype	G		Wheels equivalent rotational inertia	40	kg
Emission standard*3	EU4		Gearbox rotational inertia	0,06	kg*m2
Vehicle mass	m_vehicle	1235	Auxiliaries base power demand	P_0	0,015 normalized
Vehicle loading	m_load	50	Engine rated power	P_rated	72 kW
		0,3113	Engine rated speed	5565	rpm
Cross section área	Cd	2,11756	Engine idling speed	798	rpm
Drive train efficiency	η	0,9			
Air density	ρ	1,2			
Acceleration of gravity	g	9,8			

Figure 4. Model inputs (Vehicle and engine)

Rolling resistance coefficients		Transmission		Power nominal values	
Fr0	0,009	Loss factor	0,3	P_n_max_v0	5
Fr1	0,00005	Wheel effective diameter	0,6064	P_n_max_p0	0,15
Fr2	0	Axle ratio	4,0826 m	P_n_max_v1	40
Fr3	0	Transmission gears		P_n_max_p1	0,8
Fr4	1,6E-09	1	3,6298		
		2	2,0523		
		3	1,3801		
		4	1,0477		
		5	0,8423		
		6	0		
		c Gearshift model (Version fast driver)			
		c shift up at ratio rpm/rated rpm in actual gear greater than			
		0,768717			
		c shift down when rpm/rated rpm in lower gear is higher than			
		0,5802642			
		c Gearshift model (Version economic driver)			
		c shift up at ratio rpm/rated rpm in higher gear greater than			
		0,5288679			
		c Shift down when ratio rpm/rated rpm in actual gear is lower than			
		0,4860377			

Figure 5. Model inputs (Rolling resistance coefficients, transmission and power nominal values)

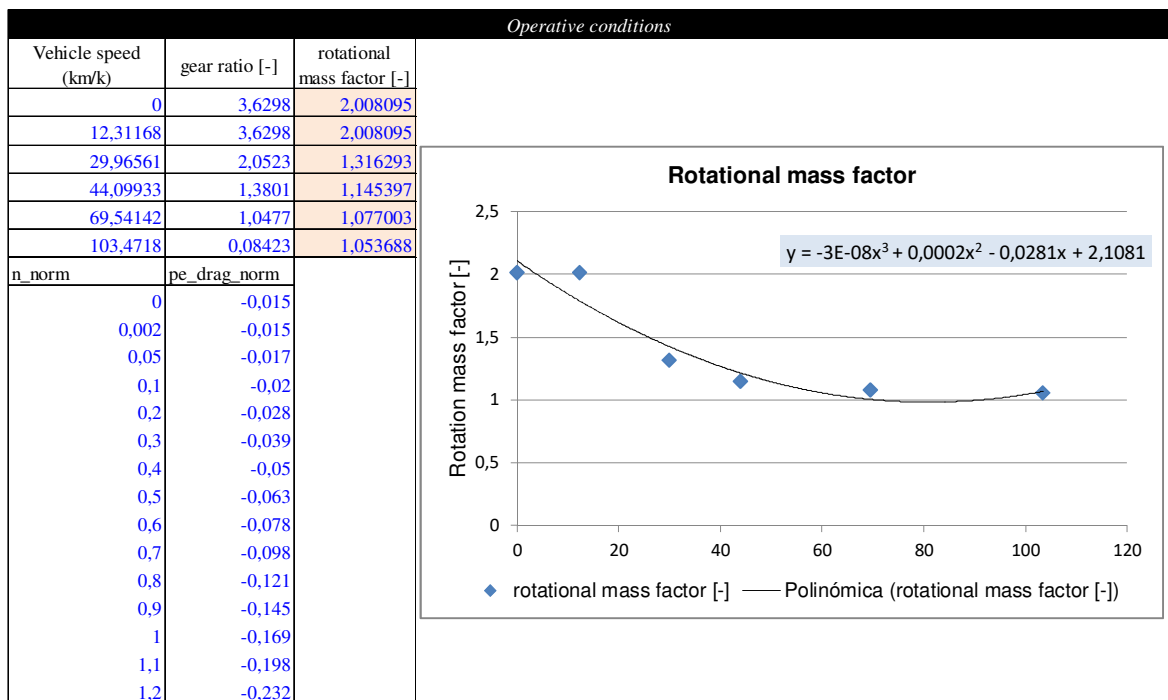


Figure 6. Model inputs (Operative conditions)

These exposed data, in addition to the driving cycle (speed-time) obtained through the simulation of the vehicle driving along the road in Sumo, are the input data needed to calculate the power output, through equation (3-1).

Figure 7 shows driving cycle obtained for a PC_G_EU4 driving along the simulated road. The vehicle is 10 minutes driving until arriving to the final node.

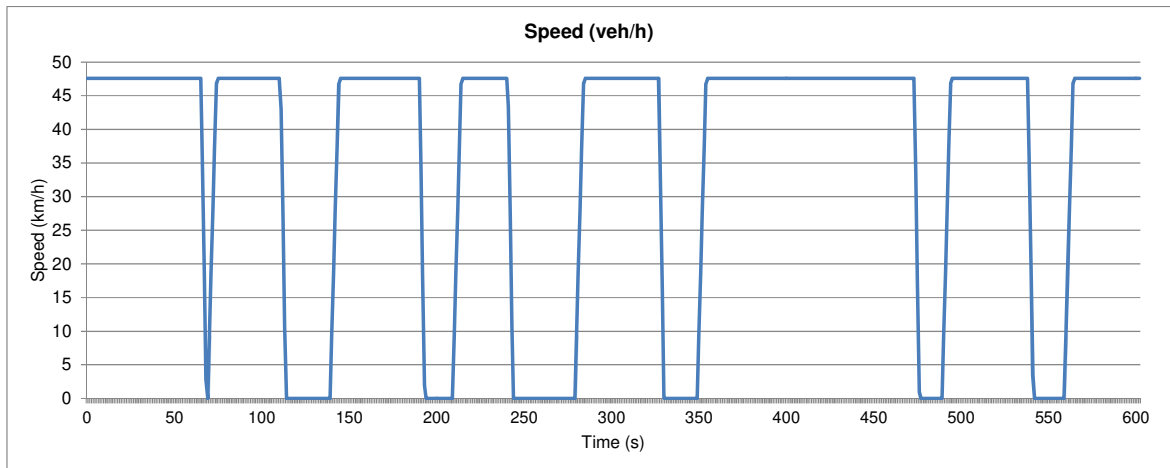


Figure 7. PC_G_EU4 driving along the road. Driving cycle

Figure 7 represents a very constant speed profile along time, just disturbed due to traffic lights presence. This is consequence of the driving model chosen in Sumo for the simulation. In this case, the chosen model was Krauß model.

Figure 8 shows the output power calculated by implementing theoretical model equations (3-1,3- 2, 3-3,3- 4,3- 5,3- 6) including base data associated to the analysed vehicle (Figure 4, Figure 5, Figure 6). A set data corresponding to the first traffic light located in the road, which is been represented in Figure 8, in order to observe acceleration and deceleration effects over the output power.

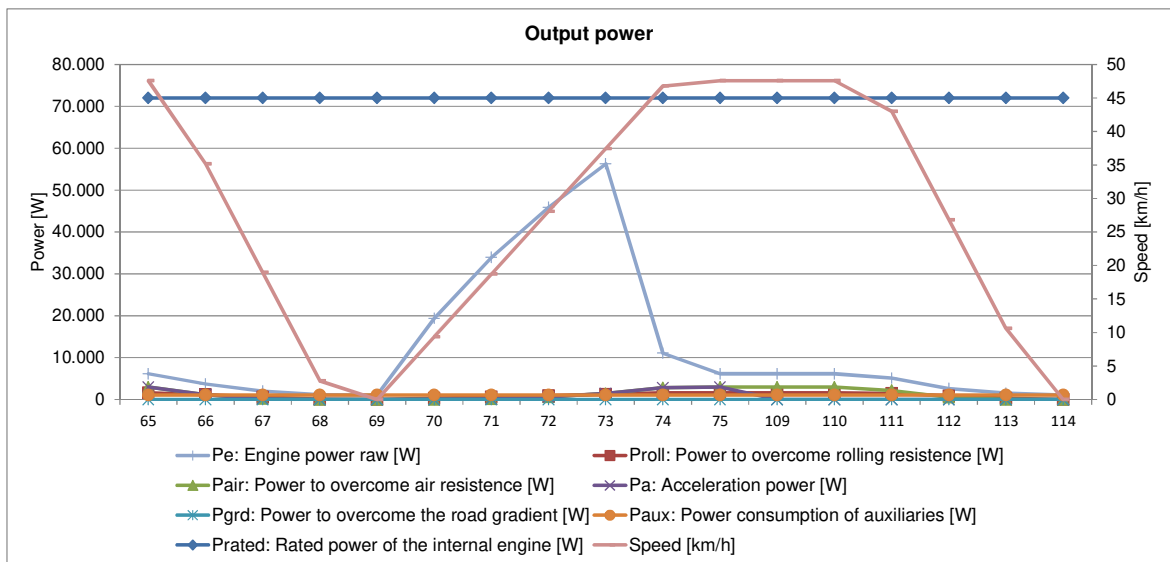


Figure 8. PC_G_EU4 Output power associated to a deceleration and acceleration period (first traffic light)

Table 3 includes represented values within Figure 8.

Table 3. Output power associated to a deceleration and acceleration period (first traffic light)

t	v	grd	a	v	P _{roll}	P _{air}	P _a	P _{grd}	P _{aux}	P _e	P _{r_{ated}}
[s]	[m/s]	[%]	[m/s^2]	[km/h]	[W]	[W]	[W]	[W]	[W]	[W]	[W]
65	13,22	0	0	47,59	1.616,49	2.935,49	0	0	1.080	6.137,77	72.000
66	9,77	0	0	35,17	1.169,20	1.184,87	0	0	1.080	3.695,63	72.000
67	5,27	0	0	18,97	614,86	185,96	0	0	1.080	1.969,79	72.000
68	0,77	0	0	2,77	87,64	0,58	0	0	1.080	1.178,03	72.000
69	0	0	2,6	0	0	0	0	0	1.080	1.080,00	72.000
70	2,6	0	2,6	9,36	298,94	22,33	16.158	0	1.080	19.390,68	72.000
71	5,2	0	2,6	18,72	606,45	178,65	28.800	0	1.080	33.952,21	72.000
72	7,8	0	2,6	28,08	922,92	602,94	38.795	0	1.080	45.880,87	72.000
73	10,4	0	2,6	37,44	1.249,26	1.429,18	47.009	0	1.080	56.288,10	72.000
74	13	0	0,22	46,80	1.587,27	2.791,37	4.595	0	1.080	11.050,48	72.000
75	13,22	0	0	47,59	1.616,49	2.935,49	0	0	1.080	6.137,77	72.000
76	13,22	0	0	47,59	1.616,49	2.935,49	0	0	1.080	6.137,77	72.000
77	13,22	0	0	47,59	1.616,49	2.935,49	0	0	1.080	6.137,77	72.000
78	13,22	0	0	47,59	1.616,49	2.935,49	0	0	1.080	6.137,77	72.000
79	13,22	0	0	47,59	1.616,49	2.935,49	0	0	1.080	6.137,77	72.000
109	13,22	0	0	47,59	1.616,49	2.935,49	0	0	1.080	6.137,77	72.000
110	13,22	0	0	47,59	1.616,49	2.935,49	0	0	1.080	6.137,77	72.000
111	11,95	0	0	43,02	1.449,20	2.168,16	0	0	1.080	5.099,29	72.000
112	7,45	0	0	26,82	879,77	525,36	0	0	1.080	2.641,25	72.000
113	2,95	0	0	10,62	339,83	32,62	0	0	1.080	1.493,83	72.000
114	0	0	0	0	0	0	0	0	1.080	1.080,00	72.000

Once the output power has been calculated for the simulated driving cycle of the vehicle, next step consists on obtaining fuel consumption associated to each operating point. Fuel consumption curves are fitting from PHEMLight database for comparison purposes. The normalized engine power output has been calculated following this equation below:

$$P_{\text{rated}_{\text{normed}}} = \frac{(P_e - P_{\text{aux}})}{\eta \cdot P_{\text{rated}}} \quad (3-7)$$

By replacing normalised engine power output associated to each operating point within obtaining regression equation, it is possible to calculate the fuel consumption associated to each operating point of the driving cycle. Fuel consumption is compared with results achieved by using the SUMO-PHEMLight integration and therefore the results can be compared. At this regard, the following equation will be applied to standardize the fuel consumption units:

$$FC \text{ [ml/s]} = \frac{FC \text{ [g/h]}}{3600 \cdot \rho_F} \quad (3-8)$$

where is the density of the fuel, in this case, gasoline (0,680g/c.c).

Figure 9 shows the comparison between fuel consumption over the driving cycle obtained through Sumo simulation and through the implementation of regression equation over driving cycle operating points.

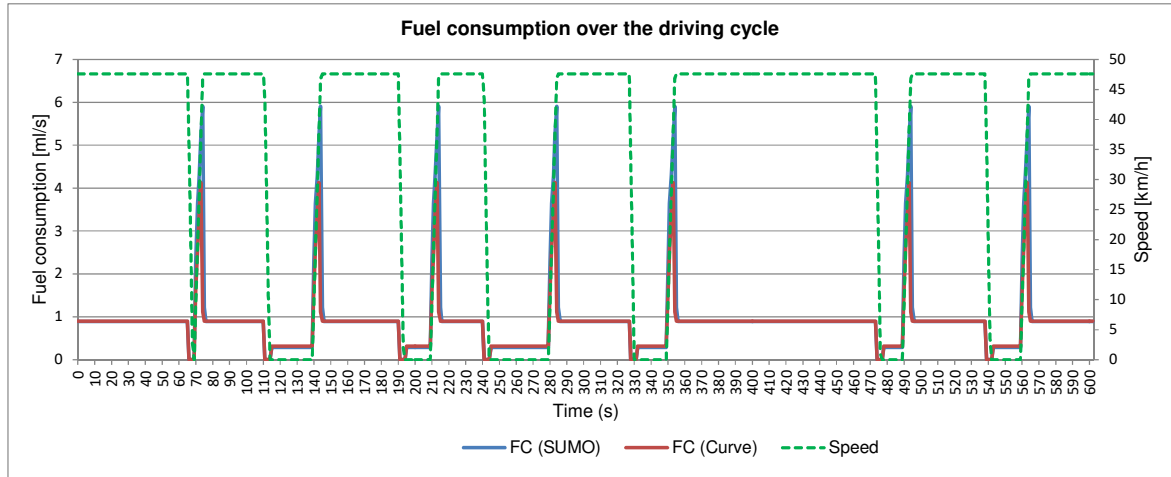


Figure 9. PC_G_EU4 Fuel consumption over driving cycle. Sumo and theoretical model results comparison

The theoretical model diverges from Sumo results during high-acceleration periods. However, these acceleration periods do not represent the most periods of the driving cycle. Table 4 shows the accumulate fuel consumption by using both the theoretical and Sumo model. As shown the difference is ~10%.

Table 4. Accumulate fuel consumption values over the driving cycle

	Sumo	Theoretical model
Fuel consumption [ml]	504,60	559,09

4 Noise module

4.1 Resume

The noise module is an application created by using Python code which implements a theoretical model based on previous CE projects (IMAGINE³ and CNOSSOS⁴). The noise module has been integrated within the IMT as the other individual modules.

Noise is one of most significant issues which affect population health and comfort, and which is directly related to road traffic, mostly in urban areas (where the most of world population lives). Due to this strongly relation it is necessary to characterize the noise associated with road traffic. Sumo allows the user to calculate the noise associated to a road traffic line.

SUMO also offers the possibility of characterize the noise of the road, which is treated as a noise source line⁵. There is no different between HBEFA results and PHEM-lights results in terms of noise due to implemented noise models in the tools are based on the Harmonoise method, which do not take into account different classification that both models (HBEFA and PHEM) implement for each type of vehicles. The noise model, as it is explained in the theoretical noise model, just takes into account the fleet definition in terms of type of vehicles: passenger cars, heavy cars. A novel ***theoretical model based on CNOSSOS has been developed within REMEDIO and it is detailed in the explanation of the noise theoretical model (implemented in the noise module after validation)***.

Main advantages of the noise module integrated within REMEDIO IMT in comparison with SUMO noise calculations are the following:

- Noise emission analysis based on fleet of vehicles.
- Sensitivity analyses of the following parameters:
 - Road surface influence
 - Ambient temperature influence
 - Road gradient influence

SUMO uses the “Harmonoise Engineering Model” developed in the context of CE IMAGINE **Errore. L'origine riferimento non è stata trovata.** project, to determine the noise level of the edges⁶, these edges are divisions of the completed analysed road, this way SUMO characterises the acoustics of a traffic flow, based on the directional source sound power levels of single moving equivalent vehicles. No more information can be extracted from

³ https://ec.europa.eu/research/fp6/ssp/imagine_en.htm

⁴ An harmonized method developed in the framework of CE projects HARMONOISE and IMAGINE.

⁵ In the Harmonoise Engineering module, the road line is treated as a source line which characterises the the particular traffic flow of the road.

⁶ In the Harmonoise Engineering module, the road line is treated as a source line which characterises the particular traffic flow of the road.

SUMO tutorial **Errore. L'origine riferimento non è stata trovata.** . So, to be able for controlling variables of influence in the noise models, the interest in implementing an acoustical theoretical model based on CNOSSOS⁷

The traffic noise is characterized as the noise pressure level (dB) calculated by edge of the traffic line.

From the noise module it is possible to obtain noise pressure levels in dB, associated to the traffic fleet driving along the road, by edge; by typology of vehicles and also normed noise results (normed values per 100meters length of edge), since edge lengths are different, in order to compare results under different operating points, resuming in different edges conditions, it seems to be more representative to compare normalized results for comparing different exposure zones of the same evaluated scenario. All results are obtained for three periods (L_{day} , $L_{evening}$ and L_{night}) and also a totalized value for the all day (L_{DEN}). This is very useful since legislation⁸ establish limits for two of these values: L_{DEN} and L_{night} .

4.2 Methodology

For the development of the noise module a progressive implementation of the CNOSSOS theoretical model⁹ has been carried out. This implementation is explained in section 4.3.

The followed methodology for obtaining the road traffic noise, emitted by vehicles driving along the simulated scenario, is shown in figure below:

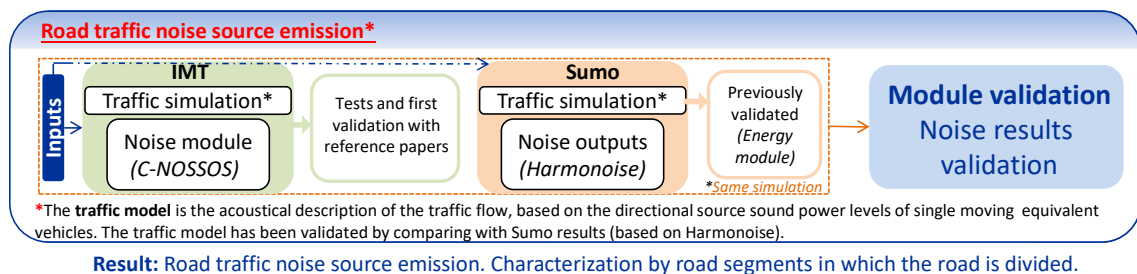


Figure 10. Road traffic noise methodology

As it is shown in the figure the followed steps for implementing the module are:

1. Collect **Inputs** data for **traffic simulation** in Sumo: Zone definition and traffic definition.
2. Simulation of the **traffic flow** in Sumo. From this simulation we obtain the totalized traffic noise based on the "Harmonoise Engineering Model"¹⁰ per

⁷ An harmonized method developed in the framework of CE projects HARMONOISE and IMAGINE.

⁸ European Parliament and Council of the European Union – 2002 – Assessment and management of environmental noise (EU Directive).

⁹ Kephelopoulous, S., Paviotti, M., & Anfosso-Lédée, F. (2012). Common Noise Assessment Methods in Europe (CNOSSOS-EU). <https://doi.org/10.2788/31776>.

¹⁰ "Van Leeuwen, H., & Nota, R. (2003). The harmonoise engineering model. Acta Acustica (Stuttgart), 89(SUPP.), 358–361". Authors represents DGMR Consulting Engineers BV, one of the partners of the CE project IMAGINE.

edge. Nevertheless this result does not take into account the following parameters: ambient temperature, road gradient and road surface influence.

3. Collect **inputs** needed by the proposed theoretical model implemented in the noise module:

- i. Global data: average temperature and hour for each period. This data should be introduced by the user of the IMT (*user interface*). From user interface the IMT generates XML files and the noise module takes required data from these files.

1.Global data (h, T)

```
<Period>
  <Day hours='12' T='20' />
  <Evening hours='4' T='20' />
  <Night hours='1' T='20' />
</Period>
```

- ii. Spatial definition: slope and road surface are two parameters to be introduced by the user of the IMT (*user interface*). If these values are not introduced the module would consider that there is no road gradient and a typical surface.

2.Spatial definition((from user)slope, road surface)

```
<edges>
  <edge id="1" slope="0" road surface="0" />
</edges>
```

- iii. Traffic inputs: flow of vehicles per category. This is an input that is needed by the traffic simulation (first step of this methodology) but also by the noise module. This data should be introduced by the user of the IMT (*user interface*) at the beginning of the process.

3.Traffic inputs

Flow of vehicles per category

- iv. Spatial definition: Once the IMT has taken from user the zone definition (nodes coordinates, number of lanes, position of traffic lights...), the IMT provides the Noise modules needed data which is required by the model.

4.Spatial definition(Sumo)

Road edges length; distance to traffic light, crossing...; traffic lights position...

- v. Traffic output: from the traffic simulation the IMT generates an XML file which includes average speed of vehicles driving along different edges in which the road is divided in.

5.Traffic outputs

Driving cycle (Speed, travel time,...)

4. The **theoretical model** is fed by previous inputs and the model is apply to the traffic scenario.
5. Both results (**Sumo and theoretical model**) are compared for a reference scenario (not considering road gradient, ambient temperature neither road surfaces) in order to realize a first validation of the theoretical module to be implement.
6. Once both results have been compared achieving positive results, the module (including the theoretical model) is **finally validated** in the test city of Treviso, achieving very promising results.

4.3 Noise model within the IMT

4.3.1 Objective Modelling variable

The noise module calculates the directional sound power per meter per frequency band¹¹ of the traffic noise determined by the source line, “The road traffic noise”.

4.3.2 Theoretical model

The following table summed up the variables of influence in the theoretical noise model integrated within the IMT.

Table 5: Variables of influence in the acoustical source model

ID	VI	Definition	Availability
1	m	Category of vehicle	Introduced by user
2	Ai	A-weighting correction for 1/3 octave band results.	Tabulated and implemented in tool IEC-61672-1
3	length _{line}	Legth of the evaluated source line	Calculated by the tool from nodes previously introduced by user.
4	Q _m	Traffic flow (vehicles per hour)	Introduced by user
5	V _m	Average speed per category of vehicle (km/h)	Calculated by the tool from the interaction with SUM.
6	V _{ref}	Reference speed per category of vehicle (km/h)	Fixed value, 70 km/h.
7	x	Distance in meters from the end of line to the nearest intersection (traffic light or roundabout).	Calculated by the tool from net data

Calculation procedure is shown below:

The directional sound power of the traffic noise:

$$L_{w',line} = 10 \cdot \log \left(\sum_m 10^{\frac{L_{w',line,m}}{10}} \right) \quad (4-1)$$

Where

m Category of the vehicle and bus line¹² indicator.

L_{w',line,m} The directional sound power per metre per category of vehicle of the traffic noise.

¹¹ CNOSSOS is valid for determining Noise in frequency range from 125 Hz to A kHz for road traffic noise. Calculations are made in octave bands.

¹² It is not possible the evaluation of buses in conjunction, due to particular traffic characteristics of each bus-line.

The directional sound power per category of vehicle of the traffic noise:

$$L_{w',line,m} = 10 \cdot \log \left(\frac{\text{length}_{line}}{1000} \cdot 10^{\frac{L_{w',m}}{10}} \right) \quad (4-2)$$

Where

$L_{w',m}$ The directional sound power per line per category of vehicle of the traffic noise.

length_{line} Legth of the evaluated source line.

The directional sound power per metre per category of vehicle of the traffic noise:

$$L_{w',m} = 10 \cdot \log \left(\sum_i 10^{\frac{L_{w',m,i} + A_i}{10}} \right) \quad (4-3)$$

Where

$L_{w',m,i}$ The directional sound power per metre per category of vehicle per frequency band of the traffic noise. The CNOSSOS-EU method is valid for frequency range from 125 Hz to 4kHz.

A_i A-weighting correction according to **IEC-61672-1**.

Table 6 A-weighting correction according to IEC-61672-1

Frequency (Hz)	31,5	63	125	250	500	1kHz	2kHz	4kHz	8kHz	16kHz
A_i (dB)	-39,4	-26,2	-16,1	-8,6	-3,2	0	1,2	2	-1,1	-6,6

Calculations are performed in octave bands. Based on these 1/3 octave band results, the A-weighted sound pressure level $L_{w',line,m}$ is computed by summation over all frequencies.

The directional sound power per meter per category of vehicle per frequency band of the traffic noise:

$$L_{w',m,i} = L_{w,m,i} + 10 \cdot \log \left(\frac{Q_m}{1000 \cdot V_m} \right) \quad (4-4)$$

Where

$L_{w,m,i}$ Instantaneous directional sound power per category of vehicle per frequency band of a single vehicle.

Q_m Traffic flow (vehicles per hour).

V_m Average speed per category of vehicle (km/h).

Instantaneous directional sound power per category of vehicle per frequency band of a single vehicle

$$L_{w,m,i} = 10 \cdot \log \left(10^{\frac{L_{w,m,i,R}}{10}} + 10^{\frac{L_{w,m,i,P}}{10}} \right) \quad (4-5)$$

Where

$L_{w,m,i,R}$ Instantaneous directional sound power per category of vehicle per frequency band of a single vehicle.

$L_{w,m,i,P}$ Instantaneous directional propulsion noise produced by the driveline (engine, exhaust) of the vehicle, per a category of vehicle per frequency band of a single vehicle.

Instantaneous directional rolling Noise:

$$L_{w,m,i,R} = A_{m,i,R} + B_{m,i,R} \cdot \log \left(\frac{V_m}{V_{ref}} \right) + \Delta L_{W,R,i,m} \quad (4-6)$$

Where

$A_{m,i,R}$, $B_{m,i,R}$ Rolling noise coefficients per category of vehicle per octave band center frequency.

$\Delta L_{W,R,i,m}$ Correction on rolling due to specific road or vehicle conditions deviating from the reference conditions.

1. Rolling noise coefficients per category of vehicle per octave band center frequency:

Table 7 Rolling noise coefficients per category of vehicle

Frequency (Hz)	$A_{m,i,R}$					$B_{m,i,R}$				
	1	2	3	4a	4b	1	2	3	4a	4b
125	85,7	88,7	91,7	0	0	41,5	35,8	33,5	0	0
250	84,5	91,5	94,1	0	0	38,9	32,6	31,3	0	0
500	90,2	96,7	100,7	0	0	25,7	23,8	25,4	0	0
1000	97,3	97,4	100,8	0	0	32,5	30,1	31,8	0	0
2000	93,9	90,9	94,3	0	0	37,2	36,2	37,1	0	0
4000	84,1	83,8	87,1	0	0	39	38,3	38,6	0	0

2. Correction on rolling due to specific road or vehicle conditions deviating from the reference conditions:

$$\Delta L_{W,R,i,m} = \Delta L_{W,R,road,i,m} + \Delta L_{W,R,acc,i,m} + \Delta L_{W,R,temp,i,m} \quad (4-7)$$

Instantaneous directional propulsion Noise:

$$L_{w,m,i,P} = A_{m,i,P} + B_{m,i,P} \cdot \frac{V_m - V_{ref}}{V_{ref}} + \Delta L_{W,P,i,m} \quad (4-8)$$

Where

$A_{m,i,P}, B_{m,i,P}$ Propulsion noise coefficients per category of vehicle per octave band center frequency.

$\Delta L_{W,P,i,m}$ Correction on propulsion noise due to specific road or vehicle conditions deviating from the reference conditions.

1. Propulsion noise coefficients per category of vehicle per octave band center frequency:

Table 8 Propulsion noise coefficients per category

Frequency (Hz)	$A_{m,i,P}$					$B_{m,i,P}$				
	1	2	3	4a	4b	1	2	3	4a	4b
125	89,2	96,5	100,6	87,5	97,2	7,2	4,7	3	7,4	5,9
250	88	98,8	101,7	89,5	92,7	7,7	6,4	4,6	9,8	11,9
500	85,9	96,8	101	93,7	92,9	8	6,5	5	11,6	11,6
1000	84,2	98,6	100,1	96,6	94,7	8	6,5	5	15,7	11,5
2000	86,9	95,2	95,9	98,8	93,2	8	6,5	5	18,9	12,6
4000	83,3	88,8	91,3	93,9	90,1	8	6,5	5	20,3	11,1

2. Correction on propulsion due to specific road or vehicle conditions deviating from the reference conditions:

$$\Delta L_{W,P,i,m} = \Delta L_{W,P,road,i,m} + \Delta L_{W,P,acc,i,m} + \Delta L_{W,P,temp,i,m} \quad (4-9)$$

4.3.3 Implementation of the model – Procedure for codifying

The theoretical model for calculating the road traffic noise in the IMT (noise module) has been implemented in Python code. The followed methodology to generate different files in the noise module (IMT procedure) is explained below.

The noise module tool developed is divided in four different files: L_{day} , $L_{evening}$, L_{night} and L_{den} .

- L_{day} , $L_{evening}$, L_{night} : These files calculate the directional sound power of the traffic noise under day, evening and night conditions based on methodology purposed within CNOSSOS-EU (Kephalopoulos et al., 2012) for the calculation of $L_{Aeq,LT}$ under different scenarios, marking out the relevance of traffic characteristics and road geometrical distribution in obtained results.

- L_{den} : This file calculates the indicator for the combination of day, evening and night conditions. The END¹³ requires Member States to limit values for L_{den} and L_{night} and, when it is appropriate, for L_{day} and $L_{evening}$. These indicators are established the same way as $L_{Aeq,LT}$ but particularizing conditions for each periods, so if exposed scenarios follows same traffic distribution, meteorological conditions and road geometrical distribution, exposed values could be compared to threshold values in order to establishes or not mitigation measures or purpose other design specifications for the road in the urban planning stage. If we do not consider attenuation effects due to propagation, the equivalent noise level due to a traffic source at a receiver point is the same than the noise level of the traffic flow. This means that $L_{Aeq,LT}$ is equal than $L_{w',line}$ for day, evening and night periods.

L_{day} , $L_{evening}$ and L_{night} values are calculated as follow:

Inputs data:

- Per period, edge and category of vehicle the following inputs are required for the calculation of the equivalent noise level:

¹³ European Parliament and Council of the European Union – 2002 – Assessment and management of environmental noise (EU Directive).

Edge	9	
<u>Input data:</u>		
Vref (km/h)	70	70km/h CNOSSOS
Vm (km/h)	50,0243478	Vehicle speed = 3,6*lenght/traveltime
m	1	vehicle class
T (°C)	20	Annual average temperature
k	1	(=1(crossing); =2(roundabout))
Slope (%)	0	The slope of the road gradient (should not vary more than 2% within a segment)
Qm (veh/h)	633	Traffic flow: Vehicles per category m per hour en el tramo
Lain legh (m)	79,9	Se toma del archivo NET
<u>Road surface (Insert number "1" to select the road surface)</u>		
Transversely brushed concrete	0	
Concrete with surface dressing 2/4	0	
Exposed aggregated	0	
Drain asphalt 6/16	0	
2-layer drain asphalt 4/8-11/16	0	
SMA 0/6	0	
Surface dressing 4/8	0	
x	0	Associated to traffic light and roundaboutDistance from the end of the edge to the nearest traffic light or roundabout.
y	0	Associated to bus stops. If a bus line is analyzed, this variable takes the value of 10 in the next edge to that where a bus stop is placed. Otherwise the value is 1000

Figure 11. Input data per period, per vehicle and per edge of the road – Excel files

- Values recovered in Figure 11 are includes in tables per edge, for all vehicles categories. These tables are used by a Excel macro in order to realize a loop that takes values per row and copy them into the cells shown in **Errore. L'origine riferimento non è stata trovata.** Calculations are realized per iteration in the loop, obtaining $L_{w',line,m}$ (The directional sound power per category of vehicle of the traffic flow).

Intermediate calculations:

The directional sound power per category of vehicle per frequency band of the traffic noise is calculated taken into account rolling and propulsion noise coefficients as well as correction factor associated to rolling and propulsion conditions. An average value is calculated considering A-weighting factors associated to considered frequency bands and the time spent by vehicles in the road section considered by taken into account velocity and flow of vehicles of the specific category of vehicles.

No correction for category Category 4: Powered two-wheeler

Input data

x m

k 1 6 2

m

	k	k
	1	2
	Crossing	Roundabout

Coefficients for acceleration and deceleration

Category m	CR	CR2
1	-4,5	-4,4
2	-4	-2,3
3	-4	-2,3
4	0	0

Coefficient selection

	Hz	$\Delta L_{wr,cc,i,m}$
CORRECTION	125	-0,1755
	250	-0,1755
	500	-0,1755
	1000	-0,1755
	2000	-0,1755
	4000	-0,1755

The correction term is attributed to all octave band

Figure 14. Traffic light and roundabouts - Rolling correction coefficients – Example

No correction for category Category 4: Powered two-wheeler

Input data

Vm km/h

Slope %

m vehicle category

	m	
$\Delta L_{wp,grad,i,m}$	1	s < -6 % -6 % <= s <= 2 % s > 2 %
	1	0 0 1,666666667
	2	s < -4 % -4 % <= s <= 0 % s > 0 %
	0	0 0 3,5
	3	s < -4 % -4 % <= s <= 0 % s > 0 %
	0	0 0 4,375

Coefficient selection

	Hz	$\Delta L_{wp,grad,i,m}$
CORRECTION	125	1,7
	250	1,7
	500	1,7
	1000	1,7
	2000	1,7
	4000	1,7

The correction term is attributed to all octave band

Figure 15– Road gradient - Propulsion correction coefficients – Example

No correction for category Category 4: Powered two-wheeler

Input data

x m

k 1 6 2

m

	k	k
	1	2
	Crossing	Roundabout

Coefficients for acceleration and deceleration

Category m	CP1	CP2
1	5,5	3,1
2	9	6,7
3	9	6,7
4	0	0

Coefficient selection

	Hz	$\Delta L_{wp,cc,i,m}$
CORRECTION	125	4,4
	250	4,4
	500	4,4
	1000	4,4
	2000	4,4
	4000	4,4

The correction term is attributed to all octave band equally

Figure 16. Traffic light and roundabouts - Propulsion correction coefficients – Example

Once corrections factors have been calculated for different rolling and noise conditions, two global corrections factor are calculated per frequency band: a rolling correction factor and a propulsion correction factor. Both factor are implemented in the calculation of the

directional sound power of the traffic line, as it is shown in Figure 12. The following table shows values of rolling and propulsion correction factors, taken into account correction factor associated to different sound and propulsion conditions defined in figures above.

Hz	Rolling $\Delta L_{wR,i,m}$	Propulsion $\Delta L_{wP,i,m}$
125	1,43190839	11,5666667
250	1,43190839	13,2333333
500	1,43190839	13,2333333
1000	0,33190839	13,2333333
2000	-3,06809161	13,2333333
4000	-3,86809161	13,2333333

Figure 17. Rolling and propulsion correction factors

Results

- $L_{w',line,m}$ (dB) calculated for each segment of the road. Same values are obtained for the other categories of vehicle in order to obtain the directional sound power of the traffic flow, taking into account the specific fleet of the traffic flow.
- $L_{w',line}$ (dB) associated to the traffic flow. This is equal to L_{day} , $L_{evening}$ or L_{night} (depending on the considered period of the day).

Example of day results:

Edge	Noise (dB)													Lday
	CAR	TRUCK		MOTO		BUS								
	m1	m2	m3	m4a	m4b	m3line3	m3line5	m3line6	m3line8	m3line33	m3line39	m3line78		
1	78,58	0,00	77,66	0,00	70,80	64,54	63,48	62,02	61,43	61,43	63,48	58,41	81,90	
10	71,32	0,00	70,40	0,00	63,53	57,19	56,22	54,74	54,16	54,16	56,22	51,15	74,64	
11	69,26	0,00	68,35	0,00	61,48	55,13	54,16	52,68	52,10	52,10	54,16	49,09	72,58	
12	76,22	0,00	79,39	0,00	64,84	66,27	65,30	63,85	63,27	63,27	65,30	60,26	81,78	
13	71,54	0,00	70,68	0,00	63,72	57,46	56,49	55,02	54,44	54,44	56,49	51,43	74,88	
14	73,53	0,00	76,70	0,00	62,15	63,58	62,61	61,16	60,58	60,58	62,61	57,56	79,09	
15	72,69	0,00	71,77	0,00	64,90	58,56	57,59	56,11	55,53	55,53	57,59	52,52	76,01	
16	76,44	0,00	79,61	0,00	65,06	69,22	68,24	66,79	63,49	63,49	65,52	63,21	82,27	
17	70,68	0,00	69,76	0,00	62,89	64,79	63,82	62,36	53,52	53,52	55,58	58,77	75,03	
18	77,11	0,00	80,28	0,00	65,73	67,16	66,19	64,74	64,16	64,16	66,19	61,15	82,67	
19	74,84	0,00	73,93	0,00	67,06	60,71	59,74	58,26	57,68	57,68	59,74	54,67	78,16	
2	75,59	0,00	78,77	0,00	64,22	65,65	64,68	63,22	62,64	62,64	64,68	59,63	81,15	
20	74,48	0,00	73,54	0,00	66,70	60,35	59,38	57,90	57,32	57,32	59,38	54,31	77,79	
21	74,37	0,00	77,55	0,00	63,00	64,43	63,46	62,00	61,42	61,42	63,46	58,41	79,93	
22	72,81	0,00	71,89	0,00	65,02	58,68	57,71	56,23	55,65	55,65	57,71	52,64	76,13	
23	73,79	0,00	72,87	0,00	66,01	59,66	58,69	57,21	56,63	56,63	58,69	53,62	77,11	
24	75,15	0,00	78,32	0,00	63,77	68,63	64,23	62,78	65,62	62,20	64,23	62,62	80,96	
25	69,86	0,00	69,24	0,00	61,84	64,68	55,07	53,59	61,67	53,01	55,07	58,66	74,12	
26	72,04	0,00	71,13	0,00	64,26	57,91	56,92	55,46	54,88	54,88	56,94	51,87	75,36	
27	73,32	0,00	72,40	0,00	65,53	59,19	58,20	56,74	56,16	56,16	58,21	53,15	76,64	
28	75,85	0,00	79,02	0,00	64,47	65,91	64,94	63,48	62,90	62,90	64,94	59,89	81,41	
29	72,22	0,00	71,31	0,00	64,44	58,08	57,11	55,64	55,06	55,06	57,11	52,05	75,54	
3	69,98	0,00	69,10	0,00	62,16	55,89	54,92	53,46	52,86	52,86	54,92	49,85	73,31	
30	74,47	0,00	77,64	0,00	63,09	64,53	63,56	62,10	61,52	61,52	63,56	58,51	80,03	
31	74,09	0,00	73,17	0,00	66,30	59,94	58,97	57,51	56,93	56,93	58,97	53,92	77,40	
4	74,48	0,00	73,56	0,00	66,69	60,35	59,38	57,92	57,32	57,32	59,38	54,31	77,80	
5	75,53	0,00	78,71	0,00	64,16	65,59	64,62	63,16	62,58	62,58	64,62	59,57	81,09	
6	74,09	0,00	73,18	0,00	66,31	59,96	58,99	57,53	56,93	56,93	58,99	53,92	77,41	
7	74,04	0,00	73,12	0,00	66,25	59,91	58,94	57,48	56,88	56,88	58,94	53,87	77,36	
8	69,09	0,00	68,92	0,00	60,71	60,26	54,77	53,30	57,26	52,71	54,77	54,25	73,00	
9	72,61	0,00	75,79	0,00	61,23	72,41	61,70	60,24	69,40	59,66	61,70	66,39	79,68	

Figure 18. The directional sound power per category of vehicle and per fleet of the traffic flow under day conditions – Excel example

Then, L_{den} is calculated:

Inputs data:

- Results of **L_{day}** , **$L_{evening}$** and **L_{night}** (dB) for each segment (edge of the traffic line) in which the road is divided.
- Duration of periods (day, evening and night) in hours.

Results:

- **L_{den}** (dB) calculated for each segment of the road.

Input data				Output data				
Period	Day	Evening	Night	Min			Average	Max
Hours	12	4	8	Lden (Db)	74,20	79,37	84,24	
Edge	Lday (dB)	Levening (dB)	Lnight (dB)	Edge	Lden (dB)			
1	81,90	80,26	74,37	1	83,52			
10	74,64	72,97	67,08	10	76,23			
11	72,58	70,94	65,06	11	74,20			
12	81,78	80,25	74,06	12	83,35			
13	74,88	73,24	67,35	13	76,49			
14	79,09	77,56	71,37	14	80,65			
15	76,01	74,37	68,48	15	77,62			
16	82,27	80,85	74,28	16	83,76			
17	75,03	73,79	66,47	17	76,37			
18	82,67	81,14	74,95	18	84,24			
19	78,16	76,52	70,64	19	79,78			
2	81,15	79,63	73,44	2	82,72			
20	77,79	76,14	70,26	20	79,40			
21	79,93	78,41	72,22	21	81,50			
22	76,13	74,49	68,60	22	77,74			
23	77,11	75,47	69,58	23	78,72			
24	80,96	79,53	72,99	24	82,46			
25	74,12	72,79	65,73	25	75,49			
26	75,36	73,72	67,84	26	76,98			
27	76,64	75,00	69,11	27	78,25			
28	81,41	79,89	73,69	28	82,98			
29	75,54	73,90	68,02	29	77,16			
3	73,31	71,67	65,78	3	74,92			
30	80,03	78,51	72,31	30	81,60			
31	77,40	75,76	69,88	31	79,02			
4	77,80	76,16	70,27	4	79,41			
5	81,09	79,57	73,38	5	82,66			
6	77,41	75,77	69,89	6	79,03			
7	77,36	75,72	69,83	7	78,97			
8	73,00	71,45	65,10	8	74,49			
9	79,68	78,66	70,46	9	80,87			

Figure 19. The directional sound power per category of vehicle and per fleet of the traffic under

day, evening and night conditions – Excel example

To sum up all this procedure is included in following scheme:

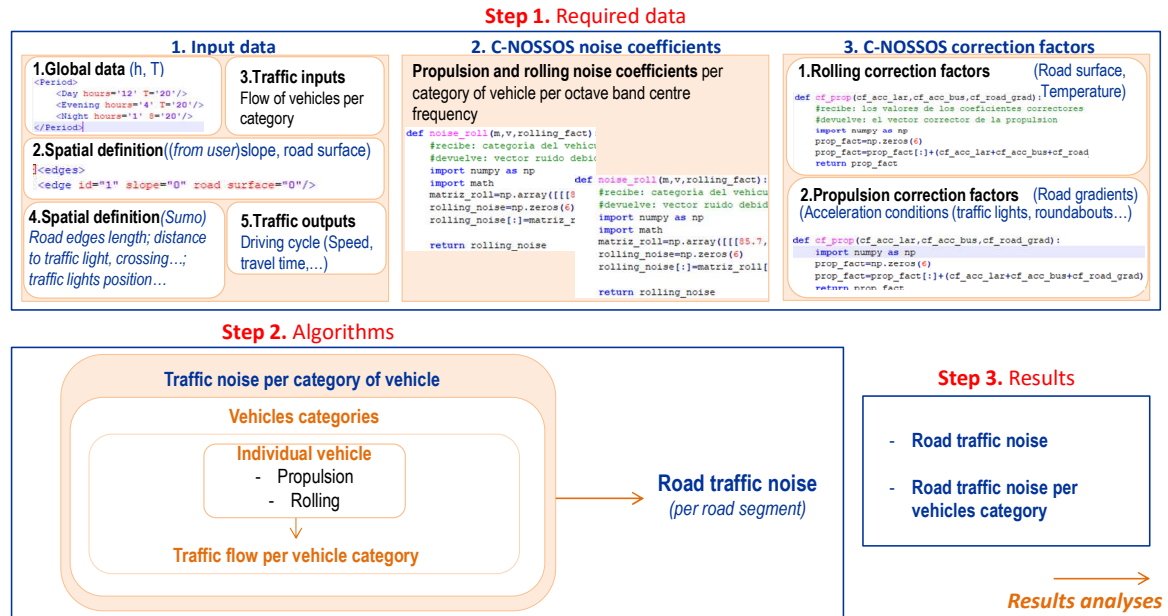


Figure 20. Followed procedure for implementing noise model in IMT.

4.3.4 Comparison with SUMO traffic results

The source line noise level is one of SUMO results and is the reference for comparison of our models. Followed procedure consists on determine the noise level per edge following the theoretical methodology and establish how to include geometrical and traffic parameters, defined in SUMO in the theoretical model in order to obtain accurate results, compared to SUMO results. Several tests have been done in order to test the theoretical described model for source noise. Tests consist on the comparison between SUMO and theoretical model results for simple traffic models. Similar results should be achieved by both methods since they are based on HARMONOISE model.

4.3.4.1 Testing 1

Objective: Verify the correct implementation of edges intersection (traffic lights and roundabouts) in the theoretical traffic model

Table 9. Testing 1. Inputs.

Net	Thessaloniki road
Number of edges	31 (traffic lights: 2,5,9, 12, 14, 16, 18)
Category of vehicle and	m=1 (Q=633 vehicles/h)

flow	
V _m	Calculated from edge lengths and travel time of the vehicle in the edge (SUMO output)
Other variables of influence	Default values

Table 10. Testing 1. Results

Noise (dB)		Error (%)	
SUMO	Theoretical Model	Average	Max
71,2348	69,9036	2,72%	5,81%

Conclusions:

- Medium speed reduction is not taken into account in the correction due to a traffic light or a roundabout.
- Just the noise correction factor due to acceleration and deceleration is taken into account in the correction.
- No correction in rolling conditions is realized in SUMO
- The end of the edge is taken as reference for the calculation of the x distance.

4.3.4.2 Testing 2

Objective: Verify the correct implementation of trucks.

Table 11. Testing 2. Inputs

Net	Thessaloniki road
Number of edges	31
Category of vehicle and flow	m=2,3 (Q=120 vehicles/h)
V _m	Calculated from edge lengths and travel time of the vehicle in the edge (SUMO output)
Other variables of influence	Default values

Table 12. Testing 2. Results m2

Noise (dB)		Error (%)	
SUMO (trucks)	Theoretical Model m2	Average	Max
74,2103	67,5435	8,95%	11,69%

Table 13. Testing 2. Results m3

Noise (dB)	Error (%)
------------	-----------

SUMO (trucks)	Theoretical Model m3	Average	Max
74,2103	70,2377	5,31%	8,09%

Conclusions:

- The vehicle category “truck” in SUMO corresponds with category m3 in the theoretical model.
- Correction factors implemented in the theoretical models delivers in lower noise level than the level obtained by SUMO model.

4.3.4.3 Testing 3

Objective: Verify the correct implementation of motorcycles.

Table 14. Testing 3. Inputs

Net	Thessaloniki road
Number of edges	31
Category of vehicle and flow	m=4a,4b (Q=168 vehicles/h)
Vm	Calculated from edge lengths and travel time of the vehicle in the edge (SUMO output)
Other variables of influence	Default values

Table 15. Testing 3. Results m4a

Noise (dB)		Error (%)	
SUMO (motorcycle)	Theoretical Model m4a	Average	Max
64,4661	63,4810	1,41%	11,39%

Table 16. Testing 3. Results m4b

Noise (dB)		Error (%)	
SUMO (motorcycle)	Theoretical Model m4b	Average	Max
64,4661	63,3689	1,64%	4,67%

Conclusions:

- The vehicle category “motorcycle” in SUMO corresponds with category m4b in the theoretical model.

- Correction factors implemented in the theoretical models delivers in lower noise level than the level obtained by SUMO model. *Idem trucks.*

4.3.4.4 Testing 4

Objective: Verify the correct implementation of buses.

Table 17. Testing 4. Inputs

Net	Thessaloniki road
Number of edges	31 (No bus stop)
Category of vehicle and flow	m=2,3 (Q=168 vehicles/h)
Vm	Calculated from edge lengths and travel time of the vehicle in the edge (SUMO output)
Other variables of influence	Default values

Table 18. Testing 4. Results m4a

Noise (dB)		Error (%)		
SUMO (bus)	Theoretical Model m2	Average	Max	Min
75,8545	68,9850	9,02%	11,86%	5,23%

Table 19. Testing 4. Results m4b

Noise (dB)		Error (%)		
SUMO (bus)	Theoretical Model m3	Average	Max	Min
75,8545	71,6815	5,46%	8,31%	1,74%

Conclusions: *Idem trucks*

4.3.4.5 Testing 5

Objective: Verify the correct implementation of a combination of different categories of vehicles

Table 20. Testing 5. Inputs

Net	Pilot zone Thessaloniki
Number of edges	31
Category of vehicles and flow	Passenger cars, m=1 (Q=633 vehicles/h) Trucks, m=3 (Q=120 vehicles/h) Motorcycles, m=4b (Q=168 vehicles/h)

Vm	Calculated from edge lengths and travel time of the vehicle in the edge (SUMO output)
Other variables of influence	Default values

Table 21. Testing 5. Results

Noise (dB)		Error (%)		
SUMO	Theoretical Model m3	Average	Max	Min
71,3245	73,2297	3,64%	6,28%	-0,18%

4.3.4.6 Testing 6

Objective: Verify the correct implementation of bus stops

Table 22. Testing 6. Inputs

Net	Pilot zone Thessaloniki (Lane3)
Number of edges	31 (Bus stops: edges 8, 16 and 24)
Category of vehicles and flow	Buses, m=3 Period: 480s (Q=7,5 vehicles/h)
Vm	Calculated from edge lengths and travel time of the vehicle in the edge (SUMO output)
Other variables of influence	Default values

Table 23. Testing 6. Results

Noise (dB)		Error (%)		
SUMO	Theoretical Model m3	Average	Max	Min
60,2006	59,1883	1,68%	4,33%	-4,66%

Conclusions:

- Considering bus stop as a traffic light in terms of noise influence. $K=1$.
- Considering congestion issues in the bus stop next edge.

4.3.4.7 Testing Treviso¹⁴

The model has been tested progressively in order to analyse different variables of influences. Then, the IMT noise module has been applied to a traffic scenario in the city of

¹⁴ Test based on first provided inputs. This results may not reflect noise results associated to the last configuration of Thessaloniki pilot zone.

Treviso and results have been again compared with Sumo results in order to test the module taking into account numerous variables of influences. As it was explained in the methodology, the final validation of this module is based on the comparison of IMT results with real data in the test pilot road of Treviso.

Line number	freq (min)	t. time (min)	Bus stop position (GPS coordinates)	Maxi number of vehicles	1574	
				Average number of cars	Number	(km/h)
9	15	5	45°40'19.14"N - 12°13'52.83"E	0h-7h	1049	>50
4	30	2	45°40'39.25"N - 12°14'16.43"E	7h-9h	2396	40-50
4	30	2	45°40'40.67"N - 12°14'16.90"E	9h-13h	5292	30-40
4	30	2	45°40'46.82"N - 12°14'23.95"E	13h-15h	2556	40-50
4	30	2	45°40'48.86"N - 12°14'25.50"E	15h-17h	2701	30-40
4	30	2	45°40'59.00"N - 12°14'35.01"E	17h-19h	2814	0-30
4	30	2	45°41'01.07"N - 12°14'37.01"E	19h-22h	2948	40-50
4	30	2	45°41'13.73"N - 12°14'46.37"E	22h-24h	1079	>50
4	30	2	45°41'21.75"N - 12°14'54.28"E	(average persons/car)	1,3	
4	30	2	45°41'33.99"N - 12°15'05.62"E	Nº of Motrobikes //trucks	295	2329
4	30	2	45°41'36.22"N - 12°15'06.99"E			

Figure 21. Inputs data for traffic simulation in Thessaloniki
Inputs data were provided by partners on July 14th 2017.

Figure 23 represents noise values emitted by the source line along different edges in which the road is divided.

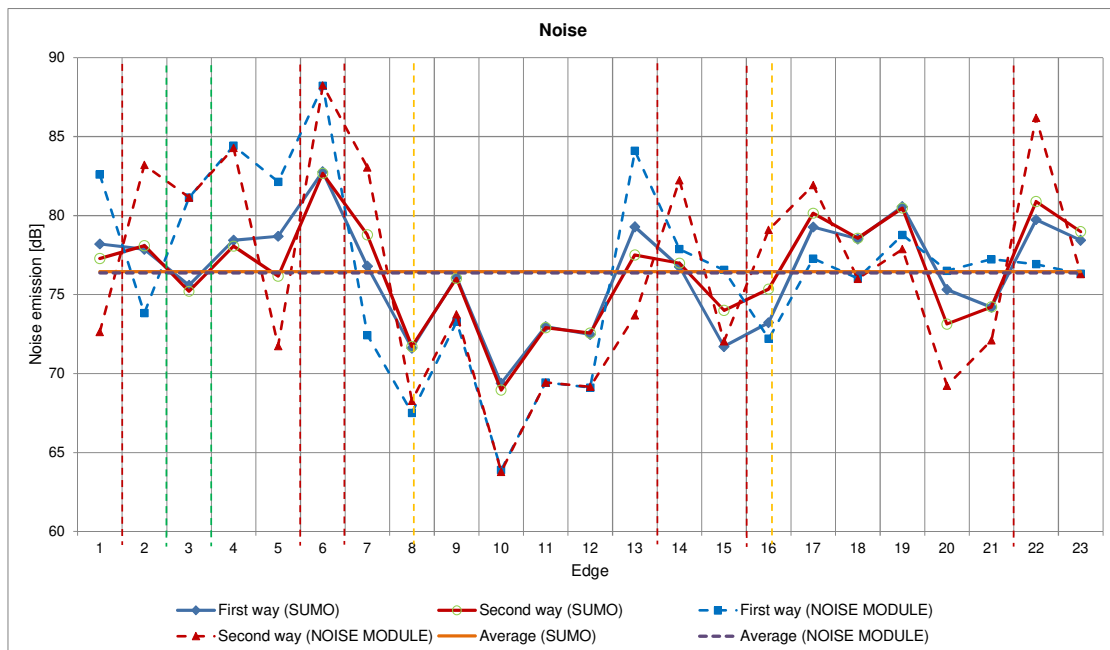


Figure 22. Noise by edge – IMT noise results for day, evening and night period

As it is represented within Figure 23, the noise emission level decreases when the traffic flow is reduced, as it is the case of the night period. Otherwise, Figure 22 shows how the noise level is increased in edges represented through yellow lines. These edges are those where a traffic light or a bus stop is located. Traffic lights and stops result in periods of

acceleration and deceleration, which are corrected though propulsion and rolling correction factors in the model implemented.

As its observed results obtained by IMT module and Sumo are very closed each other. Accuracy between both models is included in following table.

Table 24. Comparing IMT module and Sumo. Testing Treviso

Directional sound power of the traffic noise (<i>source lines</i>)						
Model	Average value [dB]		Max value[dB]		Min value [dB]	
<i>Sumo</i>	76,449		82,780		68,960	
<i>IMT module</i>	76,376		88,245		63,778	
Differences						
	Average		Max		Min	
	[dB]	[%]	[dB]	[%]	[dB]	[%]
<i>S-C</i>	0,123	0,1608	5,497	7,1902	-6,223	-8,1400

Despite the promising accuracy versus sumo results show in the above table, a validation through comparison of the IMT results with real data is necessary. This process is described in deliverable 3.4.1.

The previous table shows a good accuracy between both models (Sumo vs IMT), and from these tests we've concluded the following IMT noise module advantages vs Sumo:

- Noise emission analysis based on fleet of vehicles (Sumo does not calculate road traffic noise per category of vehicles, just a noise value associated to de road segment).
- Sensitivity analyses of the following parameters:
 - Road surface influence
 - Ambient temperature influence
 - Road gradient influence
- Evaluation of strategies for reducing noise emission levels.

4.4 Noise modules results

IMT provides the following noise results (data and graphs):

Road noise emission per edge:

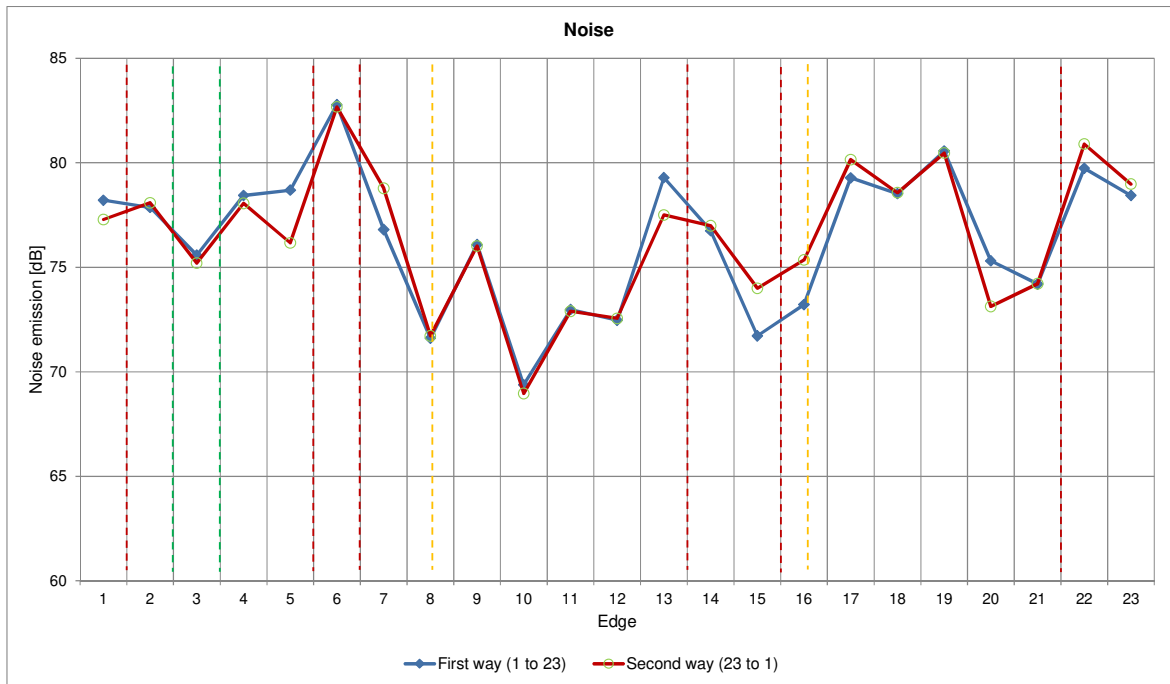


Figure 23. Noise module results – Road noise emission per edge
Normalized noise emission per edge

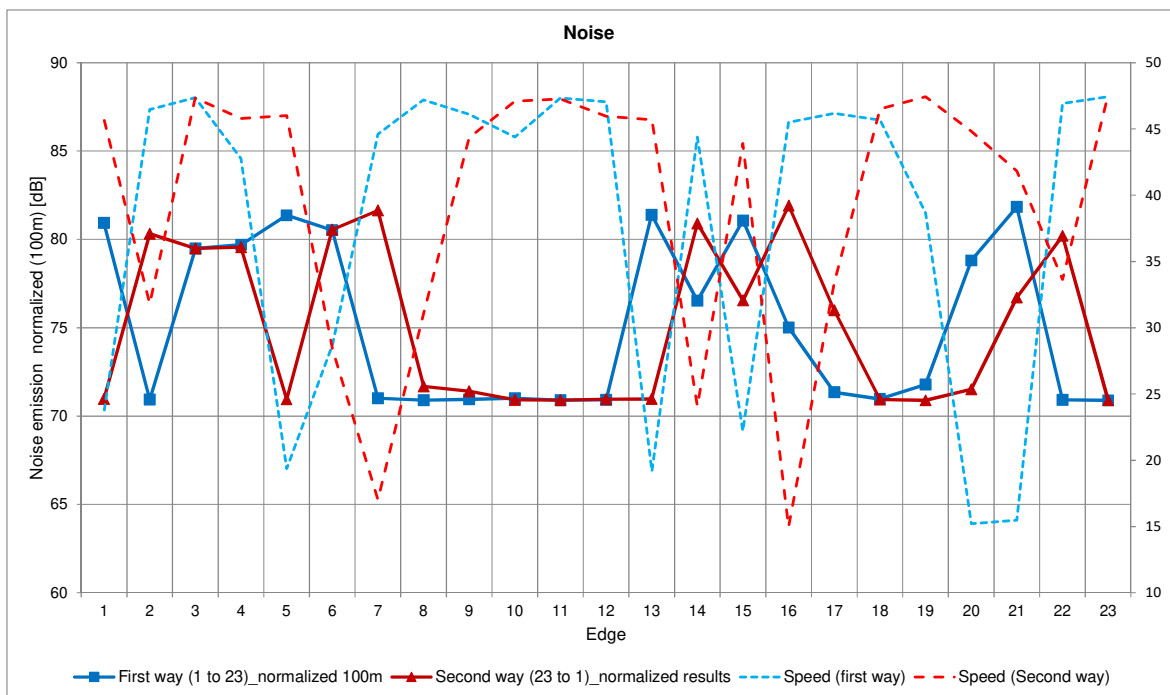


Figure 24. Noise module results – Normalized road noise emission per edge
Road noise emission per edge and typology of vehicle:

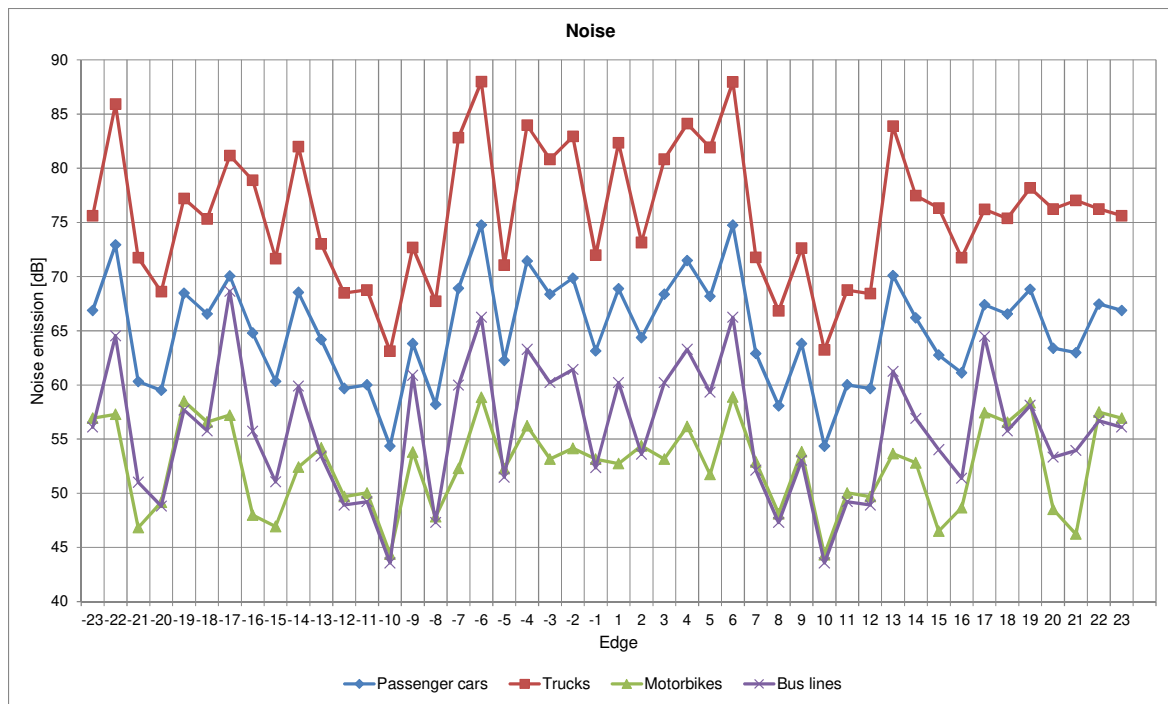


Figure 25. Noise module results – Road noise emission per edge and typology of vehicle

The IMT will generate a report including previous graphs and a brief explanation of them. Apart from this report, all results are available for the user in XML files.

5 Atmospheric pollution emission & carbon footprint module

5.1 Introduction

Atmospheric pollutant emissions and carbon footprint are estimated using a simplified version of the vehicle emission model PHEM (Passenger Car and Heavy Duty Emission Model). This simplified version, named PHEMlight, was developed within the COLOMBO project (Deliverable D4.2) (Hausberger & Krajzewicz, 2014) and it is embedded into SUMO.

PHEMlight estimates emissions of NO_x, HC, CO, PM as well as carbon footprint (CO₂) based on vehicle data to be entered for various driving cycles on basis of characteristic emission curves and vehicle longitudinal dynamics.

The main input parameters needed for the emissions computations are emission class, speed, acceleration and slope of the road. The emission class comprises information on the vehicle category and size, the technology and the emission standard. A detailed description of the methodology used and the emission classes is given in the following paragraphs.

5.2 Methodology

The methodology of the emissions computations requires, at first, the estimation of maximum acceleration and engine power. The latter depends on vehicle parameters, speed, acceleration and slope of the road.

The formula for calculating the driving power in the cycle depends on the following power demands:

- Power needed to overcome the rolling resistance
- Power needed to overcome the air resistance
- Power needed for desired acceleration
- Power to overcome the road gradient.

All the equations of the aforementioned power demands as well as the aggregated driving power have already be given in Chapter 3.

After the calculation of engine power, the power demand for acceleration is extracted from the method to compute the overall power (see equation 3-4, Chapter 3). In the following, the maximum acceleration is estimated using the maximum power demand available for acceleration $P_{a,max}$ (see equation 3-6, Chapter 3) and vehicle parameters:

$$a_{max} \left[\frac{m}{s^2} \right] = \frac{P_{a,max} \cdot 1000}{(m_{curb} \cdot \Delta + m_{loading} + m_{rot,wheels}) \cdot v} \quad (5-1)$$

where,

Λ is the rotating mass factor calculated by linear interpolation from a polygon (eq. 3-5, Chapter 3),

m_{curb} is the vehicle curb weight (kg)

m_{loading} is the vehicle loading

$m_{\text{rot,wheels}}$ is the equivalent rotational mass of wheels (kg)

Furthermore, the next step for the emissions calculations requires the vehicle data and emission handling. The PHEMLight database includes the following input data:

1. Vehicle and engine specifications (.veh)
2. Emission curves (.csv)
3. Fuel consumption curve (_FC.csv)

The vehicle parameters including data such as the road load coefficients, mass, loading etc. are included in the .veh input files of PHEMLight database describing all the vehicle and engine specification for each emission class.

The emission classes in PHEMLight, compromise information on the shape, weight and default loading of a vehicle as well as engine related properties, for example rated power, fuel type and most important the actual emission class (EU1, EU2 etc.)

In particular, emission classes based on the vehicle category and size are listed below:

- Passenger Cars (PC)
- Light Commercial Vehicles (differentiation into size classes according to legislation (N1-I, N1-II, N1-III); size class I (LCV_I) $RM < 1305\text{kg}$; size class II (LCV_II) $1305\text{kg} < RM \leq 1760\text{kg}$; size class III (LCV_III) $1760\text{kg} < RM \leq 3500\text{kg}$; "RM": reference mass (approx. Vehicle curb weight))
- Heavy Duty Vehicles - rigid trucks (HDV_RT) ; size class I 2 axle trucks; size class II 3+ axle trucks
- Heavy Duty Vehicles - truck + trailer (incl. articulated trucks = tractor + semitrailer) (HDV_TT)
- Heavy Duty Vehicles - city bus (HDV_CB)
- Heavy Duty Vehicles – coach (HDV_CO)

Furthermore, the emission classes categorized in the following technologies:

- Gasoline engine (conventional powertrain) (G)
- Diesel engine (conventional powertrain) (D)
- Gasoline engine (parallel hybrid powertrain) (G_HEV)
- Diesel engine (parallel hybrid powertrain) (D_HEV)
- Compressed Natural Gas engine (CNG)
- Battery electric vehicles (BEV)

Finally, the classification according to emission standards is as following : EU0, EU1, EU2, EU3, EU4, EU5, EU6, EU6c.

The emission and fuel consumption data files contain emission and fuel consumption levels for the whole range of normalized power demands. PHEMlight uses characteristic emission curves which define the emission amount [g/h] as function of the actual engine power of the vehicle. The generation of the specific emission curves has been effected directly over PHEM. For these a driving cycle was calculated with PHEM and the calculated emissions were rasterized over normalized engine power areas into a characteristic curve.

The emissions are interpolated from emission curves in the normalised format according to the current engine power output. In particular, the normalization process is required to combine several vehicles and emission behaviours into one average vehicle per PHEM emission class. Further, it allows varying vehicle weight, rated power and driving resistances without adopting the characteristic emission curve, what makes PHEMlight easily extendable to varying vehicle parameters. Moreover, this process is done differently for heavy and light vehicles. The two different principles are:

1. Normalization over rated power (NRP) for HDV
2. Normalization over critical power (NCP) for PC and LCV

5.3 Input/Output xml files

The emission and carbon footprint module requires as input the vehicle type distribution according to the classification of PHEMlight as described in paragraph 5.2. The distribution of the vehicle types according to PHEMlight classification is inserted in the model through the rou.xml file. For example, in case of a passenger car with gasoline engine and EURO4 emission standard, the user has to define the emission class in rou.xml file (Vtypes) as following: emissionClass="PHEMlight/PC_G_EU4"

All the input traffic data required for the emissions computations are described in detail in Chapter 9 (9.5.1.6)

An edge based vehicular emission output file writes absolute and normed values of vehicular pollutant emissions collected on edges. The absolute values hold the sum of each of the pollutants emitted on each edge, the normed values give the values normed by the interval duration and the edge's length. Thus, for each vehicle type, an output file is generated for the whole simulation period including the following output data:

- edge id
- sampledSeconds (s): number seconds vehicles were measured on the edge (may be subseconds if a vehicle enters/leaves the edge), this value is the sum of the measured times of all vehicles

- traveltime (s): time needed to pass the edge/lane, note that this is just an estimation based on the mean speed, not the exact time the vehicles needed
- poll_abs (mg): Pollutant emissions by the vehicles on this edge during the aggregation period
- poll_normed (g/km/hr): Pollutant emissions during this interval normed by time and edge length
- poll_perveh (mg): Assumed pollutant emissions a vehicle would produce when passing the edge

Moreover, an emission output file is also generated for every simulation timestep for every vehicle. It includes the following information :

- id of the vehicle
- eclass: the emission class of the vehicle
- poll (mg/s): the amount of pollutant emitted by the vehicle in the actual simulation step
- type: the name of the vehicle type
- waiting (s): the time the vehicle is waiting
- speed (km/h): the speed of the vehicle
- angle (degree): the angle of the vehicle
- pos_x, pos_y: the absolute X,Y coordinates of the vehicle, the values depend on the given geographic projection

where poll="CO", "CO2", "NOx", "PMx", "HC".

References

Hausberger & Krajzewicz, 2014. Cooperative Self-Organizing System for low Carbon Mobility at low Penetration Rates. COLOMBO: Deliverable 4.2. Extended Simulation Tool PHEM coupled to SUMO with User Guide.

PHEMLight User Guide Version 1. Passenger Car and Heavy Duty emission model. Technische Universität Graz. Erzherzog-Johann-Universität^[1]INSTITUT FÜR VERBRENNUNGSKRAFT -MASCHINEN UND THERMODYNAMIK.

Online user Documentation

http://sumo.dlr.de/wiki/SUMO_User_Documentation

6 Freight Streamlining Module

6.1 Summary

The Freight module (FM) simulates the impacts in terms of number and type of vehicles of specific scenarios regarding freight deliveries in the road segment/section to be studied, by maintaining the level of service (m³ of cargo transported). These specific scenarios can include: change in vehicle type; vehicle downsizing; changes in delivery hours; introducing of alternative technologies; and optimization of load factors.

6.2 Model description

The simulation of freight demand in a specific case studies requires a detailed characterization of the current situation, based on statistics, traffic counts or surveys.

Figure 26 presents the detailed description of the inputs variables required fr each case study.

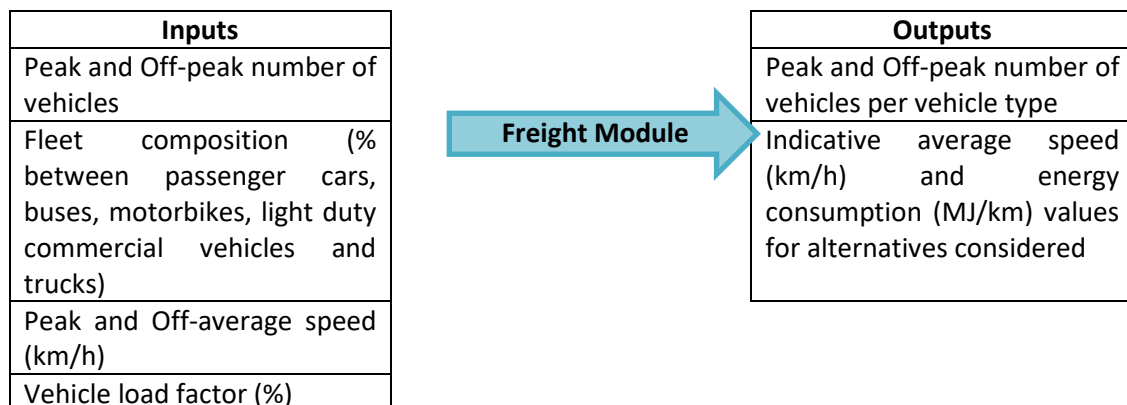


Figure 26 – Input and Output variables for the freight module

The FM is implemented through a .xlsx file as presented in Figure 27

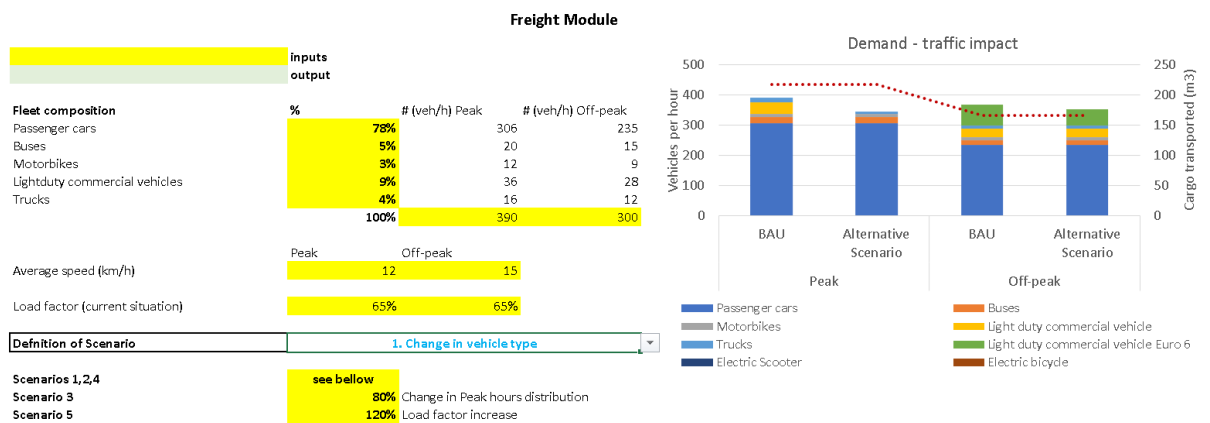


Figure 27 – Schematics of the freight module

The different scenarios that can be assessed include:

1. **Changes in vehicle type**, corresponds to the possibility of changing the type of vehicle that is performing the deliveries.
2. **Vehicle downsizing** corresponds to the option of performing deliveries using smaller vehicles, in order to enable better traffic circulation conditions and try to increase the vehicle load factors.
3. Alternatives that do not affect the total demand in terms of freight vehicle in the case study area can include **change in delivery hours** (from peak to off-peak hours) or new business models that restructure operation in deliveries.
4. **Introducing alternative technologies** in order to use more energy efficient vehicle technologies, with improved performances also in terms of local pollutants emissions and noise.
5. Optimization of freight deliveries (e.g. through deployment of ICT) to enable **higher vehicle load factors**, requiring less vehicle entering the area.

6.3 Freight module interaction within the IMT

The FM provides new traffic demand values (vehicle counts in vehicle per hour in peak and off-peak periods) per vehicle type that can be incorporated by IMT, if these vehicle categories are modelled. This output for IMT can be provided in a .txt file.

7 Air pollution dispersion module

7.1 Resume

The VADIS model was selected to be included in the IMT to simulate the dispersion of pollutants based on the traffic and emissions estimation by the previous modules of the tool. The dispersion module outputs can be visualized in the IMT for air quality assessment and/or to evaluate the impacts of emission reduction scenarios.

7.2 Model description

VADIS model, developed at the University of Aveiro, allows the calculation of urban street-canyon air pollution due to road traffic emissions and the estimation of local hot spots, particularly under unfavourable dispersion condition such as thermal stability and low wind speeds (Borrego et al. 2000)¹⁵. This model supports multiple obstacles and source definition and the characterization of time-varying flow fields and emissions.

VADIS structure is based on two modules, FLOW and DISPER. The first module, FLOW, uses the numerical solution of the three-dimensional (3D) Reynolds averaged Navier–Stokes equations and the k- ϵ turbulence closure to calculate the wind, turbulent viscosity, pressure, turbulence and temperature 3D fields. The second module, DISPER, applies the Lagrangian approach to the computation of the 3D pollutant concentration field using the wind field estimated by FLOW. In Figure 26 the input and output data of each module are presented, including pre and post processors.

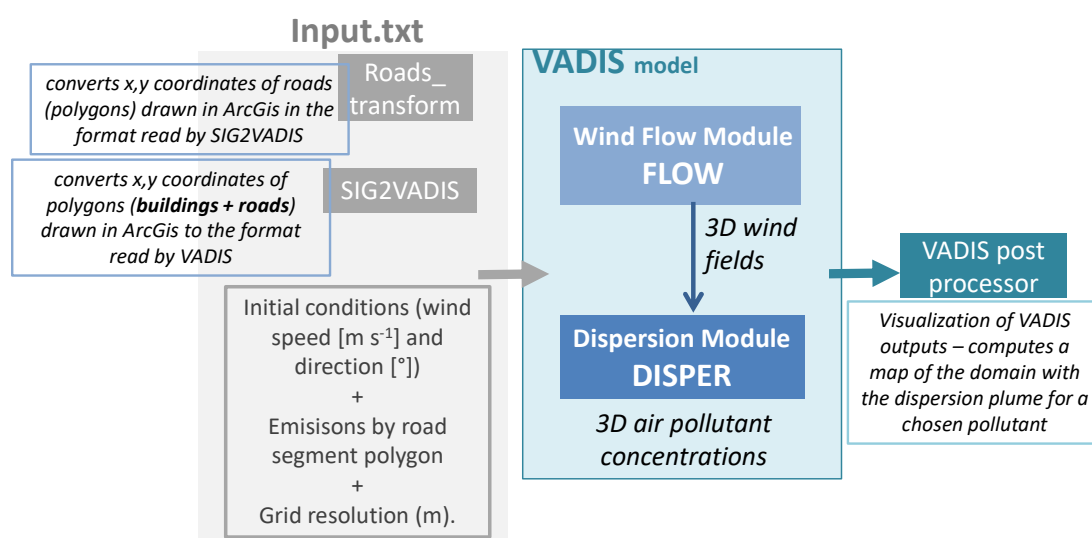


Figure 28. Input-output structure of VADIS - Pollutant dispersion in the atmosphere under variable wind conditions.

¹⁵ 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.

As input, VADIS requires information that allows to characterise the meteorological conditions, the simulation domain, and the emissions for the considered period of time. The meteorological conditions that have to be defined are basically the wind velocity and direction at the entrance of the domain at a specified reference height and the air temperature. As VADIS uses a structured mesh, complex buildings have to be previously divided in parallelepiped sections. The relation of this approximated form with the original one depends on the cell resolution used. The buildings can be aligned or in angle with the cartographic grid.

The input data required to run the VADIS model is compiled in a file always called "input.txt" based on user defined parameters and two preprocessors, as shown in Figure 26. This file defines the simulation domain, indicating the cartographic grid dimensions, wind direction, obstacles and sources position and dimensions and emission rates:

Grid dimension – includes the length, width and height of the domain (in meters), the horizontal and vertical grid resolution (in meters), and the total number of horizontal and vertical cells. The domain size should follow the best practices guidelines for the CFD simulation of flows in the urban environment pointed by the COST Action 732, which set that for urban areas with multiple buildings the top of the computational domain should be 5 Hmax away from the tallest building with height Hmax.

Wind direction – wind velocity (m s^{-1}) and direction (degrees) at the entrance of the domain at a reference height (usually 10 m) and the air temperature (hourly data).

Obstacles and Sources –the number of obstacles presented in the domain should be identified, as well as, for each obstacle, the type (buildings or trees), coordinates and angle. As VADIS uses a structured grid, complex buildings have to be previously divided in parallelepipeds, which can be aligned or in angle with the cartographic grid. For each one, the 3D extreme coordinates are defined (inferior left corner and superior right corner 3D coordinates, in metric units), as represented in Figure 27, and the angle (0-90) between the obstacle and the grid.

Emission sources - the coordinates and angle of the emission sources; the emission rates, in kg per second, should also be provided. In the case of point emission, the inferior left corner and superior right corner 3D coordinates (in metric units), must not be distanced by more than 1 meter. It is possible to define multiple sources, with different positions, dimensions and emission rates.

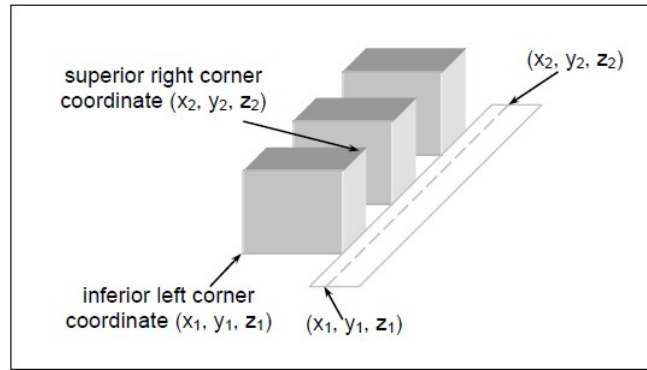


Figure 29. Definition of obstacles and sources coordinates.

7.3 VADIS model within the IMT

The VADIS model and its pre- and post-processors were adapted to be included in the REMEDIO IMT. Original files in fortran and python code were compiled in linux environment to create the executable files of all the programs suitable to the IMT.

At present, the IMT is able to upload an input.txt file provided by the user and run the dispersion module. The creation of the input.txt file within the tool is under development. It will be based on the results of the traffic module and emissions module, the outputs of the preprocessors and additional information provided by the user following the guidelines (IMT manual) that will be provided.

8 Health and Cost module. Health

8.1 Introduction

Short-term exposure to air pollution is known to be associated both with mortality and hospitalization events.¹⁻⁴ Many studies have reported the short terms effect of particular matters (PM), $< 10 \mu\text{m}$ in aerodynamic diameter (PM10) and $< 2.5 \mu\text{m}$ in aerodynamic diameter (fine, PM2.5) on mortality and hospitalizations for cardiovascular and respiratory diseases, such as heart failure, ischemic heart disease and respiratory tract infection.⁵⁻⁷ The occurrence of the above-mentioned health outcomes is known to be linked to exposure to other air pollutants, such as ozone, nitrogen dioxide and sulfur dioxide.⁸⁻¹⁰ Furthermore, several cohort and case-control studies have indicated a higher risk for lung cancer in association with different measures of exposure to ambient air pollution.¹¹⁻¹³

The goal of Health Module (HM) is to provide information on the number of health events that can occur given a certain level of concentration of several air pollutants. At the time, four air pollutants are considered in HM: PM2.5, PM10, NO₂, and O₃. Given to concentration of these four pollutants, HM is now able to estimate the number of health events related to cardiac, respiratory and cerebrovascular diseases in the short-term exposure, i.e., mean exposure in a range of 3 days maximum. Furthermore, HM can also inform the user on the occurrence of lung cancer given the long-term exposure, i.e., the yearly average exposure.

To provide such information to IMT users, additional information on seasonal trends, holidays, temperature and barometric pressure are taken into account, due to the known effects that previously mentioned variables could have on health outcomes.^{14,15} HM embeds all this information using Generalized Additive Models (GAMs), statistical models able to flexibly relate air pollution, temperature, seasonal trends, the barometric pressure to the health events. Using GAMs, HM can provide an estimation of a daily number of health events for all the time simulated by IMT.

In summary, HM provides information on the number of health events given the IMT parameters that regulate simulate traffic situations pre-specified by the user. HM will be then able to support the user in the decision-making process, by providing the potential implications on health events that could arise in several simulated scenarios. Estimated health outcomes will be the integrated into the Cost Module (CM), considering them as the inputs for the CM. Thus, more information on the economics implications of health effects of air pollution will be then available, helping the IMT users to understand how they can act to optimize the costs associated to health outcomes.

8.2 Modules setup and assumptions

Daily summary data are the gold-standard in modeling health-related environmental variables as pollution. HM uses historical data to assess inference on health based on actual simulation outcomes. To achieve the best performance, historical data are needed spanning at least one year of complete hourly data. If they are provided daily, HM will suppose constant levels for each variable of interests within each day. In case of missing data, HM will adopt the NOCB (next observation carried backward) strategy to fill them. This way, in the extreme case of totally missing information, i.e., historical data are not provided at all, the same strategy will assure the execution of the module considering one year of the same hourly levels (i.e., equal to the simulated ones) for each variable involved.

8.3 XML input/output definition

The package can be installed on GitHub (<https://github.com/UBESP-DCTV/imthcm>). It is continuously tested on Linux machines with the current version of R (3.4) and the develop one by Travis (<https://travis-ci.org/>). Instruction in the README file.

In the folder `inst/test_xml/` there is an example of input data (i.e., `test_event_history.xml` for historical data about the events, `test_weather_history.xml` for historical data about pollutants and weather conditions in the area and `test_weather_new.xml` for the weather and pollutant condition passed for the prediction of events (e.g., output of the simulation)).

In the folder `inst/modules`, there are the main modules file, which automatically loads the package (if installed) and the necessary auxiliary package. The scripts are completely runnable on a linux machine following the instruction on the README file inside the folder. The program `hm.R` can predict one or more simulation at a time (depends of the number of record of the `test_weather_new.xml` provided).

At the beginning of the file, and here below in the corresponding section, there is the instruction to run the script from the command line.

Documentation for the function in the package is provided with the package itself by the standard R help (i.e., `?<function_name>`).

The health module provides both XML with tabular results and figure output (a type of figure depends on the extension of the filename provided to the function and is automatically detected)

8.4 Core functions description

HM module works on two type of information: historical information and information of the day simulated by IMT. Historical information is used by HM as training set for the GAM models, which are the statistical tools employed to predict health events. HM is then able

to estimate, using trained GAM models, the number of health events on the day of interest, i.e. the one simulated by IMT.

Historical information is provided in the form of two datasets: one dataset containing historical data on the number of health events of interest and one dataset containing historical data on environmental information. The first dataset must have as many rows as the number of days of the historical data and 8 columns containing the following variables:

- Date of the day
- Daily number of deaths for all causes until the previous day of the simulated one
- Daily number of deaths for cardiac diseases until the previous day of the simulated one
- Daily number of deaths for respiratory diseases until the previous day of the simulated one
- Daily number of deaths for cerebrovascular diseases until the previous day of the simulated one
- Daily number of hospitalizations for cardiac diseases until the previous day of the simulated one
- Daily number of hospitalizations for respiratory diseases until the previous day of the simulated one
- Daily number of hospitalizations for cerebrovascular diseases until the previous day of the simulated one

The second dataset must have as many rows as the number of days of the historical data and 7 columns containing the following variables:

- Date of the day
- Daily average concentration of PM_{2.5} in $\mu\text{g}/\text{m}^3$ until the previous day of the simulated one
- Daily average concentration of PM₁₀ in $\mu\text{g}/\text{m}^3$ until the previous day of the simulated one
- Daily average concentration of PMNO₂ in $\mu\text{g}/\text{m}^3$ until the previous day of the simulated one
- Daily average concentration of PMO₃ in $\mu\text{g}/\text{m}^3$ until the previous day of the simulated one
- Daily average temperature in C° until the previous day of the simulated one
- Daily average barometric pressure in hPa until the previous day of the simulated one

At least three days of historical data before the simulated day are request, but to obtain minimum performance at least one week each month for the previous year are needed. Anyway, if possible full year of historical data, possibly for more than one year should be provided.

Information on the simulated day includes only environmental data and it must be provided in the same form of historical environmental information.

HM proceeds with a pre-process phase on input data by computing the lagged concentration of air pollutants, i.e. the average daily concentration of pollutants of the simulated day and the previous historical days. HM considers lag 0-3 concentration, that is the mean of daily detected concentration of pollutants of the simulated day and the 3 previous days. This information is used by GAM models to predict the number of health events.

After the pre-processing phase, HM trains GAM models on historical data. The goal of the training phase is to make the models able to learn the relationship between environmental data and health events. Once the relationship is learned, the models will be capable of estimating the number of outcomes of interest.

Three different GAM models are trained on historical data, in order to take into account the different effects that pollutants can have on health outcomes during different periods of the year. GAM models are characterized as follows:

- a “Summer Model” (SM), which predicts the number of health outcomes during the summer period, i.e. the period that goes from 04/01 to 09/31.
- a “Non-Summer Model” (NSM), which predicts the number of health outcomes during the non-summer period, i.e. the period that goes from 01/01 to 03/31 and from 10/01 to 12/31.
- A “Full-Year Model” (FYM), which predicts the number of health outcome during all the period of the year.

All the three models assumed that the number of events follows a Poisson distribution and they consider the following covariates, i.e. the variables that impact outcome predictions:

- an interaction between the year, the month and the day of the week
- the daily average temperature in C°
- the daily average barometric pressure in hPa
- the lag 0-3 PM2.5 concentration

The first variable gives the effect that seasonal trends can have on health event predictions. The second and third variables control for the impact that temperature and barometric pressure can have on the outcomes. Both are modeled with penalized splines, in order account for the non-linear relationship between the variables and the outcomes. The fourth variable include the effect that lagged concentration of pollutants can have on health outcomes. Only one pollutant is considered, given the high correlation between them (especially between PM2.5, PM10 and NO₂). In this way, the effect that the variation of one pollutant can have on health outcomes can summarize the effect of the variation of all the other pollutants. Each model has a correction for overdispersion, i.e. the possibility that a large number of health events is observed during in any day.

The main difference between the models relies in the fact that SM considers simultaneously both the effect of PM2.5 and O₃, whereas the NSM considers only the effect of PM2.5. This distinction has been made since O₃ has a significant effect on health outcomes only during the period that goes from the start of April to the end of September. Furthermore, FYM, that considers only lagged PM2.5 concentration, is used as alternative in case of no information on O₃ is provided.

After the training step, HM estimates the number of daily average health events. Each estimate is provided with relative 95% Confidence Interval (CI), which expresses the uncertainty surrounding the estimate. At the moment, HM is able to provide insights on the following health outcomes:

- Short term, i.e. same day (incidence cases of)
 - o Death (any causes);
 - o Death (cardiac);
 - o Death (respiratory)
 - o Death (cerebrovascular);
 - o Hospitalization (cardiac);

- Hospitalization (respiratory);
- Hospitalization (cerebrovascular)

The previous mentioned HM outcomes are then used by CM as inputs information.

The workflow of HM has been implemented using the following core functions, coded in R:

- *weather_lag*: compute the lagged average daily concentration of a pollutant.
- *weather_preproc*: pre-processing of environmental data to be taken as inputs by GAM models.
- *train_event_models*: train GAM models on historical data in order to make them able to predict the daily average number of health events.
- *predict_hm*: trained GAM models predict the daily average number of health events with relative 95% CI.

In addition to the previous mentioned functions, there are two more functions that plot the estimates of HM. These functions are:

- *plot_pred_event_outcomes*: show the number of average daily predicted events for every considered health outcome
- *plot_pred_event_outcomes_time*: show the average daily predicted number of health events in function of the time

These graphical functions help to user to visualize and to better understand the trend of the health outcome events given a certain level of concentration of several pollutants.

8.5 Executable usage and options

Usage:

```
hm.R [((--weather=<weather_history> --events=<events_history.xml>) | --default) --new=<weather_new> --output=<output.xml> --figures=<figures_path> --single]
```

Options:

-w <weather_history> --weather=<weather_history> historical weather informations
[default: weather_history.xml]

-e <events_history.xml> --events=<events_history.xml> historical events informations
[default: events_history.xml]

-d --default flag to use default italian weather and events data

-n <weather_new> --new=<weather_new> new weather informations
[default: weather_new.xml]

-o <output.xml> --output=<output.xml> tabular output file [default: hm_output.xml]

-f <figures_path> --figures=<figures_path> zip file containing pictures [default: hm_figures.png]

-s --single
time smooth pattern

flag to save a windowed daily plot [default: TRUE] or

9 Health and Cost module. Cost

9.1 Introduction

An individual cost is associated to each health outcome. Individual cost can be decomposed in two parts: a part related to medical costs and a part related to indirect costs, i.e. all the costs that do not cover health care procedures.

The module is able to use default costs stored into it or take a set of customized costs for each health outcome.

At the moment, default costs are available for two type of health outcomes: hospitalizations for cardiac diseases and hospitalizations for respiratory diseases. Costs associated to cardiac hospitalizations are those related to Costs for Coronary Heart Disease (CHD) and stroke, while cost associated to respiratory hospitalizations are those related to Chronic obstructive pulmonary disease (COPD).

Costs for Coronary Heart Disease (CHD) and stroke were derived from the report of the American Heart Association ¹⁶ (which reported data on costs derived from the Medical Expenditure Panel Survey (MEPS) of the U.S. Agency for Healthcare Research and Quality), considering 2015 data. Unitary costs (medical, indirect, and total) have been calculated by dividing the projected number of CHD and strokes by the corresponding projected costs (for 2015) (Table 1).

Costs for COPD were derived from the paper of Fen et al ¹⁷, they were represented only by medical costs and referred to the year 2010. Also COPD costs reported in the paper were derived from the MEPS survey (Table 25). Cost estimates are based on an exchange rate EUR-USD of 1.233.

Table 25. Costs for CHD and Stroke

	Year	Mecial costs		Indirect costs		Total *	
		US\$	Euro	US\$	Euro	US\$	Euro
CHD	2015	5286.35	4287.39	5874.38	4764.29	11160.74	9051.69
Stroke	2015	4903.90	3977.21	3955.19	3207.77	8859.08	7184.98
COPD	2010	710	575.83	–	–	710	575.83

9.2 Core functions description

CM module uses HM output to provide information about the costs of related health outcomes. CM is able by default to provide costs related to hospitalizations for cardiac diseases and hospitalizations for respiratory diseases.

The workflow of CM has been implemented using the following core function, coded in R:

- *compute_cost*: compute the costs associated to each predicted health outcome with relative 95% CI.

This function takes as input a dataset, which should be the output dataset from HM, structured as described in the HM section.

The function computes the costs associated to the predicted health outcome, with relative 95% CI, of cardiac and respiratory hospitalizations. The computation is performed by multiplying the individual costs for the predicted average daily number of health events. Thus, an estimate of the average daily costs associated to the predicted health events of the simulated days is provided. For cardiac hospitalizations, default individual costs were derived as the crude mean between individual costs for stroke and CHD. The naïve approximation of cardiac health costs was done because HM is not able to provide by default insights on the proportion of cardiac hospitalizations associated to each type of cardiac diseases. Regarding respiratory hospitalizations, only medical costs are considered by the default function because of the lack of indirect cost for COPD.

The output of the function consists into a dataset composed by a number_days times m rows (where number_days is the number of simulated days whose prediction of health events are computed by HM, and m is the number of health events for which individual costs data are provided (2 by default)). The columns contains respectively: the date of the simulated day, the health outcomes, the currencies in which the costs are reported, the 95% CI lower bound of costs associated to a particular health events, the average daily costs associated to a particular health event and the 95% CI upper bound of costs associated to a particular health events.

In addition to the main function of CM, two more functions that plot the estimates of HM have been implemented. These functions are:

- *plot_cost*: show the number of costs associated to the average daily predicted events for a particular health outcome;
- *plot_cost_time*: show the costs associated to the average daily predicted events for a particular health outcome in function of the time

These graphical functions help the user to visualize and understand the trend of the economical burden associated to hospitalizations for cardiac and respiratory diseases for a given concentration of air pollutants.

9.3 Executable usage and options

Usage:

```
cm.R [--events=<predicted_events> (--costs=<costs_tables> | --default) --  
output=<output> --figures=<figures_path> --single]
```

Options:

-e <predicted_events> --events=<predicted_events> Predicted events (hm.R module)
[default: hm_output.xml]

-c <costs_table> --costs=<costs_table> Costs tables for the events predicted
[default: cost_data.xml]

-d --default flag to use default MEPS cost data

-o <output> --output=<output> tabular output file [default: cm_output.xml]

-f <figures_path> --figures=<figures_path> figure file (type based on the extension)
[default: cm_figures.png]

-s --single flag to save a windowed daily plot [default: TRUE] or time
smooth pattern

9.4 Future new feature

HM are going to support also the next health outcomes:

- Long term, i.e., one year
 - o Lung cancer

9.5 Software

For the integration into the IMT, HM and CM have been programmed in R (ver. 3.4 or greater).¹⁸ They are provided as one R-package and two R scripts fully executable on a Linux machine which R and the needed packages installed (tested on Ubuntu 16.04 LTS).¹⁹

9.6 References

1. Samoli E, Peng R, Ramsay T, Pipikou M, Touloumi G, Dominici F, et al. Acute effects of ambient particulate matter on mortality in Europe and North America: results from the APHENA study. *Environ Health Perspect.* 2008 Nov;116(11):1480–6.
2. Wichmann HE, Spix C, Tuch T, Wölke G, Peters A, Heinrich J, et al. Daily mortality and fine and ultrafine particles in Erfurt, Germany part I: role of particle number and particle mass. *Res Rep Health Eff Inst.* 2000 Nov;(98):5–86; discussion 87-94.

3. Stafoggia M, Forastiere F, Faustini A, Biggeri A, Bisanti L, Cadum E, et al. Susceptibility factors to ozone-related mortality: a population-based case-crossover analysis. *Am J Respir Crit Care Med*. 2010 Aug 1;182(3):376–84.
4. Chiusolo M, Cadum E, Stafoggia M, Galassi C, Berti G, Faustini A, et al. Short-Term Effects of Nitrogen Dioxide on Mortality and Susceptibility Factors in 10 Italian Cities: The EpiAir Study. *Environ Health Perspect*. 2011 Sep;119(9):1233–8.
5. Alessandrini ER, Faustini A, Chiusolo M, Stafoggia M, Gandini M, Demaria M, et al. [Air pollution and mortality in twenty-five Italian cities: results of the EpiAir2 Project]. *Epidemiol Prev*. 2013 Oct;37(4–5):220–9.
6. Powell H, Krall JR, Wang Y, Bell ML, Peng RD. Ambient Coarse Particulate Matter and Hospital Admissions in the Medicare Cohort Air Pollution Study, 1999-2010. *Environ Health Perspect*. 2015 Nov;123(11):1152–8.
7. Di Q, Dai L, Wang Y, Zanobetti A, Choirat C, Schwartz JD, et al. Association of Short-term Exposure to Air Pollution With Mortality in Older Adults. *JAMA*. 2017 26;318(24):2446–56.
8. WHO Regional Office for Europe. Review of evidence on health aspects of air pollution – REVIHAAP Project: Technical Report [Internet]. Copenhagen: WHO Regional Office for Europe; 2013 [cited 2017 Dec 10]. Available from: <http://www.ncbi.nlm.nih.gov/books/NBK361805/>
9. Sunyer J, Spix C, Quenel P, Ponce-de-Leon A, Ponka A, Barumandzadeh T, et al. Urban air pollution and emergency admissions for asthma in four European cities: the APHEA Project. *Thorax*. 1997 Sep;52(9):760–5.
10. Katsouyanni K, Schwartz J, Spix C, Touloumi G, Zmirou D, Zanobetti A, et al. Short term effects of air pollution on health: a European approach using epidemiologic time series data: the APHEA protocol. *J Epidemiol Community Health*. 1996 Apr;50(Suppl 1):S12–8.
11. Raaschou-Nielsen O, Andersen ZJ, Hvidberg M, Jensen SS, Ketzel M, Sørensen M, et al. Lung cancer incidence and long-term exposure to air pollution from traffic. *Environ Health Perspect*. 2011 Jun;119(6):860–5.
12. Hamra GB, Guha N, Cohen A, Laden F, Raaschou-Nielsen O, Samet JM, et al. Outdoor particulate matter exposure and lung cancer: a systematic review and meta-analysis. *Environ Health Perspect*. 2014 Sep;122(9):906–11.
13. Chen X, Zhang L, Huang J, Song F, Zhang L, Qian Z, et al. Long-term exposure to urban air pollution and lung cancer mortality: A 12-year cohort study in Northern China. *Science of The Total Environment*. 2016 Nov 15;571:855–61.
14. Stafoggia M, Forastiere F, Agostini D, Biggeri A, Bisanti L, Cadum E, et al. Vulnerability to heat-related mortality: a multicity, population-based, case-crossover analysis. *Epidemiology*. 2006 May;17(3):315–23.

15. Michelozzi P, de Donato F, Bisanti L, Russo A, Cadum E, DeMaria M, et al. The impact of the summer 2003 heat waves on mortality in four Italian cities. *Euro Surveill*. 2005 Jul;10(7):161–5.
16. Khavjou O, Phelps D, Leib A. Projections of cardiovascular disease prevalence and costs: 2015–2035 [Internet]. [cited 2018 Mar 31]. Available from: http://www.heart.org/HEARTORG/Advocate/Cardiovascular-Disease-A-Costly-Burden-for-America_UCM_491316_Article.jsp#.Wr_3Zohua2U
17. Ford ES, Murphy LB, Khavjou O, Giles WH, Holt JB, Croft JB. Total and state-specific medical and absenteeism costs of COPD among adults aged ≥ 18 years in the United States for 2010 and projections through 2020. *Chest*. 2015 Jan;147(1):31–45.
18. R Core Team. R: A Language and Environment for Statistical Computing [Internet]. Vienna, Austria: R Foundation for Statistical Computing; 2017. Available from: <https://www.R-project.org/>
19. Jonge E de. docopt: Command-Line Interface Specification Language [Internet]. 2016. Available from: <https://CRAN.R-project.org/package=docopt>

10.1 IMT platform development

The Integrating Modelling Tool (IMT) is a platform designed to integrate a traffic simulator and a set of executable modules that provide the possibility of analysing the impact of traffic on the population.

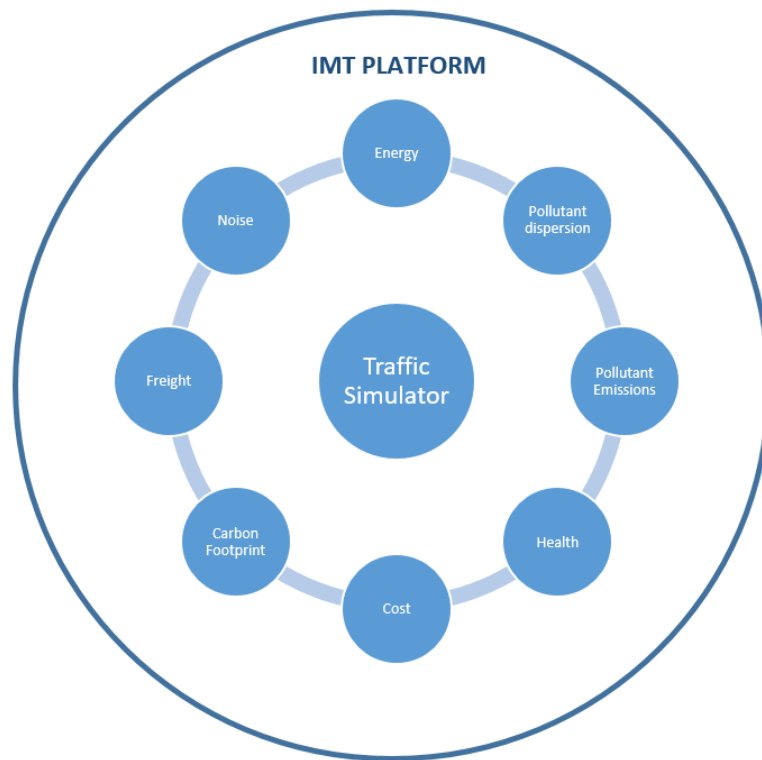


Figure 30. IMT platform concept

10.1.1 Platform programming

The IMT has been developed as a web application based on an architectural pattern known as Model-View-Controller (MVC). This kind of architectural pattern divides an application into three interconnected parts: Model, View and Controller. The image below shows the diagram of interactions within the MVC pattern:

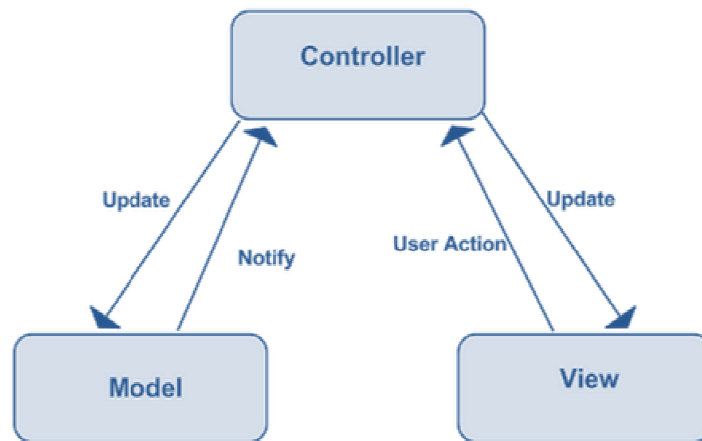


Figure 31. MVC pattern diagram (extracted from https://developer.chrome.com/apps/app_frameworks)

The components of MVC framework and the programming languages used for their development are presented below:

- **Model:** Contain a representation of data managed by the system. Implement the logic for the application's data domain. Often model objects retrieve and store model state in database. Responsible for managing the data of the application.

To model the data used, it has been employed MongoDB database. MongoDB is part of the new family of NoSQL database systems. Instead of storing data in tables as is done in relational databases, MongoDB stores data structures in JSON-like documents with a dynamic schema (MongoDB uses a specification called BSON), making data integration in certain applications easier and faster.

- **Views:** Components that display the application's user interface. Responsible for displaying information. It is the user's way of interacting with the platform.

To manage the view system, it has been employed CSS/ PUG languages. PUG is a JADE evolution, it is simpler than HTML but uses the same labels and tags. To modify the information shown in views, has been employed Javascript and Ajax.

- **Controller:** Components that handle user interaction, does the operations over the models to deliver the results of the query to the user. Ultimately select a view to render that displays user interface. Responsible for responding to user input and interaction.

To programming the controllers, it has been used NodeJS with Express framework. NodeJS is basically JavaScript server-side oriented, so is very easy to use. ExpressJS or Express, is a web application framework for NodeJS, released as free and open-source software under the MIT License. It is designed for building web applications and APIs. It has been called the facto standard server framework for NodeJS.

FIWARE SERVER:

The whole application is hosted on a FIWARE server.

FIWARE is a platform, driven by European Union, for developing applications of Future Internet. The Fiware platform provides a rather simple yet powerful set of APIs (Application Programming Interfaces) that ease the development of Smart Applications in multiple vertical sector.

TRAFFIC SIMULATOR:

For traffic Simulation, IMT integrates the software SUMO – Simulation of Urban MObility. Mainly developed by employees of the Institute of Transportation Systems at the German Aerospace Center, SUMO is an open source, microscopic, multi-modal traffic simulation.

10.1.2 Integrating the energy and noise modules. An example for the rest of modules

In this section, an example of integrating of Energy and Noise modules is presented. Both modules make use of outputs from traffic simulation as inputs. These modules are developed in Python, an interpreted high-level programming language. Through running these modules, the IMT users could study the traffic implications on fuel consumption and noise.

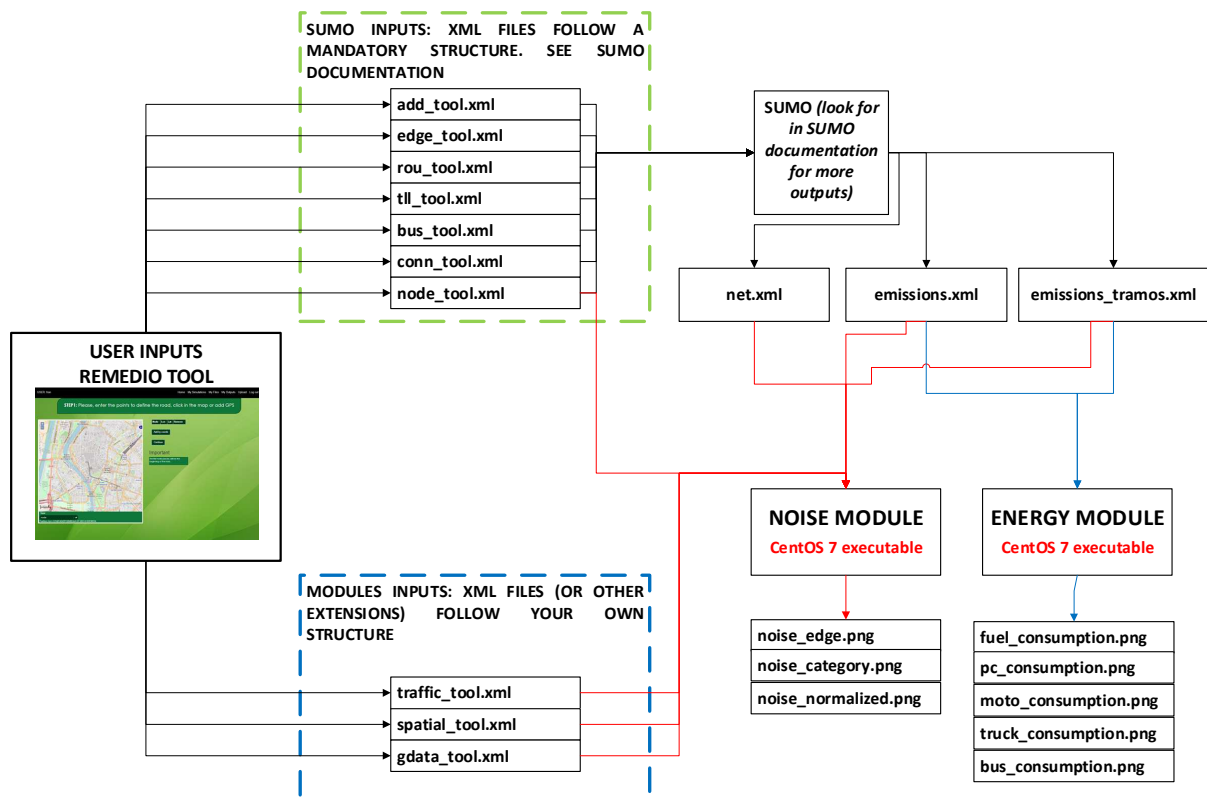


Figure 32. A general schema of Noise and Energy module operation

SUMO Inputs	XML extension files required for SUMO simulation. These files collect the information about the traffic entered by the user in the REMEDIO TOOL.
SUMO Outputs	XML extension files generated by SUMO. These files collect some information that you can use as inputs for your modules. It is important to analyse the SUMO documentation to detect some useful SUMO outputs for your modules.
MODULES Inputs	XML extension files (or other extensions files) required for your own module. These files collect some particular information entered by the user in the REMEDIO TOOL.

NOISE MODULE	
INPUTS	
SUMO INPUTS	node_tool.xml
SUMO OUTPUTS	net.xml
	emissions.xml
	emissions_tramos.xml
MODULES INPUTS	traffic_tool.xml
	spatial_tool.xml
	gdata_tool.xml
OUTPUTS	
	noise_edge.png
	noise_category.png
	noise_normalized.png

ENERGY MODULE	
INPUTS	
SUMO OUTPUTS	emissions.xml
	emissions_tramos.xml
OUTPUTS	
	Fuel_consumption.png
	pc_consumption.png
	moto_consumption.png
	truck_consumption.png
	bus_consumption.png

EXAMPLE OF MODULE INPUTS STRUCTURE

"traffic_tool.xml"

```
<edges>
  <edge id="1">
    <Passenger_Car m="1" Qm="500"/>
    <Medium_Heavy_Vehicles m="2" Qm="0"/>
    <Heavy_Vehicles m="3" Qm="170"/>
    <Powered_Two_Wheelers m="4" Qm="20"/>
    <Line_Bus id_bus="line_1" period="10" v="30" stop_lane="0"/>
    <Line_Bus id_bus="line_2" period="8" v="30" stop_lane="0"/>
  </edge>
  <edge id="2">
    <Passenger_Car m="1" Qm="500"/>
    <Medium_Heavy_Vehicles m="2" Qm="0"/>
    <Heavy_Vehicles m="3" Qm="170"/>
    <Powered_Two_Wheelers m="4" Qm="20"/>
    <Line_Bus id_bus="line_1" period="10" v="30" stop_lane="0"/>
    <Line_Bus id_bus="line_2" period="8" v="30" stop_lane="1"/>
  </edge>
  <edge id="3">
    <Passenger_Car m="1" Qm="500"/>
    <Medium_Heavy_Vehicles m="2" Qm="0"/>
    <Heavy_Vehicles m="3" Qm="170"/>
    <Powered_Two_Wheelers m="4" Qm="20"/>
    <Line_Bus id_bus="line_1" period="10" v="30" stop_lane="1"/>
    <Line_Bus id_bus="line_2" period="8" v="30" stop_lane="0"/>
  </edge>
  <edge id="4">
    <Passenger_Car m="1" Qm="500"/>
    <Medium_Heavy_Vehicles m="2" Qm="0"/>
    <Heavy_Vehicles m="3" Qm="170"/>
    <Powered_Two_Wheelers m="4" Qm="20"/>
    <Line_Bus id_bus="line_1" period="10" v="30" stop_lane="0"/>
    <Line_Bus id_bus="line_2" period="8" v="30" stop_lane="0"/>
  </edge>
</edges>
```

10.1.3 Traffic patterns

An attempt will be made to make an approximation of traffic patterns in the four cities with data available in the study: Seville, Thessaloniki, Treviso and Loures. These patterns are predefined within the IMT to allow 24 hours simulation. If traffic flow along the day is known for the IMT user, the data can be introduced in a user-defined mode to simulate the real daily pattern.

The measurements to develop the predefined patterns have been made using the Google Maps traffic tool. To do this, the following program colour code has been followed:

- Green: no deductions. Traffic in good condition.
- Orange: average traffic density. Acceptable traffic.

- Red: there are traffic stops. Traffic in bad conditions.
- Intense red: very slow, starting and stopping the cars. Traffic in poor conditions

Google Maps data has been collected for the streets studied within each of the cities and a weighting criterion has been established in which the maximum traffic per day would correspond to 100% of traffic and with a residual traffic value of 10%.

With the weighting values achieved, it has been observed that traffic on working days (Monday to Friday) does not correspond to weekend traffic (Saturday and Sunday) so it has been decided to make two patterns for the week. It has also been seen that the traffic varies for each city, although in some cases it looks quite similar, so it was decided to make two patterns to cover any differences that may exist. In total, we will have four skippers (two for Monday to Friday and two for Saturday and Sunday).

In order to make the patterns we have collected the average data of each city taking into account the weekly division described above and the average has been made. Three cases have been made:

1. Taking the average of the four cities.
2. Taking only the average data from Thessaloniki and Loures.
3. Taking only the average data of Seville and Treviso.

From the three described patterns, it is established that the second one adapts faithfully to reality and will be used without modification. Of the other two, an average will be made between the two because they separately show enough error when comparing it with the traffic of each of the cities. So, finally, you get the two patterns that we are going to use.

A table has also been made with the errors obtained for each of the skippers with the cities studied. These are the data and graphs generated.

Note: Traffic measurements have been taken every five minutes, but for correct operation of the tool only the hourly and 24-hour values will be taken.

10.1.3.1 Pattern making

As indicated above, the values have been taken every five minutes for the four cities studied and for each day of the week. It was noted that the flow of traffic relative to working days (Monday to Friday) is very similar and that the same applies to weekends (Saturdays and Sundays). For this reason, it was concluded that a pattern covering working days and another one referring to weekends should be carried out.

Another issue is the heterogeneity of the cities for which data are available, so it is decided to make two patterns for the four cities to encompass as much as possible the traffic trend. So, finally, there will be four employers: two for workdays and two for weekends.

The following data processing has been carried out for each city:

1. Data have been collected throughout the week (Monday to Sunday).
2. Data have been averaged in two groups: working days and weekends.
3. With the data of the four cities' averages, a standard has been obtained for each group.
4. It is decided to make a second and third pattern taking into account the most similar cities in the traffic trend. They were divided into: Thessaloniki and Loures and Seville and Treviso.
5. The previous patterns are established as the most appropriate and the error and comparison with each of the cities is studied.

10.1.3.2 Proposed patterns to simulate the daily traffic flow

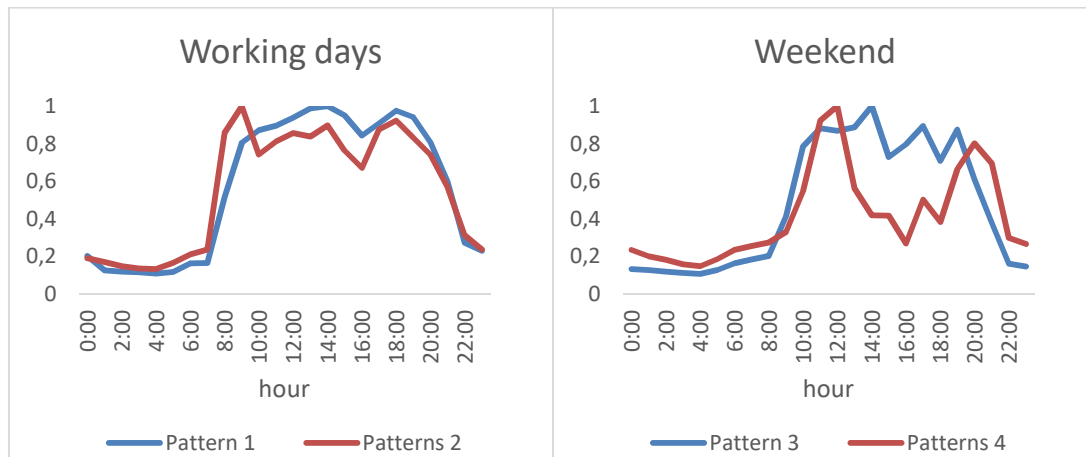


Figure 33. Proposed patterns

10.1.3.3 Data analysis

We will compare as example the proposed the patterns described above with some of the cities involved in the REMEDIO project.

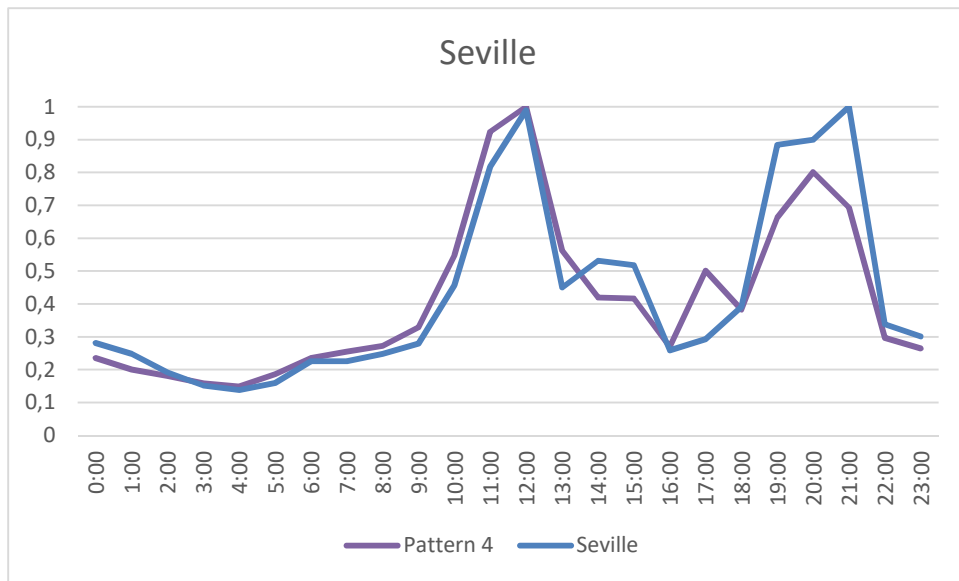


Figure 34. Sevilla vs Pattern 4

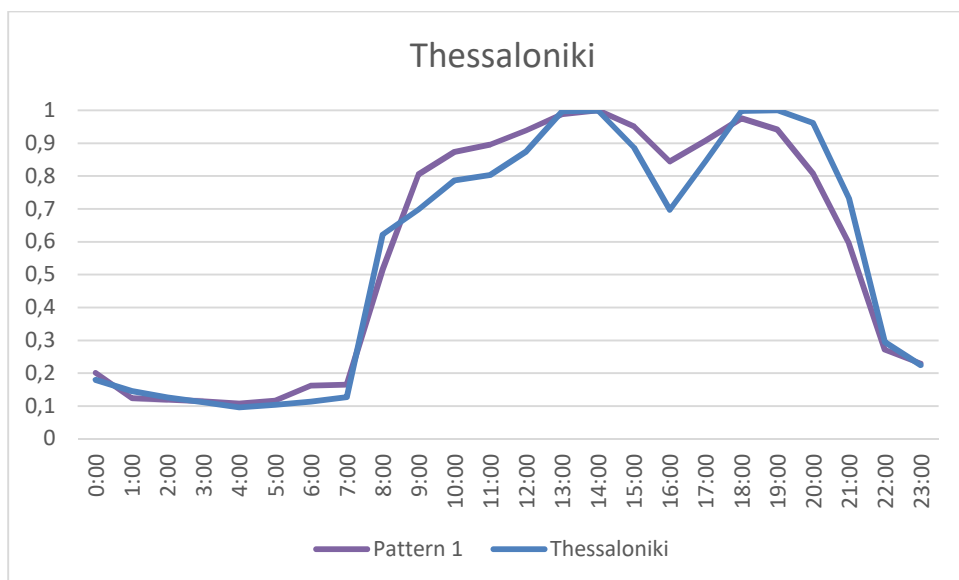


Figure 35. Thessaloniki vs Pattern 1

Simulation time within the IMT

We will study the time it takes to generate the traffic calculations and, as example, the energy module. A sensitivity analysis has been carried out module taking as varying parameters the number of vehicles in a certain simulation and the interval of hours to be simulated.

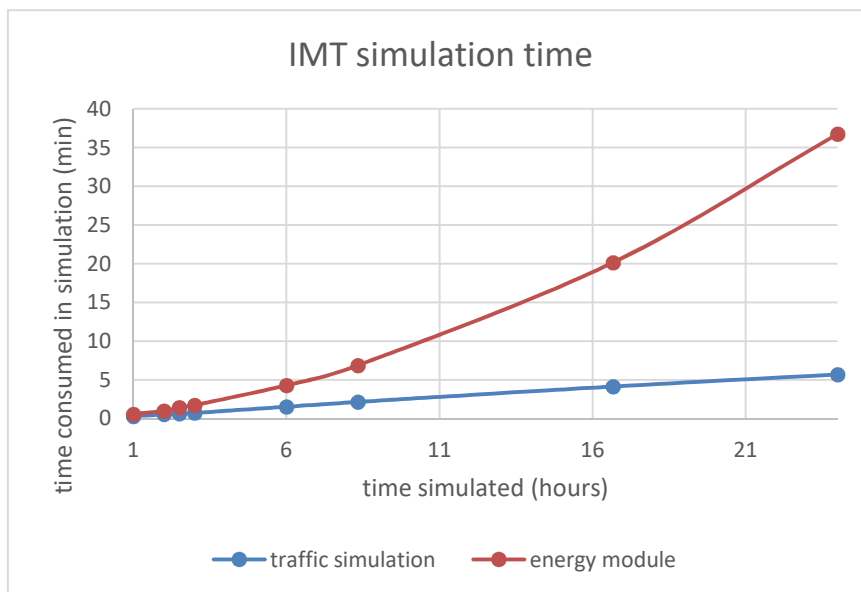


Figure 36. IMT simulation time

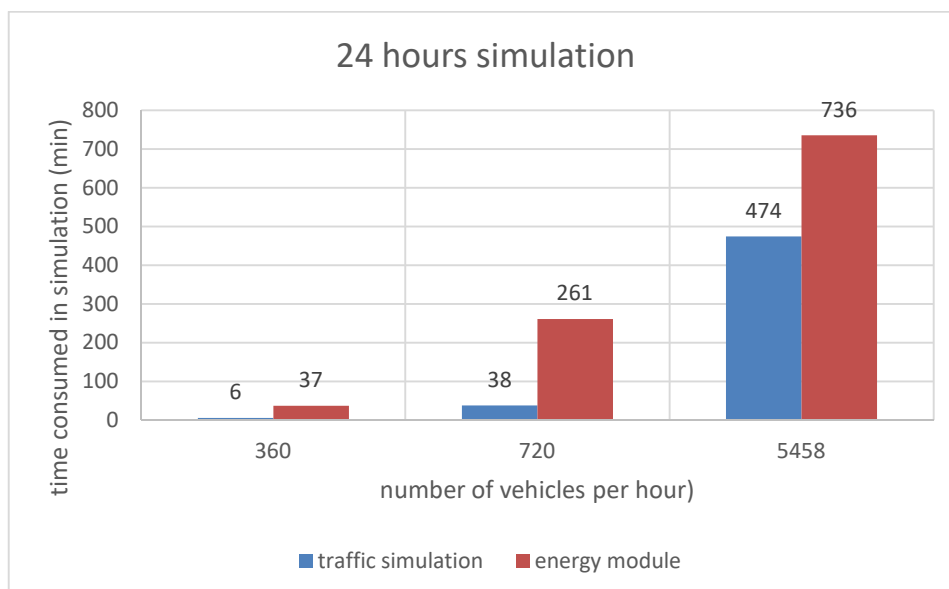


Figure 37. 24 hours simulation

10.2 Platform description

The IMT aims to provide an environment that allows the study of how certain traffic conditions affect some sectors as noise, fuel consumption, pollutant emissions, pollutant dispersion, carbon footprint, freight, health or cost.

Developed as a **web application** with <http://remedio-imt.eu> as URL, the homepage of the IMT is showed below:

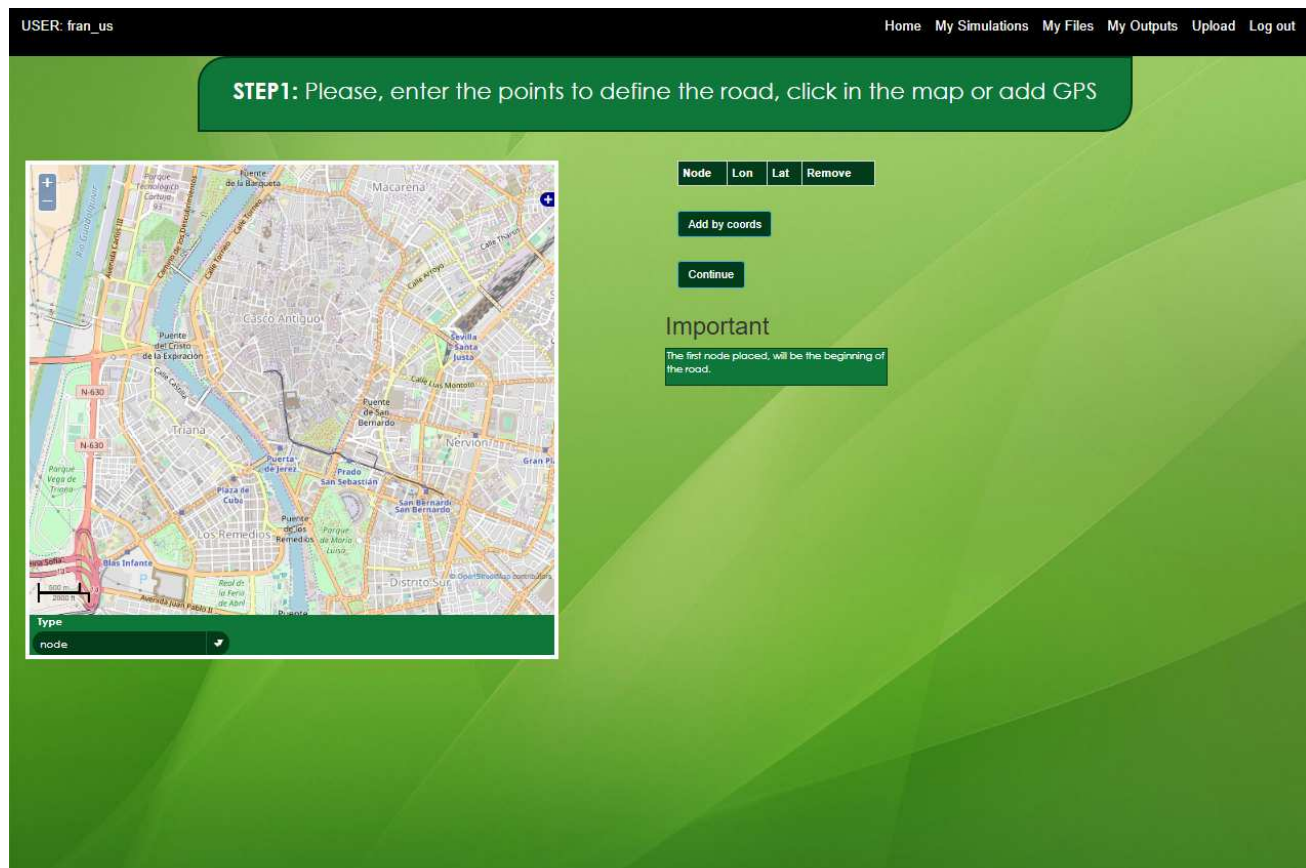


Figure 38. IMT web application homepage

Upper black toolbar shows the different features (explained in following sections) of the IMT platform:



Figure 39. IMT Toolbar

The resolution process followed by the IMT involves **two main steps**: first step involves traffic characterization and simulation, and second step, using outputs from traffic simulation, carries out Modules execution. An **extra step**, under development, will consist in the execution of an action plan where a series of interesting actions in order to improve traffic congestion and its consequences will be studied. A general schema of these steps is showed below:

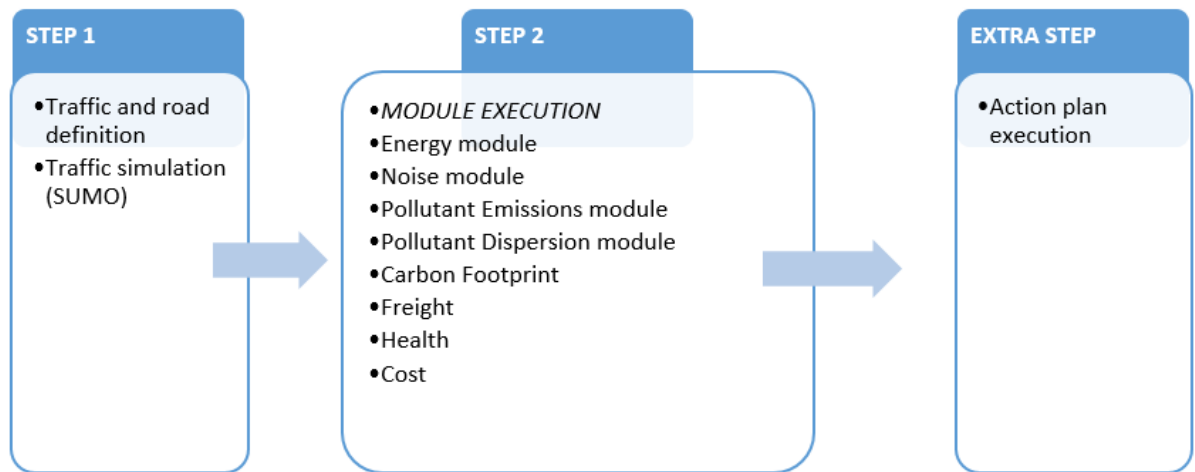
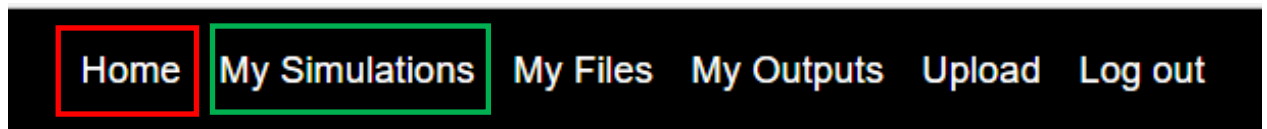


Figure 40. IMT execution schema

10.2.1 Characterization and simulation of traffic

IMT has been developed to allow the user to generate traffic features in two ways: first, through a guided **step-by-step process** and second through the **upload of some perfectly defined files**. First option is recommended for novel users and second one is recommended for more experienced user, since it allows small changes in the characterization of traffic without repeat all guided process. To select the preferred option, user only have to click on the “Home” tab for step-by-step way (red rectangle) or “My Simulations” for upload-files way (green rectangle).



10.2.1.1 Step-by-step process:

In this guided process, user have to complete the different steps views of the application in order to characterize the road and the traffic. Edges number, traffic lights, bus stops, traffic information, etc. can be entered as inputs. The more details entered, the more real the simulation will be. The whole process is detailed in the user guide. The image below summarizes the process:



Figure 41. Step-by-step traffic characterization

Once all data have been entered, in step 9 view will appear a button called “Run tool”. Clicking on that button, IMT generate the **traffic files** and run **SUMO** software. SUMO makes use of traffic files as inputs, and generates some outputs that will be processed in the **MAIN STEP 2 by the Modules**.

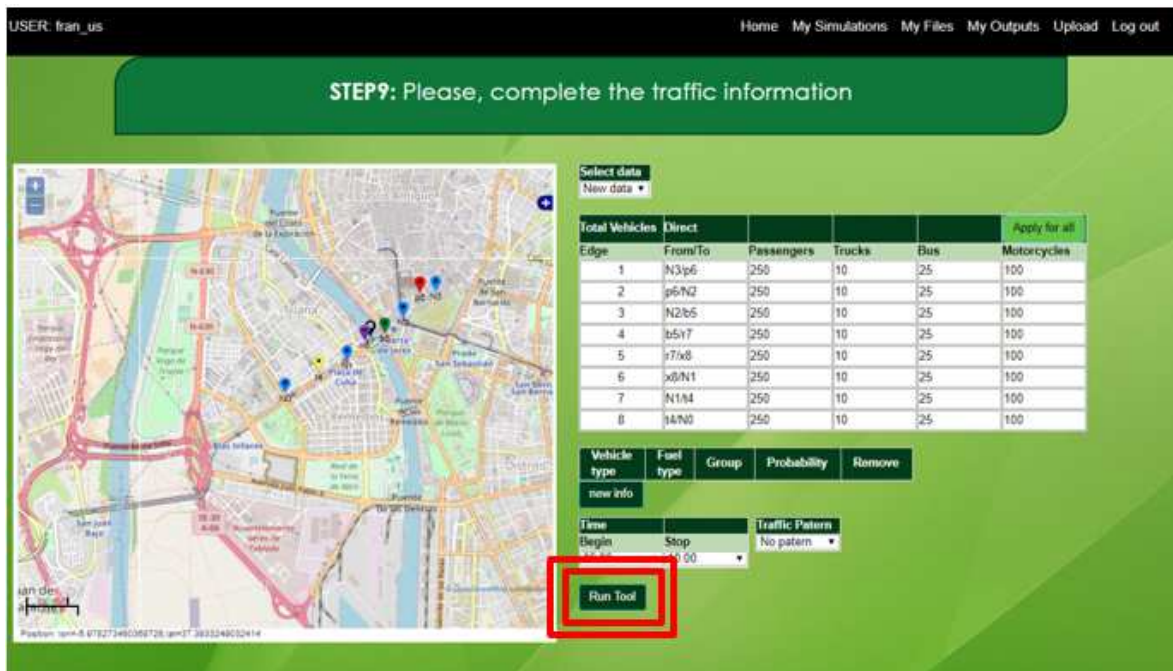


Figure 42. "Run tool" button location in step 9 view

Every simulation will be registered and stored with an ID. The traffic files generate in each simulation are characterized by a name composed of a first code concerning the file type and a second code with the simulation ID. These files are accessible and can be found in "My files" and in "My Simulations". In "My files" folder all traffic files generated automatically by the tool are stored, as well as all the files upload by the user:

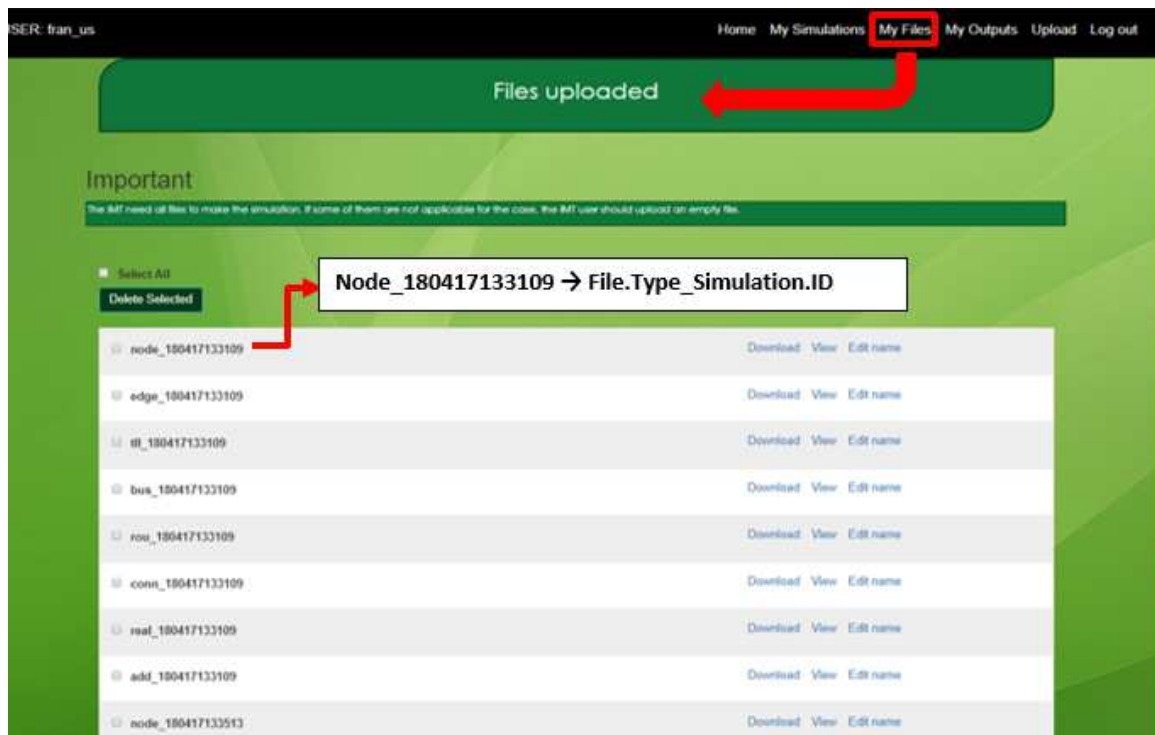


Figure 43. "My files" folder description

In “My Simulations” folder, traffic files will be sorted by simulation ID. Every time that step-by-step process is executed, a new simulation folder will be created, and accessible in “My simulations”. Click on “select” option allows to access to the set of files belonging to that simulation:

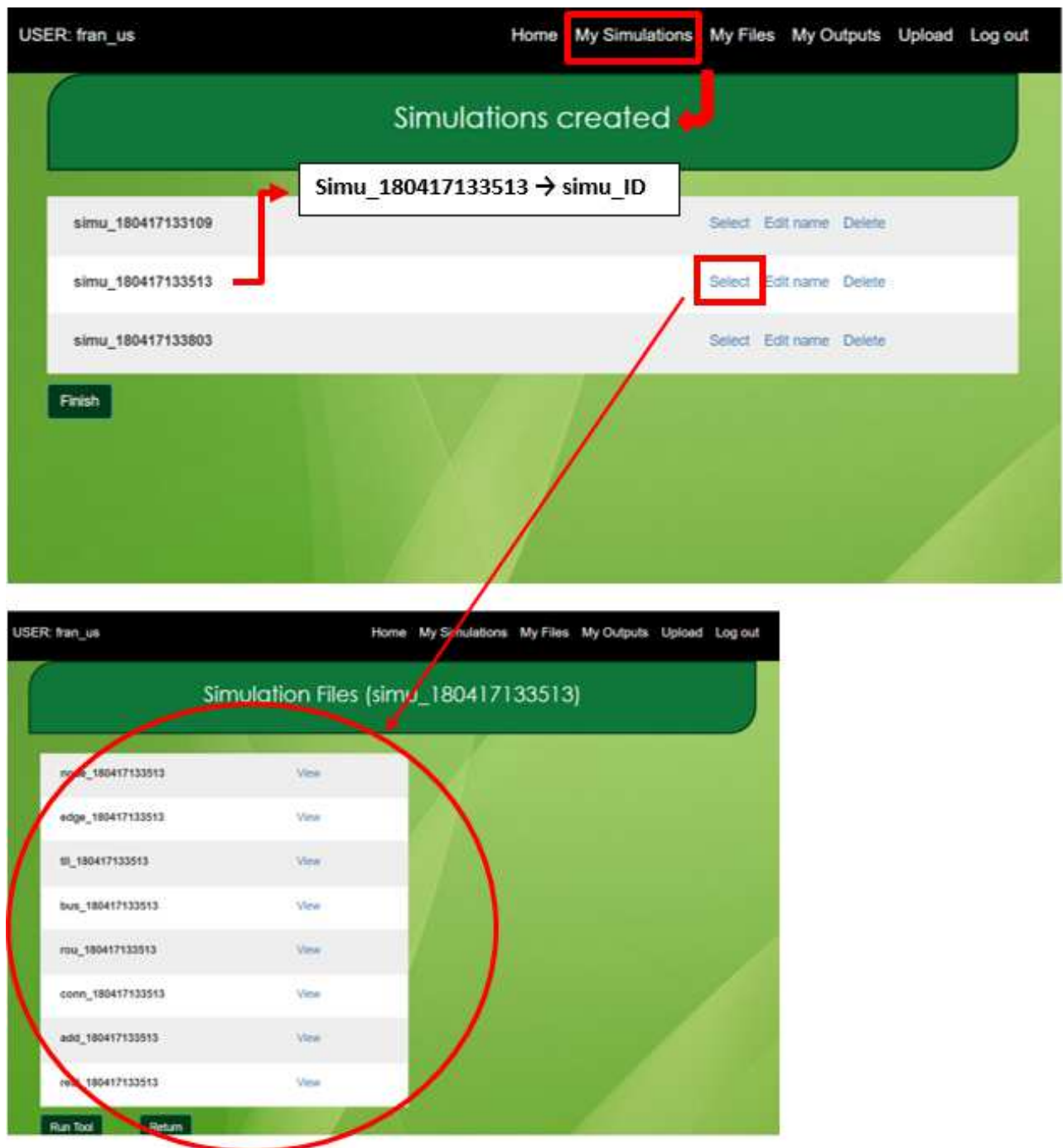


Figure 44. “My Simulations” folder description

10.2.1.2 Upload-files process:

In this kind of process, user have to upload the required files to run traffic simulation. The structure of this files must follow the instruccions provided in the user guide. The entire process is explained in detail in the user guide, however, in this section, a brief summary of the steps for a better understanding will be made.

To upload new files, user have to click on “upload” tab in the application toolbar:

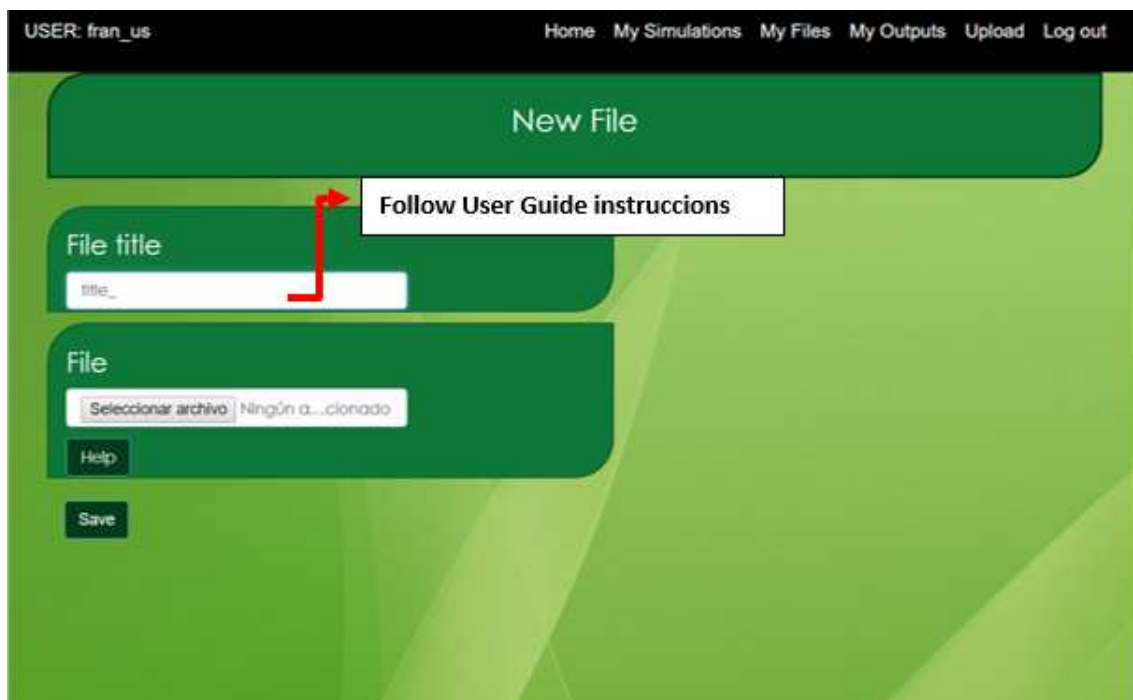
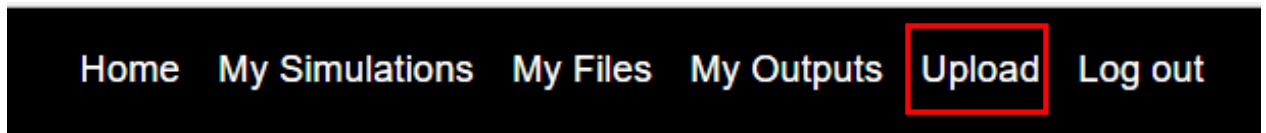


Figure 45. “Upload” view description

Once the required files are upload, and following a similar procedure as the one described in step-by-step process, user can access to these files clicking on “My Files” tab. From those files, user can create a new simulation:

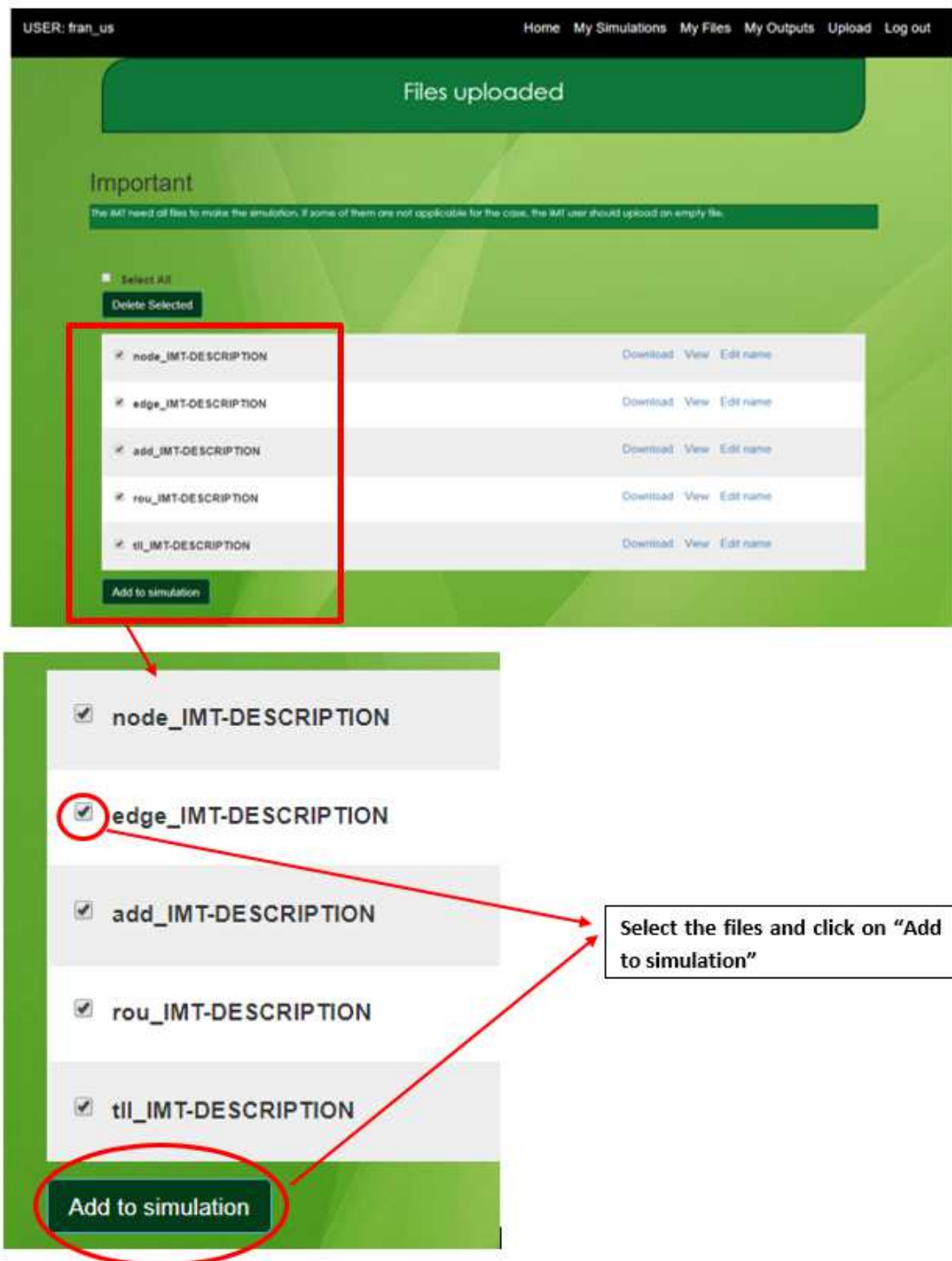


Figure 46. Description of how to create a new simulation

This simulation is stored in "My simulations". To complete this process and run the Traffic Simulator (SUMO) the simulation must be selected, and "Run tool" button must be clicked:

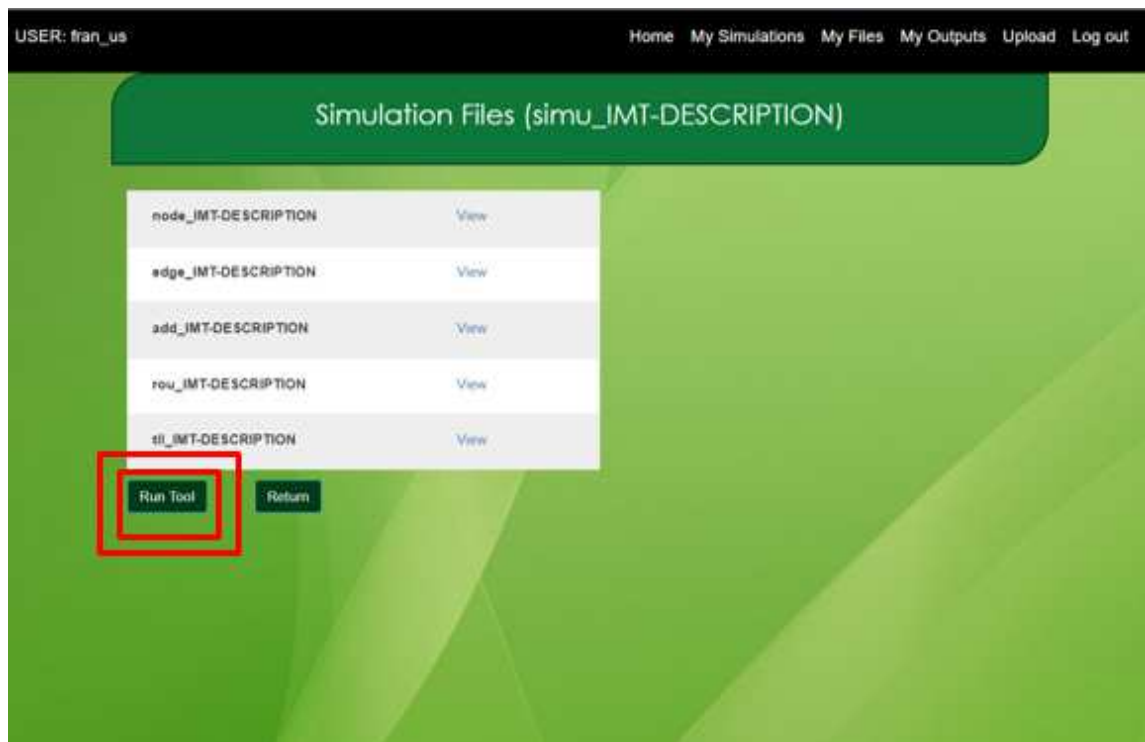


Figure 47. Files-Upload process execution

10.2.2 Modules execution

IMT allows to study the impact of traffic in eight sectors: energy consumption, noise, pollutant emissions, pollutant dispersion, freight, carbon footprint, health and cost. These modules, using the results from traffic simulation, will analyse the consequences of traffic congestion in these sectors.

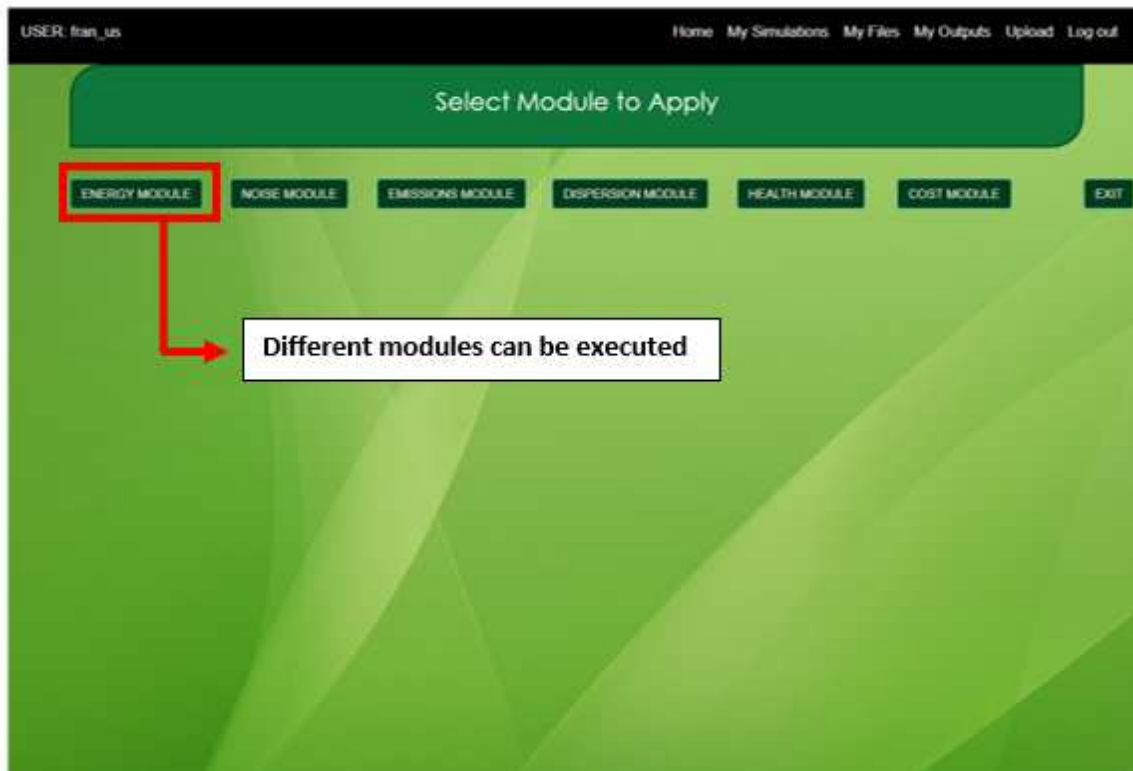


Figure 48. Modules Execution: options menu

It is important to understand that some outputs of particular modules, will be used as inputs for other modules. For this reason, it is necessary to follow the user guide.

When a module is executed, a view with the outputs files and charts will be showed. These files and charts can be directly downloaded in this view, but they will be also stored in “My Outputs” folder. To access this folder, click on “My Outputs” in the main toolbar.

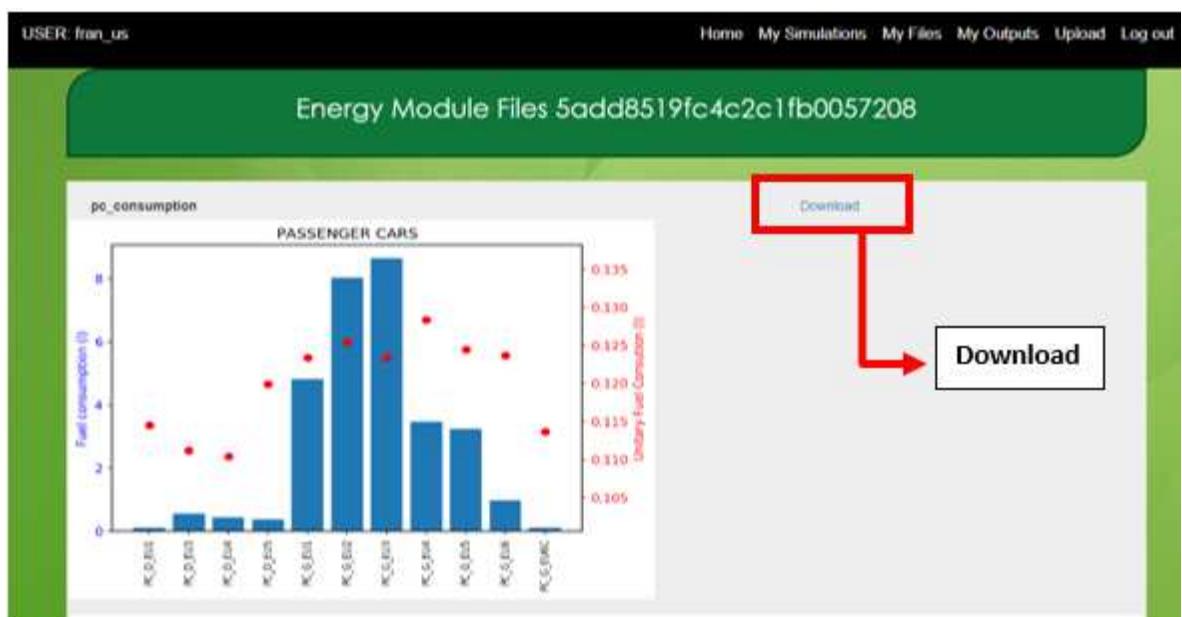


Figure 49. Example of module outputs after energy module execution

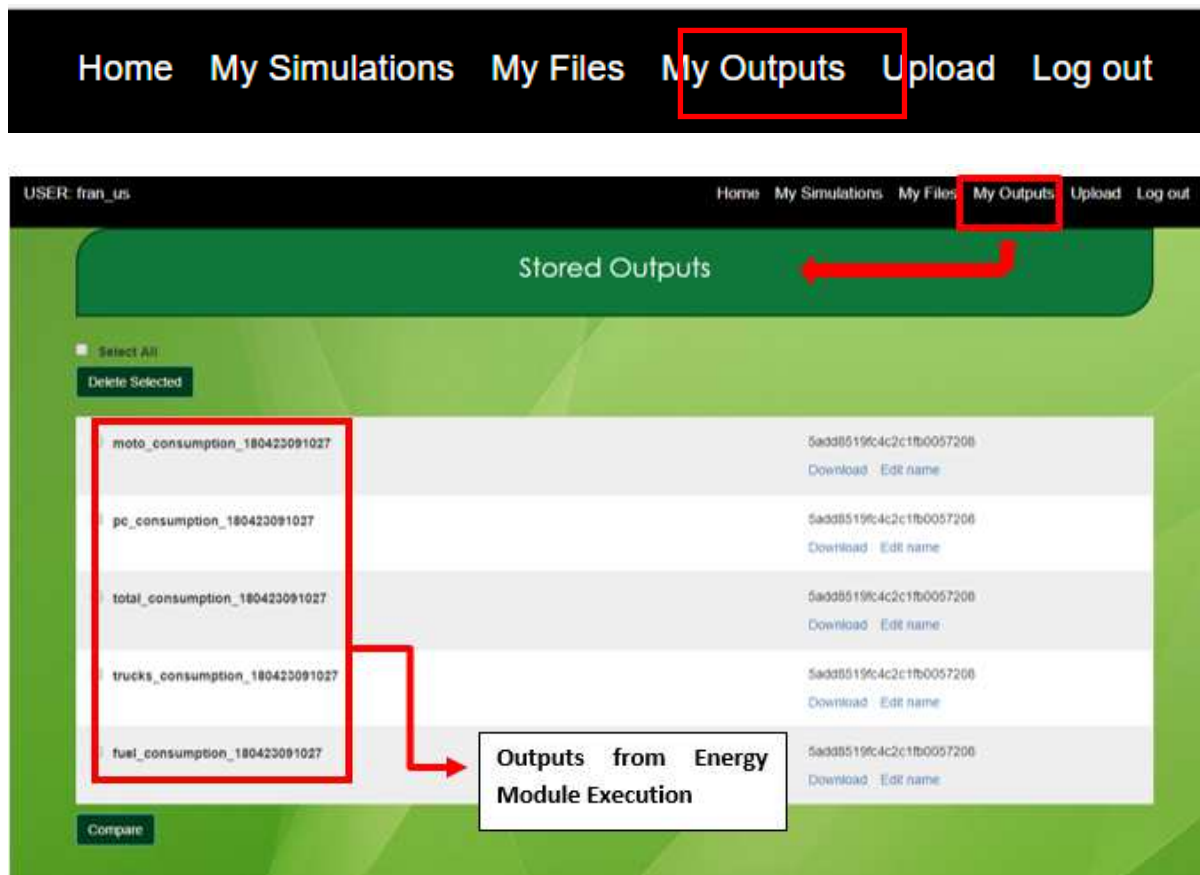


Figure 50. "My Outputs" view description

10.3 Legal notice and disclaimer:

To get access to the IMT platform the user has to accept the legal notice and disclaimer. Its content is as follows:

"This website is created as a non-profit tool developed in the Remedio project, within the Interreg Med program, oriented to the study and characterization of the impact of traffic in linear roads. Its use is only linked to the implementation of the project.

Personal data that may be needed for the use of the website will be stored and treated in a secure manner respecting the confidentiality of the user. Personal data will be only used for managing the access to the tool.

The Remedio Consortium is not responsible for the inappropriate use that may be given to the tool, as well as any possible inconvenience derived of the use of the software or the results.

The Remedio Consortium does not take any legal responsibility about accuracy of results given by the software or the effects derived by their application.

Neither will be responsible for the information uploaded by the user and the use that may be made of the results obtained through the use of the tool.

The cookies used by the website are only associated with an anonymous user and his/her computer, and do not themselves provide the user's personal data. Under no circumstances cookies will be used to collect personal information."

10.4 User manual

This section aims to be a complete guide to help the user to properly manage the IMT application.

As explained in previous sections, IMT can simulate traffic through a **step-by-step process** or through an **upload-files process**. In this guide, both processes will be explained in detail, as well as, modules and action plan execution. Each step will be described in detail below.

10.4.1 Logging

Writing in the browser the following URL: <http://remedio-imt.eu> user can access to IMT web application. If the user has not registered yet, it is necessary to contact USE team. Otherwise, user only have to click on "Log in".

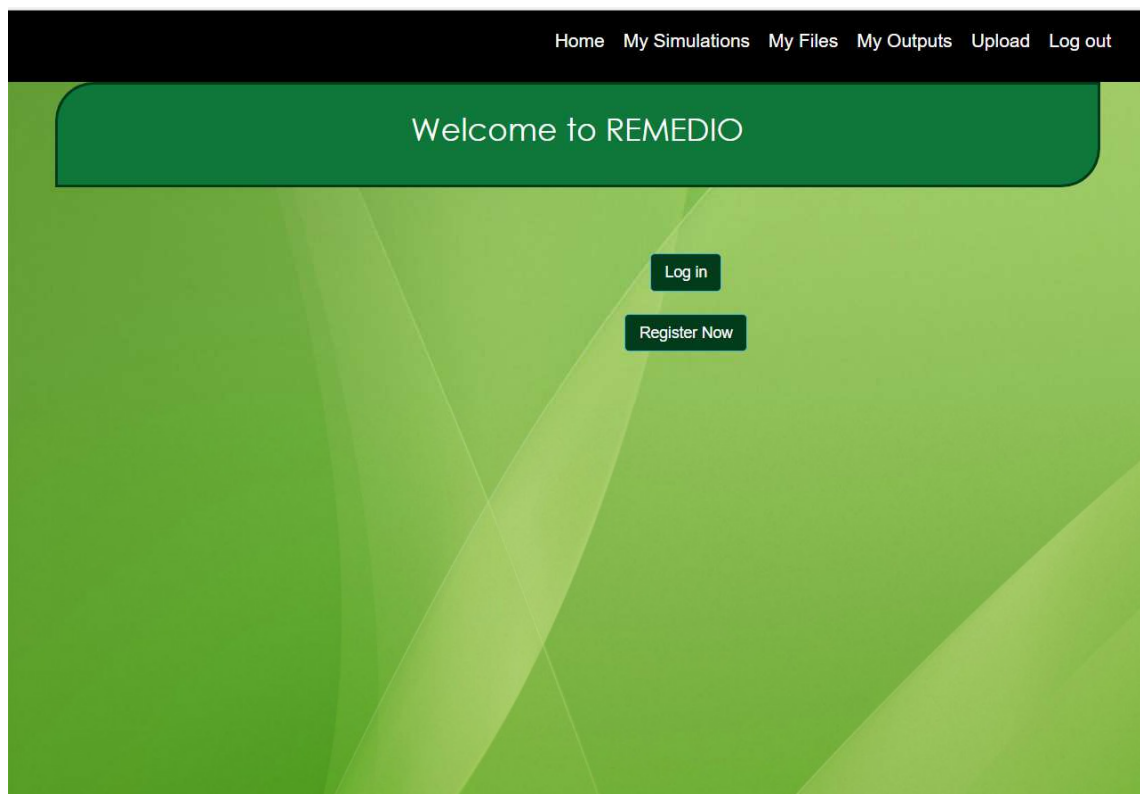


Figure 51. Welcome page of the IMT

If the user is not registered (but you have contacted USE), the user has to create a username and password to access the platform. This is done in the following screen:

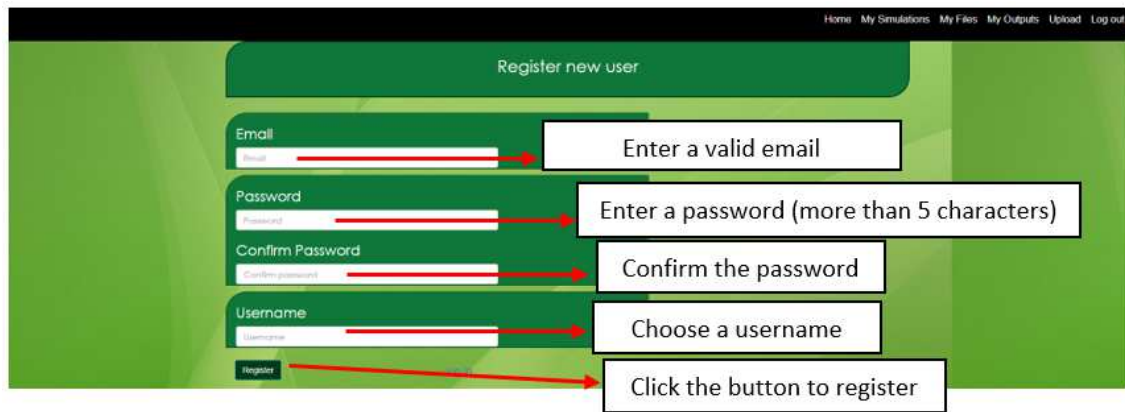


Figure 52. Register new user screen

When you press the Register button, a window appears to accept the legal notice. It must be accepted to conclude with registration.

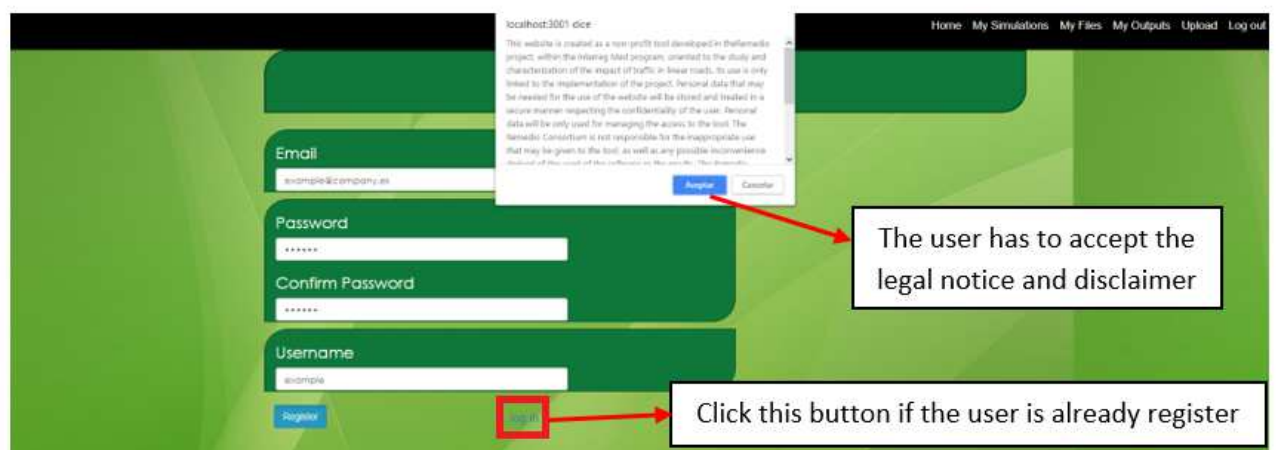


Figure 53. Register new user screen

10.4.2 Step-by-step process

Clicking on “Home” in the IMT main toolbar, the user can access the step-by-step process.

10.4.2.1 Step 1: Points to define the road

In this step user defines the main nodes of the road. These nodes help to define the geometry of the road. They are coordinates of the road but they do not represent any specific road elements as lights, bus stops or similar. The beginning and the end of the road must be defined for this kind of nodes.

Nodes can be aggregated clicking on the map (new node description with its latitude and longitude will be added to the table) or pressing “Add by coords” button (user have to introduce the description of the new node and click on add marker “addmk” button). In the case of creating a node with the second way, never change the first letter “N” of the

node name, because this letter expresses the type of node. It's possible to delete some nodes pressing "remove" button.

In the following example a road called "Paseo de las Delicias" in Seville is defined with four main nodes. Nodes 0-2 will be added by clicking directly on the map (in red) and node 3 will be added clicking on "Add by coords" button (in blue).

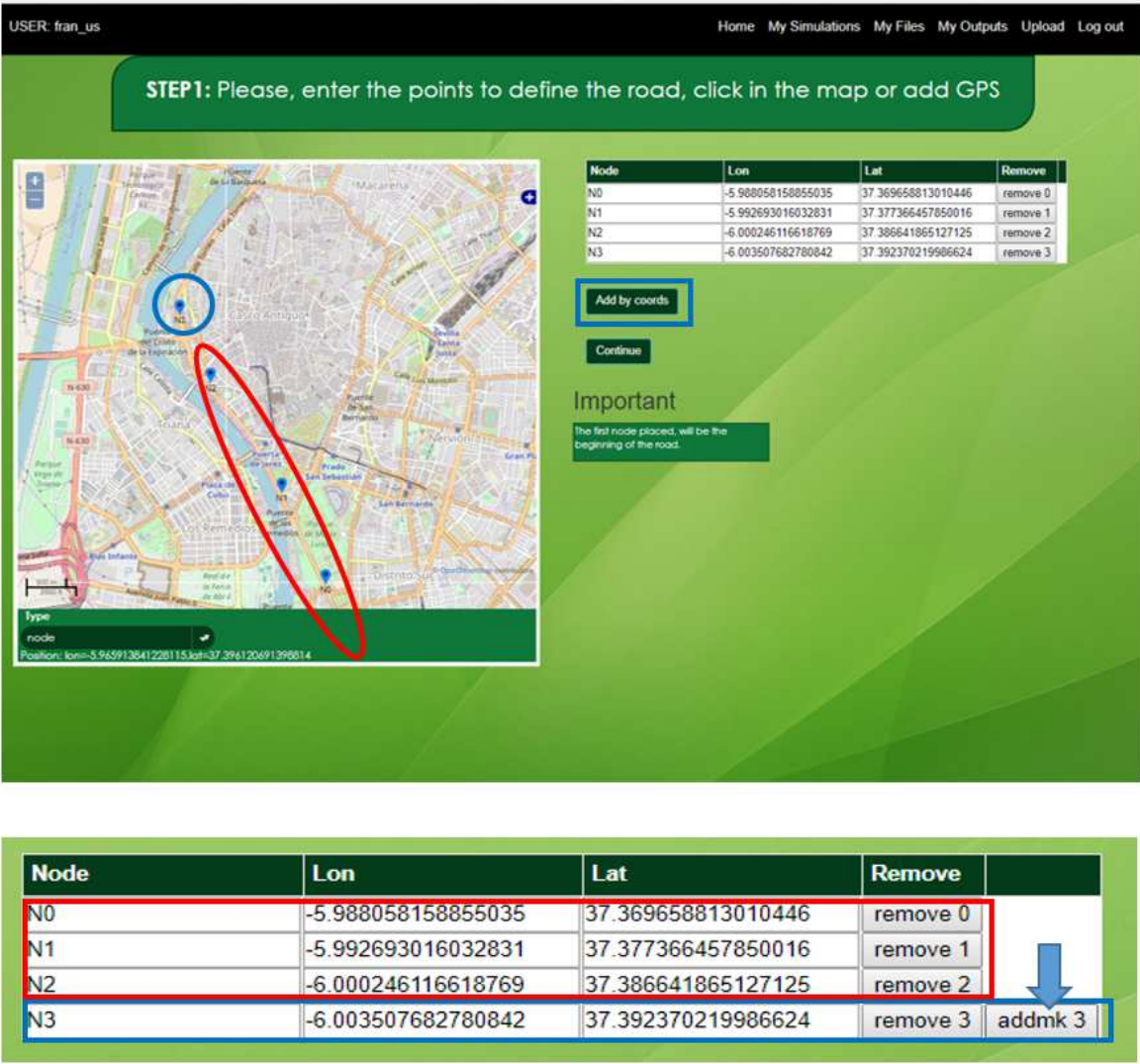


Figure 54. Step 1 description and ways to add new nodes in the step-by-step process

The IMT Dispersion module (further described in section 1.4.4) requires the nodes coordinates. Therefore, the user should copy the nodes coordinates from the IMT tool to a .csv file (e.g. DISPERSION_MODULE.csv). In the figure below, there is a screenshot of .csv file showing the nodes coordinates of the road segments.

	A	B	C	D	E	F	G	H	I	J
1	Node	Lon	Lat							
2	N0	-5.99	37.37							
3	N1	-5.99	37.38							
4	N2	-6.00	37.39							
5	N3	-6.00	37.39							
6										
7										

Figure 55. Nodes coordinates – Step 1

10.4.2.2 Step 2: Enter the traffic light along the road

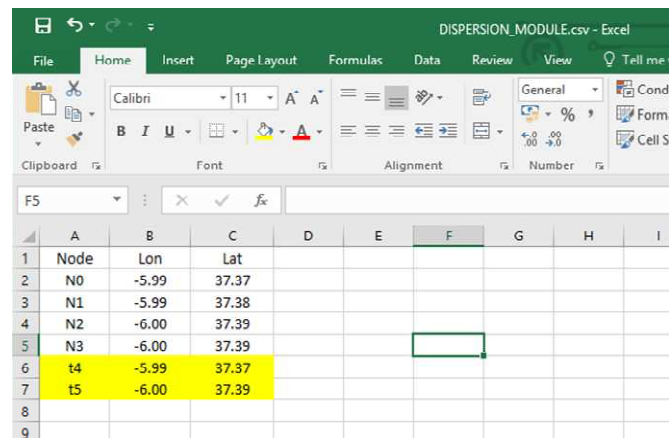
In this step, the user defines the traffic light nodes of the road. These nodes must be located between the first and the last nodes defined in step 1. The way to add a new node is similar to the step 1 (clicking on the map or pressing “Add by coords” button). In this case, letter “t” has to be present in node name.

Continuing with the same example, two traffic light nodes are added:

Node	Lon	Lat	Phase time(s)
t4	-5.9906330795094265	37.37380786434903	30/10/30
t5	-4.002649375896105	37.38991526436746	30/10/30

Figure 56. Step 2 description in the step-by-step process

Similarly to the previous step, the user should copy the nodes coordinates from the IMT tool to the .csv file (e.g. DISPERSION_MODULE.csv). In the figure below, there is a screenshot of .csv file showing the nodes coordinates of the traffic lights.



	A	B	C	D	E	F	G	H	I
1	Node	Lon	Lat						
2	N0	-5.99	37.37						
3	N1	-5.99	37.38						
4	N2	-6.00	37.39						
5	N3	-6.00	37.39						
6	t4	-5.99	37.37						
7	t5	-6.00	37.39						
8									
9									

Figure 57. Nodes coordinates – Step 1 and 2

10.4.2.3 Step 3: Enter the bus stop along the road

In this step user defines the bus stops nodes of the road. These nodes must be located between the first and the last nodes defined in step 1. The way to add a new node is similar to the step 1 (clicking on the map or pressing “Add by coords” button). In this case, letter “b” has to be present in node name.

Continuing with the same example, four bus stops nodes are added:

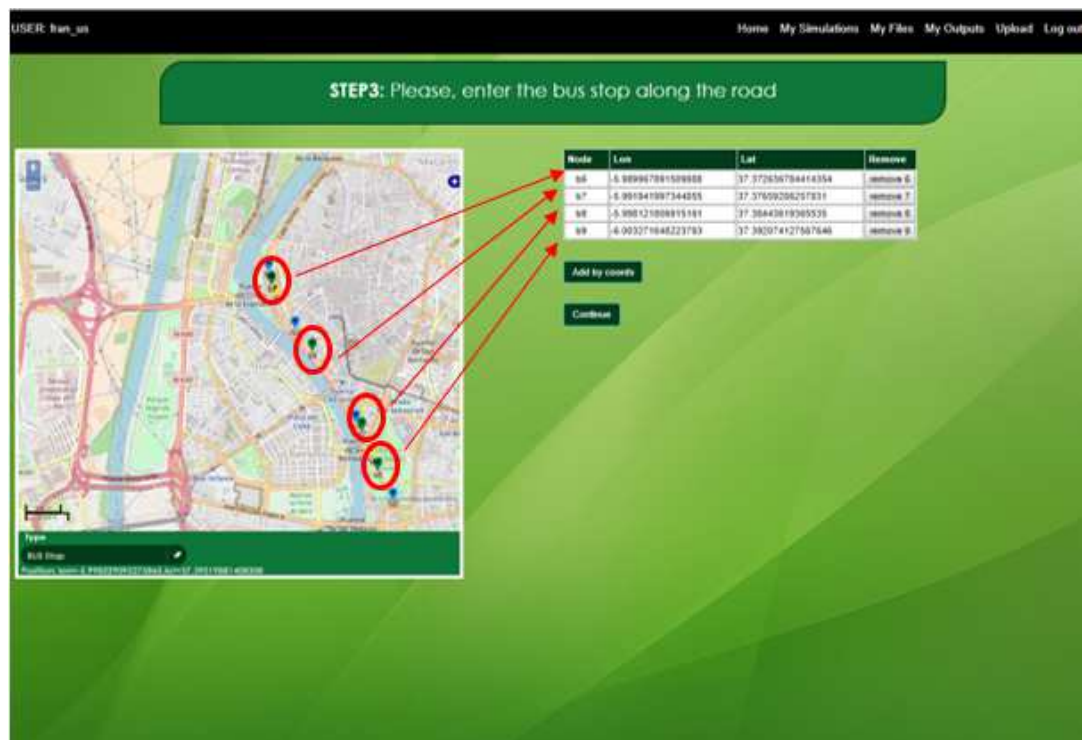


Figure 58. Step 3 description in the step-by-step process

Again, the user should copy the nodes coordinates from the IMT tool to the previous referred .csv file (e.g. DISPERSION_MODULE.csv). In the figure below, there is a screenshot of .csv file showing the nodes coordinates of the bus stops.

	A	B	C
1	Node	Lon	Lat
2	N0	-5.99	37.37
3	N1	-5.99	37.38
4	N2	-6.00	37.39
5	N3	-6.00	37.39
6	t4	-5.99	37.37
7	t5	-6.00	37.39
8	b4	-5.99	37.37
9	b7	-5.99	37.38
10	b8	-5.99	37.38
11	b9	-6.00	37.39

Figure 59. Nodes coordinates – Step 1, 2 and 3

10.4.2.4 Step 4: Enter the pedestrian crossing along the road

In this step user defines the pedestrian crossing nodes of the road. These nodes must be located between the first and the last nodes defined in step 1. The way to add a new node

is similar to the step 1 (clicking on the map or pressing “Add by coords” button). In this case, letter “p” has to be present in node name.

Continuing with the same example, one pedestrian crossing node is added:

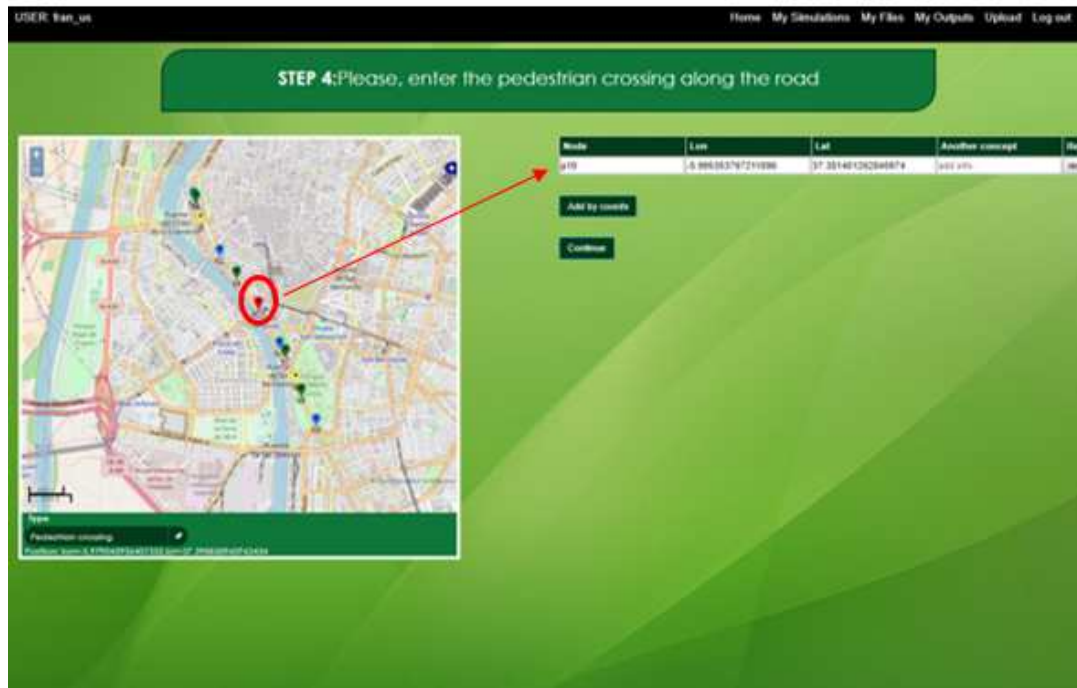


Figure 60. Step 4 description in the step-by-step process

The user should copy the nodes coordinates from the IMT tool to the .csv file (e.g. DISPERSION_MODULE.csv). In the figure below, there is a screenshot of .csv file showing the nodes coordinates of the pedestrian crossings.

	A	B	C	D	E	F	G	H	I
1	Node	Lon	Lat						
2	N0	-5.99	37.37						
3	N1	-5.99	37.38						
4	N2	-6.00	37.39						
5	N3	-6.00	37.39						
6	t4	-5.99	37.37						
7	t5	-6.00	37.39						
8	b4	-5.99	37.37						
9	b7	-5.99	37.38						
10	b8	-5.99	37.38						
11	b9	-6.00	37.39						
12	p10	-5.99	37.56						
13									

Figure 61. Nodes coordinates – Step 1, 2, 3 and 4

10.4.2.5 Step 5: Enter the roundabouts along the road

In this step user defines the roundabouts nodes of the road. These nodes must be located between the first and the last nodes defined in step 1. The way to add a new node is similar to the step 1 (clicking on the map or pressing “Add by coords” button). In this case, letter “r” has to be present in node name.

Continuing with the same example, two roundabouts nodes are added:

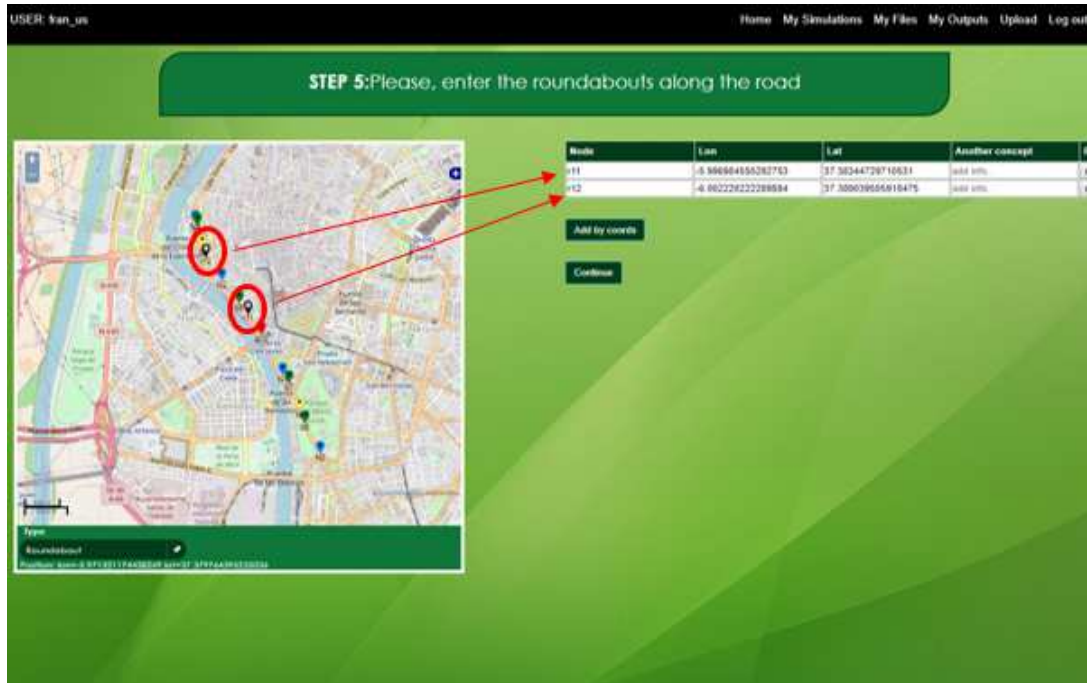


Figure 62. Step 5 description in the step-by-step process

The user should copy the nodes coordinates from the IMT tool to the .csv file (e.g. DISPERSION_MODULE.csv). In the figure below, there is a screenshot of .csv file showing the nodes coordinates of the roundabouts.

	A	B	C	D	E	F	G	H	I
1	Node	Lon	Lat						
2	N0	-5.99	37.37						
3	N1	-5.99	37.38						
4	N2	-6.00	37.39						
5	N3	-6.00	37.39						
6	t4	-5.99	37.37						
7	t5	-6.00	37.39						
8	b4	-5.99	37.37						
9	b7	-5.99	37.38						
10	b8	-5.99	37.38						
11	b9	-6.00	37.39						
12	p10	-5.99	37.56						
13	r11	-5.99	37.36						
14	r12	-6.00	37.39						
15									
16									

Figure 63. Nodes coordinates – Step 1, 2, 3, 4 and 5

10.4.2.6 Step 6: Enter the STOP signals along the road

In this step user defines the STOP signals nodes of the road. These nodes must be located between the first and the last nodes defined in step 1. The way to add a new node is similar to the step 1 (clicking on the map or pressing “Add by coords” button). In this case, letter “x” has to be present in node name.

Continuing with the same example, two STOP signals nodes are added:

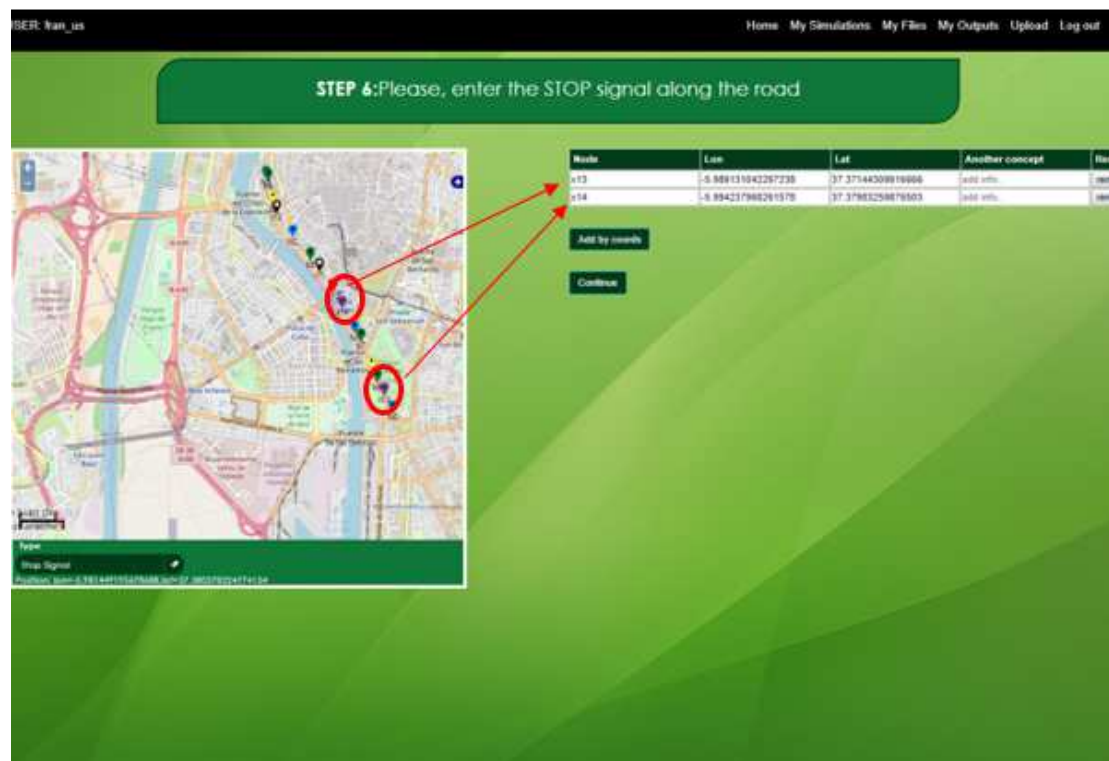


Figure 64. Step 6 description in the step-by-step process

The user should copy the nodes coordinates from the IMT tool to the .csv file (e.g. DISPERSION_MODULE.csv). In the figure below, there is a screenshot of .csv file showing the nodes coordinates of the stop signals.

	A	B	C	D	E	F	G	H	I
1	Node	Lon	Lat						
2	N0	-5.99	37.37						
3	N1	-5.99	37.38						
4	N2	-6.00	37.39						
5	N3	-6.00	37.39						
6	t4	-5.99	37.37						
7	t5	-6.00	37.39						
8	b4	-5.99	37.37						
9	b7	-5.99	37.38						
10	b8	-5.99	37.38						
11	b9	-6.00	37.39						
12	p10	-5.99	37.56						
13	r11	-5.99	37.36						
14	r12	-6.00	37.39						
15	x13	-5.99	37.37						
16	x14	-5.99	37.38						
17									

Figure 65. Nodes coordinates – Step 1, 2, 3, 4, 5 and 6

10.4.2.7 Step 7: Complete bus stop information

In this step user defines the features of each bus line. User can characterize a bus line in the following way:

- Bus Stop number: Bus stop numbers where this bus line stops (separate with commas!).
- Freq pass (min): Bus frequency, in minutes.
- Stop time (s): Stop time of the bus in a bus stop, in seconds.
- Begin (h): Start time of bus line service.
- End (h): End time of bus line service.


To add a new bus line, click on “new info” button.

Continuing with the same example, four bus lines are added:

USER: Nabil

Home My Simulations My Files My Outputs Upload Log out

STEP7: Please, complete the bus stop information



Bus Line	Bus Stop number	Freq pass(min)	Stop time(s)	Begin (h)	End (h)	Remove
line_1	b6.b9	10	30	8	24	remove
line_2	b6.b8	15	30	8	22	remove
line_3	b7.b9	10	30	6	24	remove
line_4	b6.b7.b8.b9	10	30	9	20	remove

new info

Continue

Bus Line	Bus Stop number	Freq pass(min)	Stop time(s)	Begin (h)	End (h)	Remove
line_1	b6.b9	10	30	8	24	remove
line_2	b6.b8	15	30	8	22	remove
line_3	b7.b9	10	30	6	24	remove
line_4	b6.b7.b8.b9	10	30	9	20	remove

new info

Continue

Figure 66. Step 7 description in the step-by-step process

10.4.2.8 Step 8: Complete the edges info

User must define the characteristics of each edge in this step. In the IMT application an edge is define as a road section. Each road section may be characterized by the following options:

- Edge Id: Identification of road section.
- From: Start node of road section.
- To: End node of road section.
- Length (km): Length of road section, in kilometres.
- Two Ways (y/n): Two-way road section (yes or no) ^a
- Car Lanes/way: Number of car lanes in each way ^b
- Bus Lane position: Position of the bus lane in the set of lanes ^c

- Bike lane position: Position of the bike lane in the set of lanes ^c
- Slope (%): Road section slope, in percentage.
- Road surface: Type of road section surface.

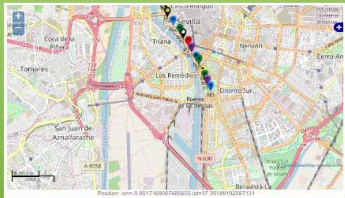
^a If user defines a two-way road section, the edge will transform in two edges, one of them with a positive ID (direct direction) and the other one with a negative ID (reverse direction).

^b If user defines a bus or bike lane, the total number of car lanes has to be at least two. If user define a bus and a bike lane, the total number of car lanes has to be at least three.

^c Lanes are ordered from 0 to the number of lanes minus one. Lane 0 corresponds to the right lane. Bus lane and bike lane always must be selected as lane 0 (if only a bus lane or a bike lane is considered) or lane 1 (if a bus lane and a bike line is considered. In this case, bus lane must be selected as lane 0 and bike lane as lane 1!).

USER: Iran_us Home My Simulations My Files My Outputs Upload Log out

STEP8: Please, complete the edges info



Edge Id	From	To	Length (km)	Two Ways (yn)	Car Lanes/way	Bus Lane Position	Bike lane Position	Slope (%)	Road surface
1	N3	09	0.036	5	1	-	-	0	Asphalt
2	09	05	0.240	5	1	-	-	0	Asphalt
3	05	r12	0.104	5	1	-	-	0	Asphalt
4	r12	N2	0.318	5	1	-	-	0	Asphalt
5	N2	08	0.306	5	1	+	-	0	Asphalt
6	08	r11	0.140	5	1	+	-	0	Asphalt
7	r11	p10	0.260	5	1	+	-	0	Asphalt
8	p10	x14	0.2	5	1	+	-	0	Asphalt
9	x14	N1	0.305	5	1	+	-	0	Asphalt
10	N1	07	0.100	5	1	+	-	0	Asphalt
11	07	04	0.322	5	1	+	-	0	Asphalt
12	04	00	0.151	5	1	+	-	0	Asphalt
13	00	x13	0.152	5	1	-	-	0	Asphalt
14	x13	N0	0.22	5	1	-	-	0	Asphalt

Continue

Figure 67. Step 8 view in the step-by-step process

Edge Id	From	To	Length (km)	Two Ways (y/n)	Car Lanes/way	Bus Lane Position	Bike lane Position	Slope (%)	Road surface
1	N0	x13	0.337	y	2	0	-	0	Average
2	x13	b6	0.186	y	2	-	0	0	Average
3	b6	t4	0.105	y	3	0	1	0	Average
4	t4	b7	0.379	n	1	-	-	0	Average
5	b7	N1	0.027	n	1	-	-	0	Average
6	N1	x14	0.346	n	1	-	-	0	Average
7	x14	p10	0.099	n	1	-	-	0	Average
8				n	1	-	-	0	Average
9				n	1	-	-	0	Average
10				n	1	-	-	0	Average
11				n	1	-	-	0	Average
12				n	1	-	-	0	Average
13	t5	b9	0.321	n	1	-	-	0	Average
14	b9	N3	0.044	n	1	-	-	0	Average

If the user selects “y”, a two-way road section will be considered. This option will double the edges 1, 2 and 3, creating the edges -1,-2 and -3 in the outputs!

If the user enter a bus lane position or/and a bike lane position, the option Car Lanes per way has to be at least 2/3. Traffic simulator require that the position of bus lane and bike lane are always 0 (right lane) or 1 (if the user enter a bus lane and a bike lane).

Figure 68. Step 8 description

Step 9: Complete the traffic information

In this step, the user has to complete the traffic information. To facility data entry, user can select standard information (of course, new information can be provided). Below, tables and buttons are explained in detail:

- “Select data” button: The users must select between the vehicle type and technology distributions of three countries (Italy, Greece and Portugal). The table of values obtained can be modified if the user can provide new data.
- “Total Vehicles” table: This table show the characterization of traffic in each road section. Passenger cars as light and medium motor vehicles representation, Trucks as heavy motor vehicles representation, and Motorcycles as powered two-wheelers representation, are considered. It’s essential that the user provided this traffic flow in vehicles per hour. The value entered must match the real traffic flow at peak time (patterns will correct this value for each hour).

If in step 8 the user defines some edge as two-ways road sections, two “Total Vehicles” tables will be generated in this step (Direct and Reverse direction).

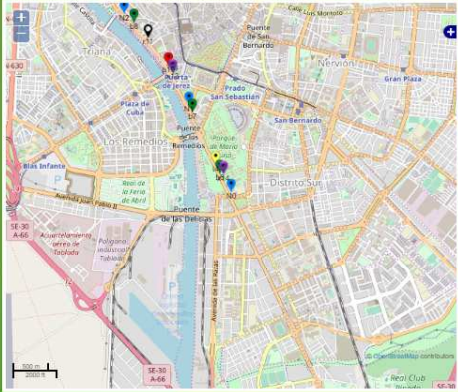
- “Time” table: In this table, user can define the start (“begin”) and the end (“stop”) time of the simulation.
- “Traffic pattern” button: User must select between two traffic patterns. This traffic pattern represents the correction of peak flow for each hour. It can be modified if the user wants to provide new data.

- “Run tool” button: Once traffic information is completed, click on this button to run traffic simulator.

USER: fran_us

[Home](#)
[My Simulations](#)
[My Files](#)
[My Outputs](#)
[Upload](#)
[Log out](#)

STEP9: Please, complete the traffic information



Select data

New data ▼

Total Vehicles	Direct				Apply for all
Edge	From/To	Passengers	Trucks	Bus	Motorcycles
1	N3/b9	250	10	25	100
2	b9/t5	250	10	25	100
3	t5/r12	250	10	25	100
4	r12/N2	250	10	25	100
5	N2/b8	250	10	25	100
6	b8/r11	250	10	25	100
7	r11/p10	250	10	25	100
8	p10/x13	250	10	25	100
9	x13/N1	250	10	25	100
10	N1/b7	250	10	25	100
11	b7/t4	250	10	25	100
12	t4/b6	250	10	25	100
13	b6/x14	250	10	25	100
14	x14/N0	250	10	25	100

Total Vehicles	Reverse				Apply for all
Edge	From/To	Passengers	Trucks	Bus	Motorcycles
i1	b9/N3	250	10	25	100
i2	t5/b9	250	10	25	100
i3	r12/t5	250	10	25	100

Vehicle type

Fuel type

Group

Probability

Remove

new info

Time

Begin

Stop

09:00

10:00

Traffic Pattern

No pattern ▼

Run Tool

Figure 69. Step 9 view in the step-by-step process

Total Vehicles	Direct			Apply for all
Edge	From/To	Passengers	Trucks	Motorcycles
1	N0/x13	250	10	100
2	x13/b6	250	10	100
3	b6/t4	250	10	100
4	t4/b7	250	10	100
5	b7/N1	250	10	100
6	N1/x14	250	10	100
7	x14/p10	250	10	100
8	p10/r12	250	10	100
9	r12/b8	250	10	100
10	b8/N2	250	10	100
11	N2/r11	250	10	100
12	r11/t5	250	10	100
13	t5/b9	250	10	100
14	b9/N3	250	10	100
Total Vehicles	Reverse			Apply for all
Edge	From/To	Passengers	Trucks	Motorcycles
i1	x13/N0	250	10	100
i2	b6/x13	250	10	100
i3	t4/b6	250	10	100

“Apply for all” button: allows to copy the values of the first row in the other rows

Two sub-tables: Direct and reverse direction.

Figure 70. “Total Vehicles” table (step 9)

Vehicle type	Fuel type	Group	Probability	Remove
Passenger	Gasoline	PC_G_EU0	0.0529	remove0
Passenger	Gasoline	PC_G_EU1	0.0230	remove1
Passenger	Gasoline	PC_G_EU1	0.0928	remove2
Passenger	Gasoline	PC_G_EU2	0.0704	remove3
Passenger	Gasoline	PC_G_EU3	0.1494	remove4
Passenger	Gasoline	PC_G_EU5	0.0689	remove5
Passenger	Gasoline	PC_G_EU5	0.0137	remove6
Passenger	Diesel	PC_D_EU6	0.0083	remove7
Passenger	Diesel	PC_D_EU5	0.0041	remove8
Passenger	Diesel	PC_D_EU4	0.0332	remove9
Passenger	Diesel	PC_D_EU3	0.1008	remove10
Passenger	Diesel	PC_D_EU2	0.1544	remove11
Passenger	Diesel	PC_D_EU1	0.1361	remove12
Passenger	Diesel	PC_D_EU0	0.0096	remove13
Passenger	Natural Gas	PC_CNG_EU5	0.0755	remove14
Passenger	Natural Gas	PC_CNG_EU5	0.0040	remove15
Motorcycle	Gasoline	LCV_I_G_EU2	0.40	remove16
Motorcycle	Gasoline	LCV_I_G_EU1	0.16	remove17
Motorcycle	Gasoline	LCV_I_G_EU3	0.14	remove18
Motorcycle	Gasoline	LCV_I_G_EU4	0.3	remove19
Truck	Diesel	HDV_RT_I_D_EU0	0.1277	remove20
Truck	Diesel	HDV_RT_I_D_EU1	0.0710	remove21
Truck	Diesel	HDV_RT_I_D_EU2	0.1827	remove22
Truck	Diesel	HDV_RT_I_D_EU3	0.2474	remove23
Truck	Diesel	HDV_RT_I_D_EU4	0.2383	remove24
Truck	Diesel	HDV_RT_I_D_EU5	0.1309	remove25
Truck	Diesel	HDV_RT_I_D_EU6	0.0018	remove26
Bus	Diesel	HDV_CB_D_EU0	0.1578	remove27
Bus	Diesel	HDV_CB_D_EU1	0.0493	remove28
Bus	Diesel	HDV_CB_D_EU2	0.1616	remove29
Bus	Diesel	HDV_CB_D_EU3	0.2564	remove30
Bus	Diesel	HDV_CB_D_EU4	0.1995	remove31
Bus	Diesel	HDV_CB_D_EU5	0.1662	remove32
Bus	Diesel	HDV_CB_D_EU6	0.0091	remove33

The user could modify data!

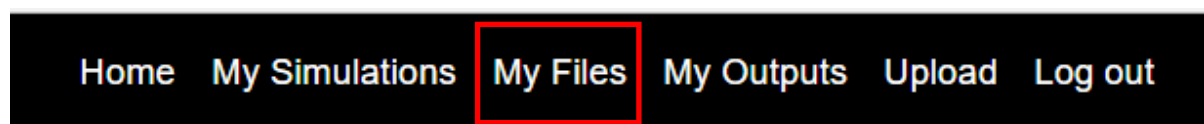
Pattern	Begin	End	Probability	Remove
Pattern 0	00:00	01:00	1	remove0
Pattern 0	01:00	02:00	1	remove1
Pattern 0	02:00	03:00	1	remove2
Pattern 0	03:00	04:00	1	remove3
Pattern 0	04:00	05:00	1	remove4
Pattern 0	05:00	06:00	1	remove5
Pattern 0	06:00	07:00	1	remove6
Pattern 0	07:00	08:00	1	remove7
Pattern 0	08:00	09:00	1	remove8
Pattern 0	09:00	10:00	1	remove9
Pattern 0	10:00	11:00	1	remove10
Pattern 0	11:00	12:00	1	remove11
Pattern 0	12:00	13:00	1	remove12
Pattern 0	13:00	14:00	1	remove13
Pattern 0	14:00	15:00	1	remove14
Pattern 0	15:00	16:00	1	remove15
Pattern 0	16:00	17:00	1	remove16
Pattern 0	17:00	18:00	1	remove17
Pattern 0	18:00	19:00	1	remove18
Pattern 0	19:00	20:00	1	remove19
Pattern 0	20:00	21:00	1	remove20
Pattern 0	21:00	22:00	1	remove21
Pattern 0	22:00	23:00	1	remove22
Pattern 0	23:00	24:00	1	remove23

Figure 71. “Vehicle type” and “Pattern” tables (step 9)

10.4.2.9 Traffic files:

After run traffic simulator, a set of traffic files will be generated and stored in “My files”. These set of files are: **edge, node, tll, bus, rou, conn, add, real, traffic, gdata and spatial**. All of them are necessary to run SUMO in a correct way. The annex of the present manual provides detailed information of the structure of these files.

“My files” folder stores all files of all simulations executed by the user. It is accessible through clicking on “My files” tab in the main IMT toolbar:



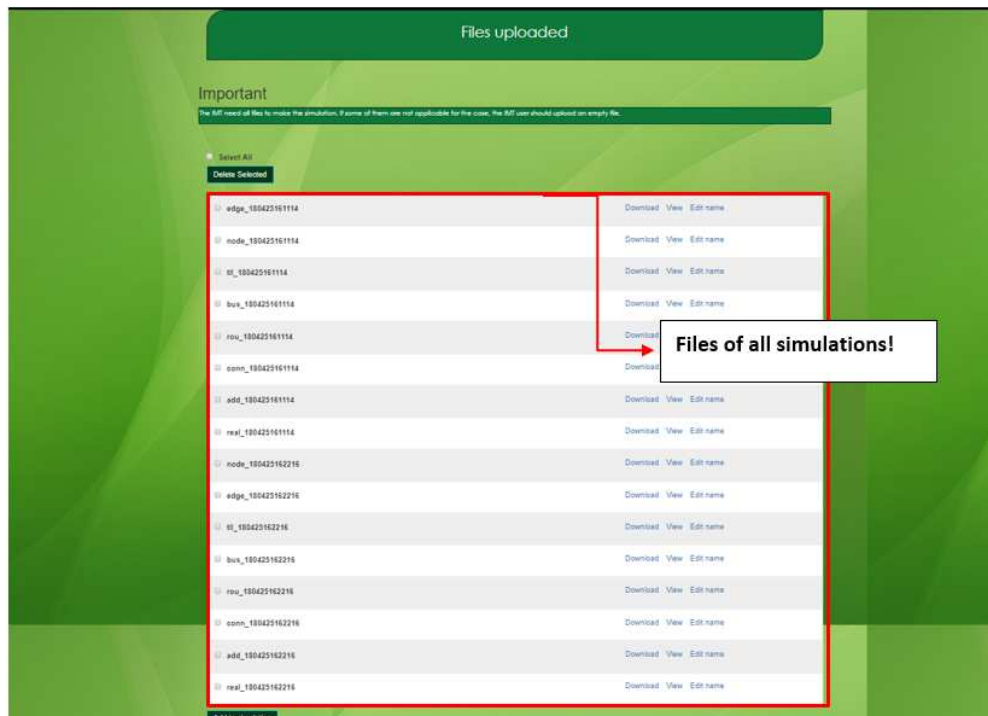


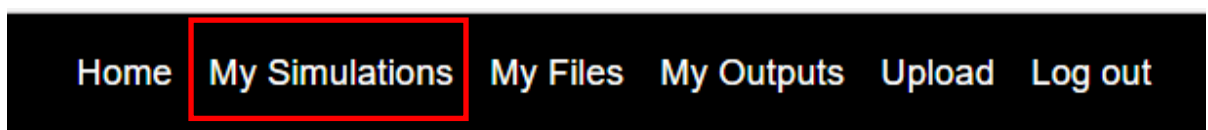
Figure 72. "My Simulations" folder description (user manual)

These files can be downloaded, viewed or deleted:



Figure 73. "My Files" folder options: Download, View or delete

Every simulation will be also registered and stored with an ID in "My Simulations" folder, accessible through clicking on "My Simulations" tab in the main IMT toolbar:



In "My Simulations" folder, traffic files will be sorted by simulation ID. Every time that step-by-step process is executed, a new simulation folder will be created, and accessible in "My

simulations”. Click on “select” option allows to access to the set of files belonging to that simulation:

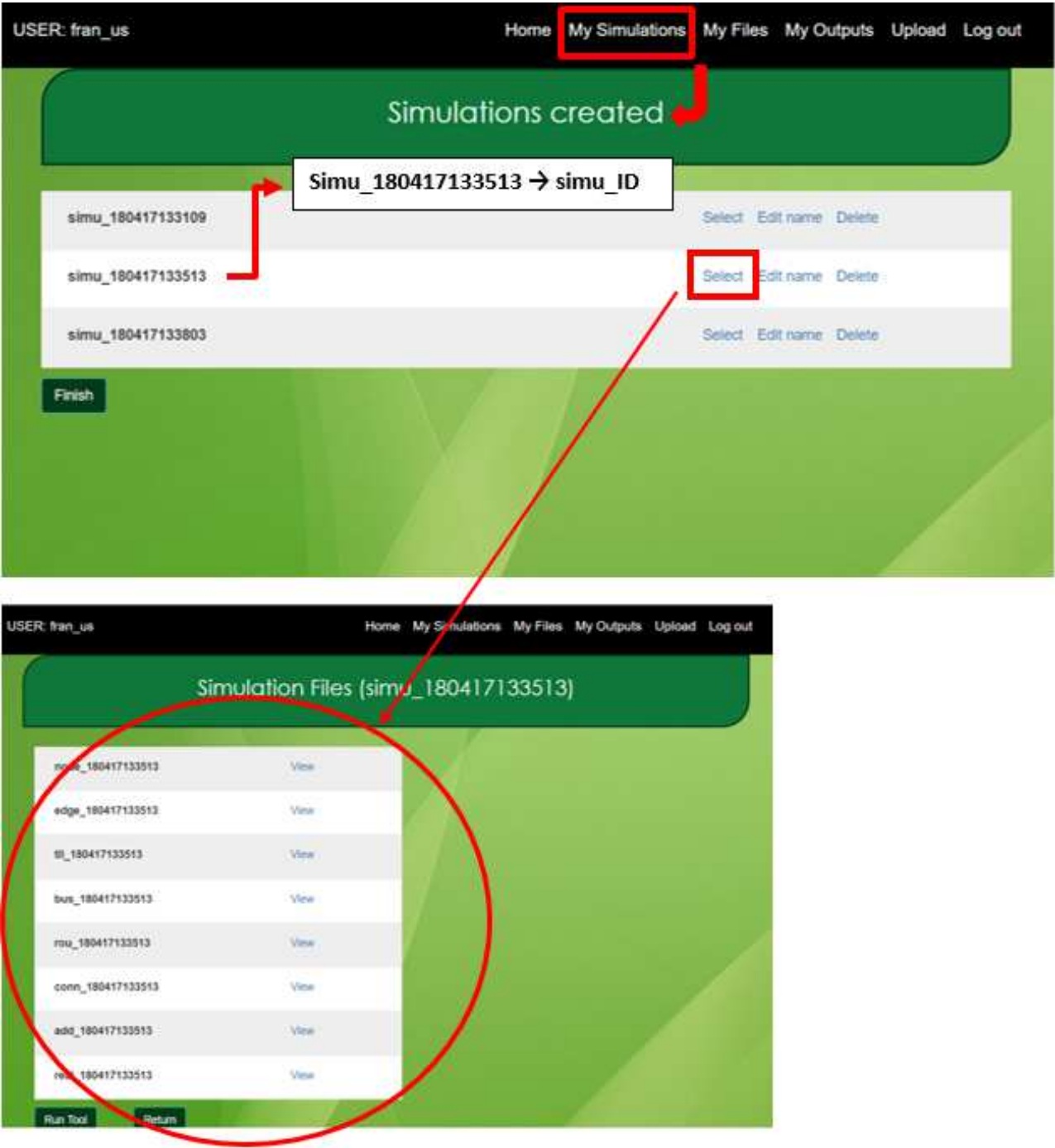


Figure 74. “My Simulations” folder description

10.4.3 Upload-files process

To access the **upload-files process** and perform the simulation, the user must follow a series of steps. The operation of this process will be explained step by step below.

10.4.3.1 Step 1

To access the upload-files process from the IMT homepage, click on the "Upload" tab on the main toolbar. This takes you to a screen where the user can upload files.

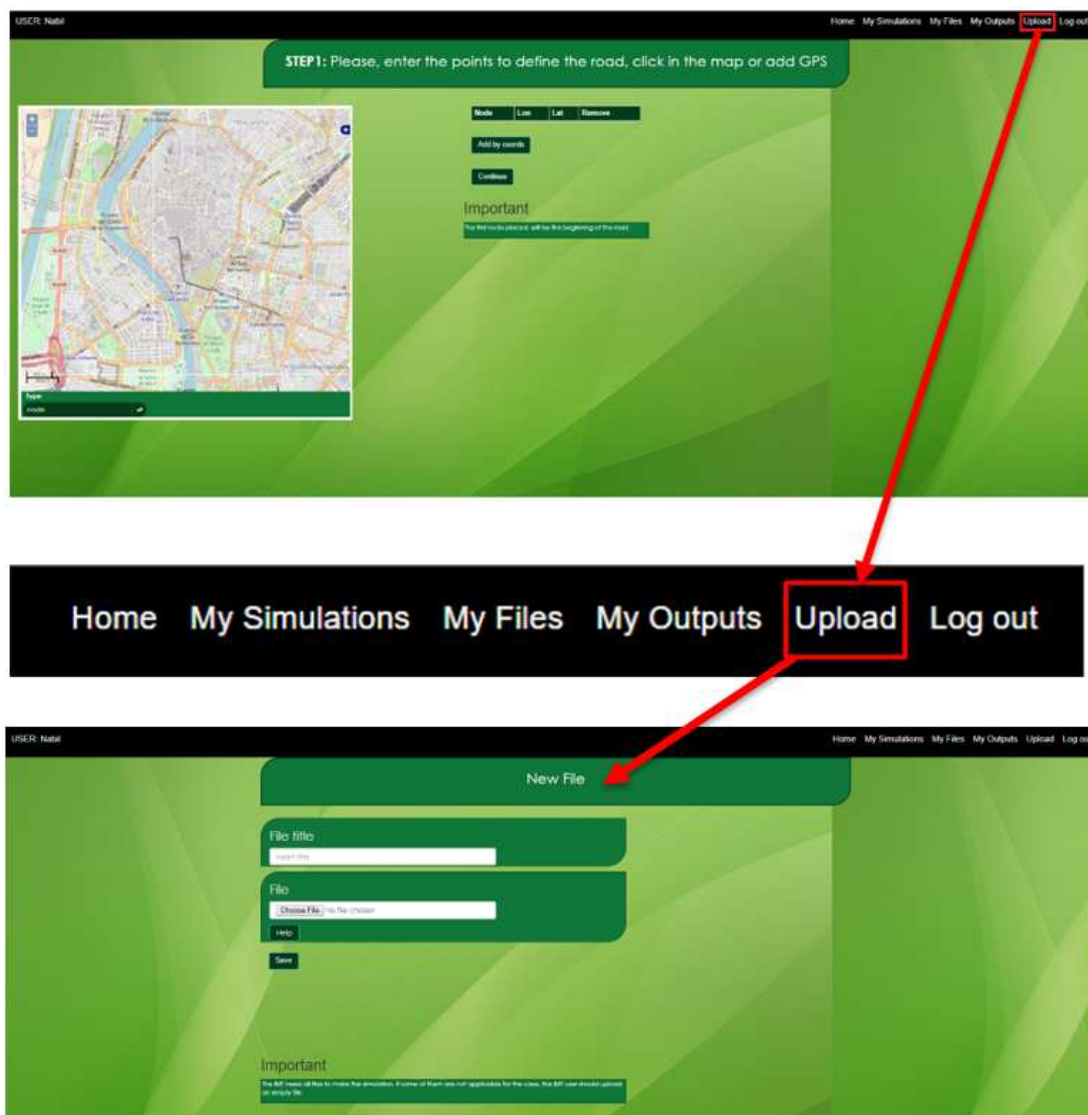


Figure 75. Files upload process Step 1

10.4.3.2 Step 2

On this screen, the user can select the files to be uploaded by clicking on the "Choose Files" button in the "File" section. The user can only upload one file at a time. The format for uploading files is with the .xml extension which is the one mostly used in the tool.

In the "File" section the user will fill in the name under which the file will be saved. A description of the format of each file will be given later (see 8.4 Files description). When the user includes the title to the file, it must match the type of file uploaded. For example, if the user uploads a node file format, the user should put as the initial part of the title the file that is, in this case "node_", followed by any word or phrase that makes it easier to identify which simulation the file belongs to. This process should be followed for all other files:

- For the edge file: the title will begin with "edge_".
- For the traffic lights file (tll file): the title will begin with "tll_".
- For the pedestrians crossing file (conn file): the title will begin with "conn_".
- For the bus file: the title will begin with "bus_".
- For the real file: the title will begin with "real_".
- For the additional file (add file): the title will begin with "add_".
- For the routes file (rou file): the title will begin with "rou_".
- For the gdata file: the title will begin with "gdata_".
- For the spatial file: the title will begin with "spatial_".
- For the traffic file: the title will begin with "traffic_".
- For the pattern file: the title will begin with "pattern_".

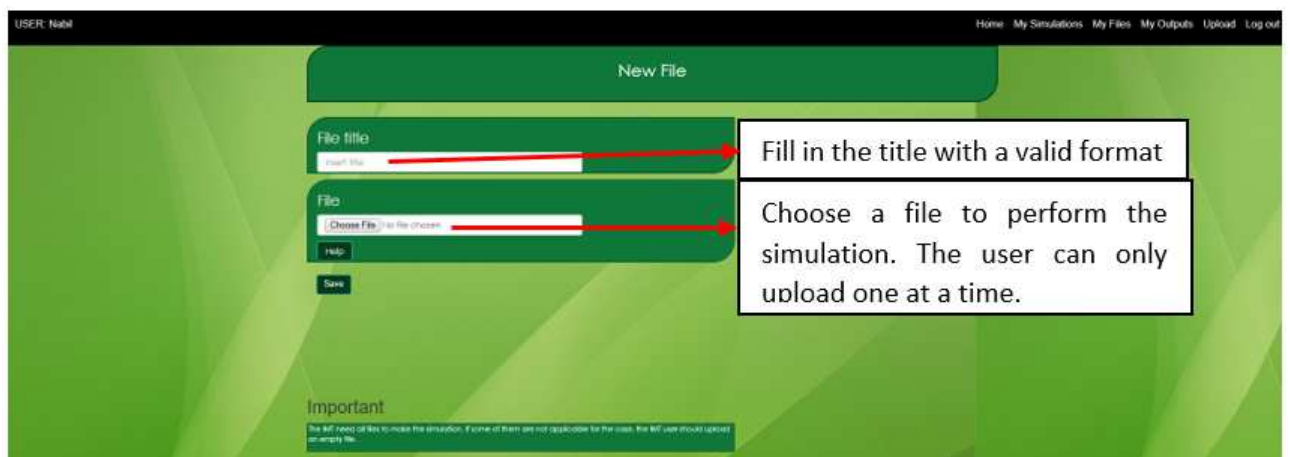


Figure 76. Files uploaded process Step 2

A short summary of how to name the files will appear under the "Help" button.

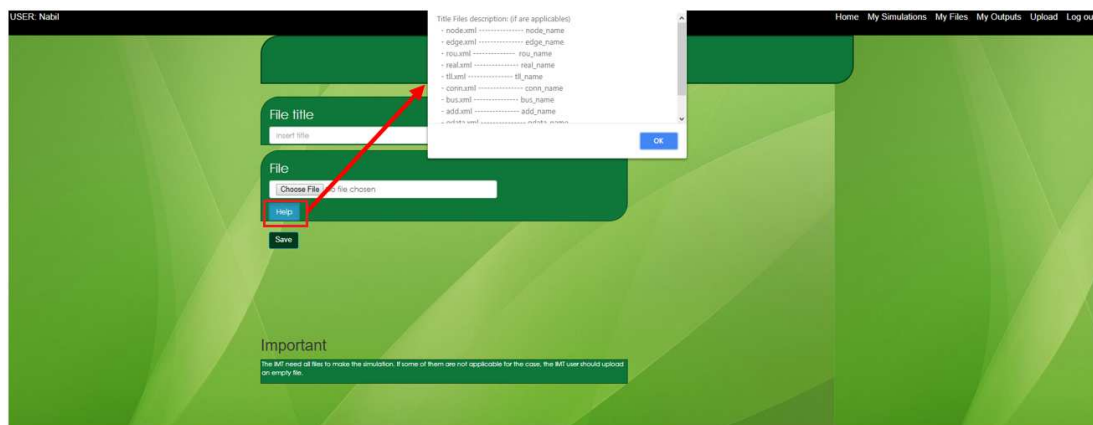


Figure 77. Step 2, help button operation

Once the title of the file is added we click on the "Save" button.

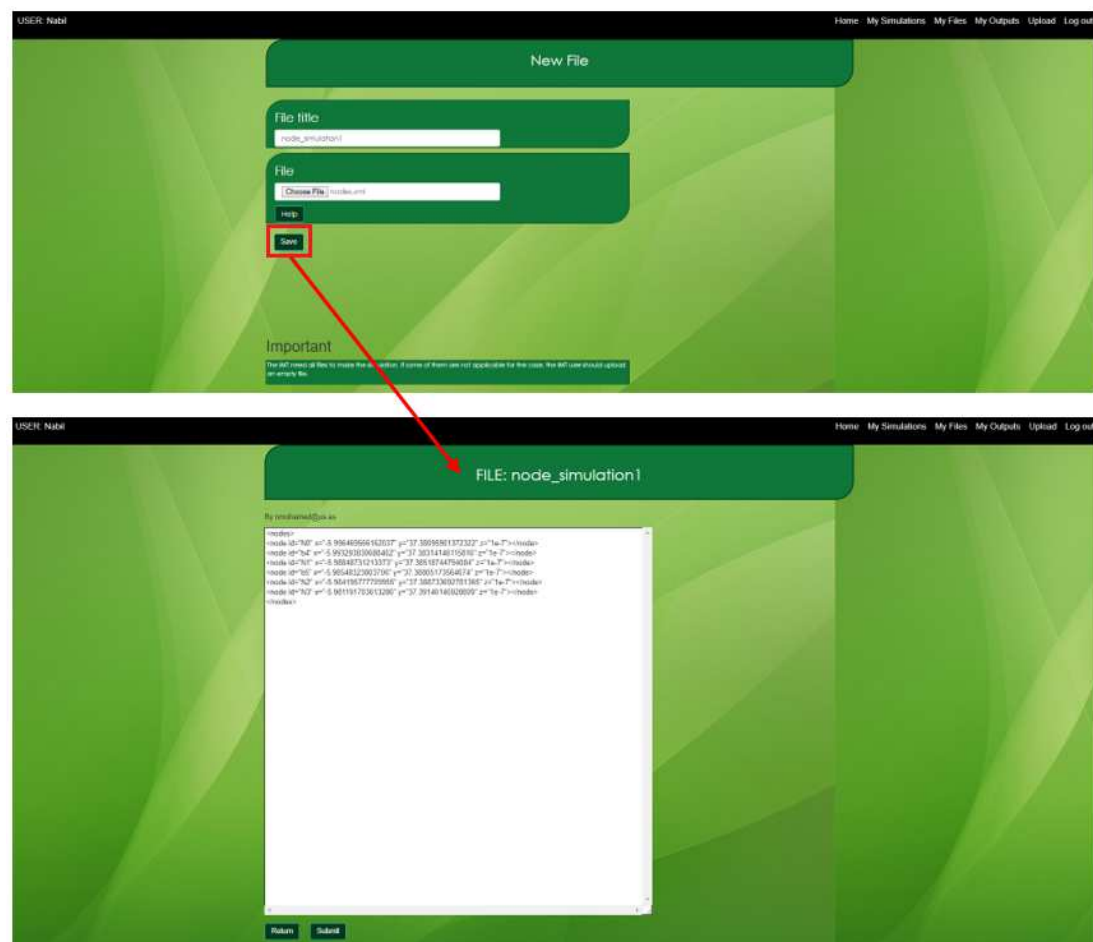


Figure 78. Step 2 to Step 3 screens

10.4.3.3 Step 3

The "Save" button will take us to a new screen where the user can see the content of the uploaded file. At this moment, the file is already uploaded, so if the user presses the "submit" button the user will be taken to the view where all the uploaded documents are stored. To perform a complete traffic simulation, eight files are needed (node, edge, tl, conn, bus, add, others, req).

conn, bus, real, add, and rou) and if the noise module simulation is to be performed, three more files are needed: gdata, spatial and traffic. It is recommended to upload all eleven files.

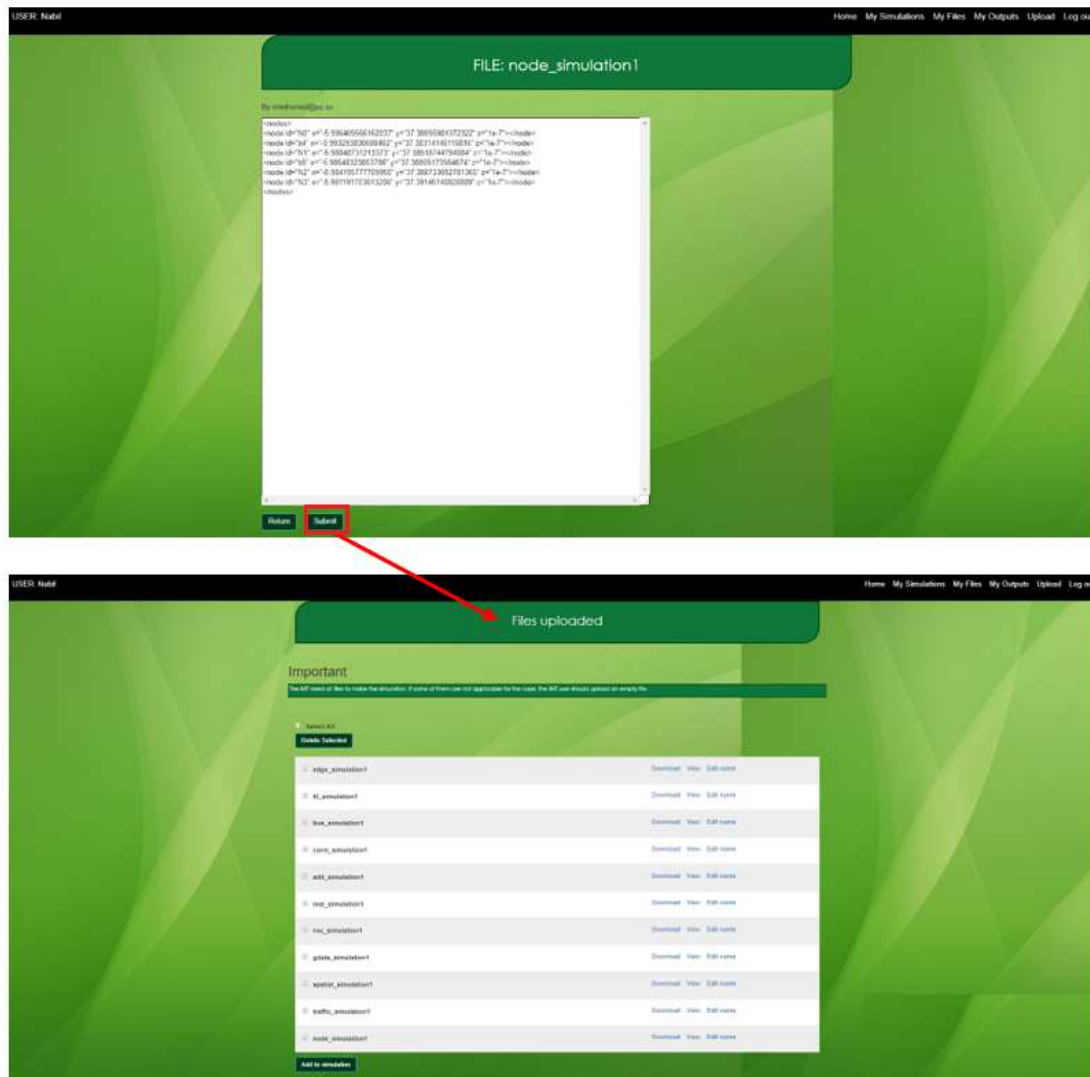


Figure 79. Files upload process Step 3

The user has to repeat this process (step 1 to step 3) until all the files needed are uploaded before proceeding to the next step.

10.4.3.4 Step 4

Once all the files have been uploaded, select them and click on the "Add to simulation" button. The user can select the files one by one if there are more files from other simulations or by clicking on the select all button.

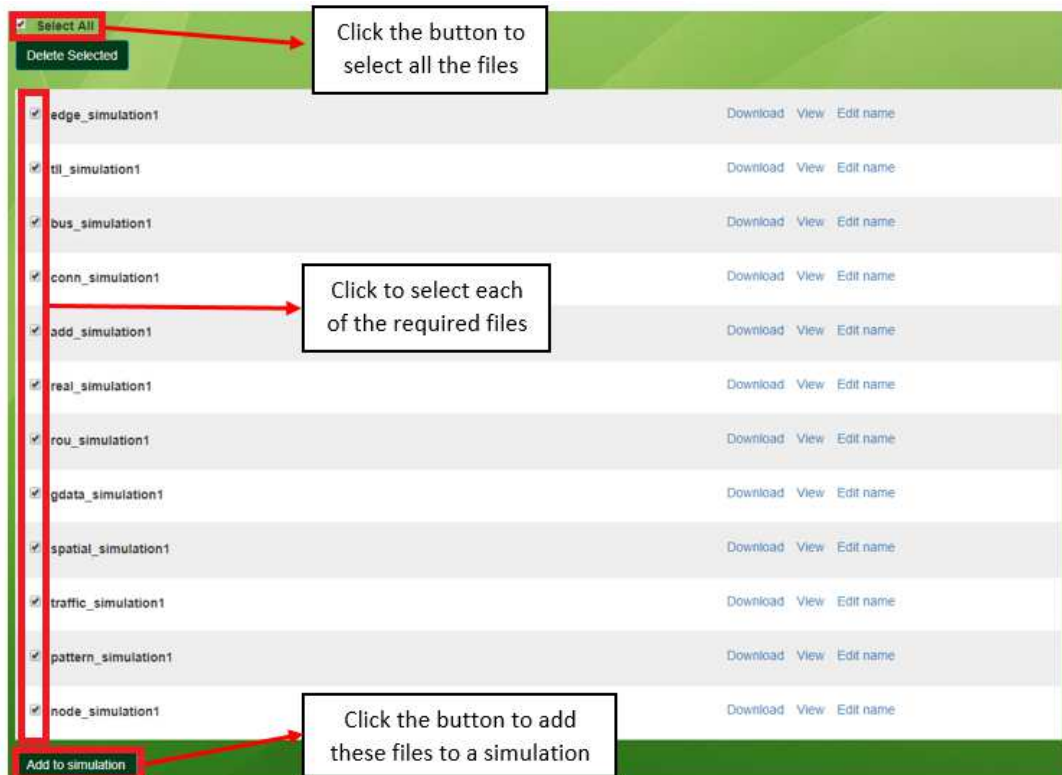


Figure 80. Files uploaded process Step 4

10.4.3.5 Step 5

The following screen will appear, in which the user must put a title to the simulation (in this case, there are no restrictions) and click on the "Create Simulation" button.

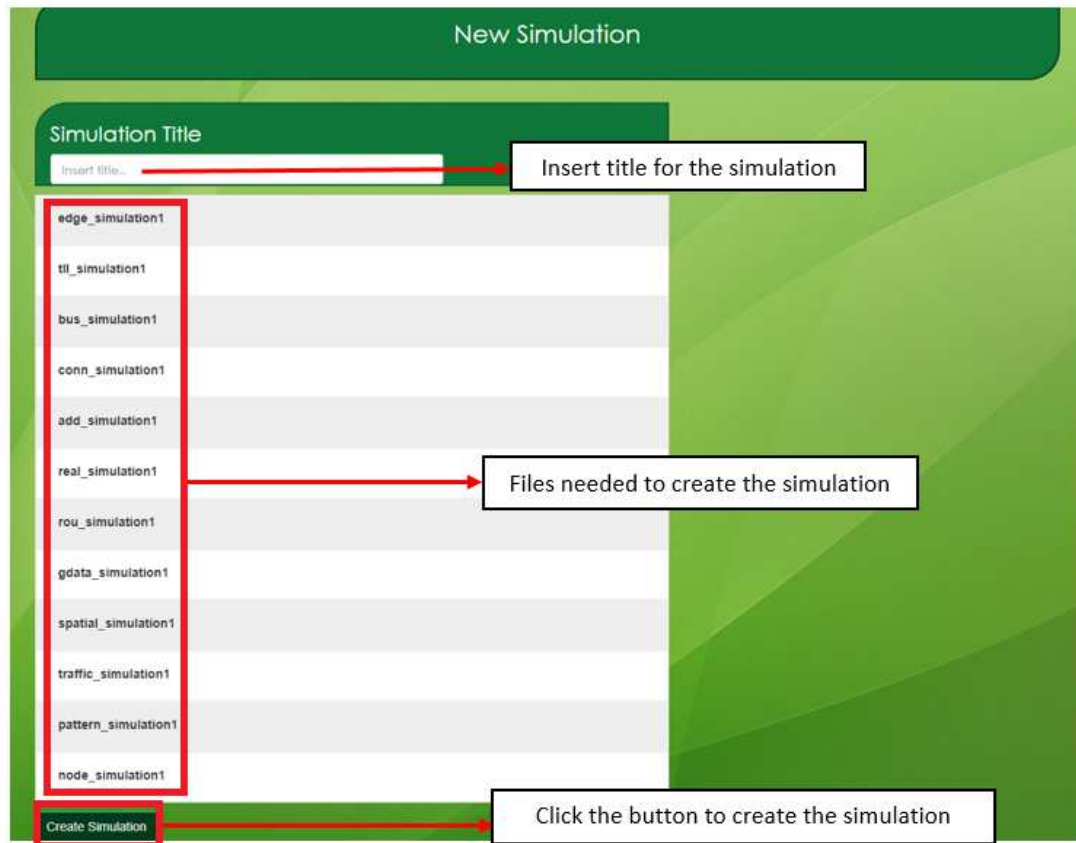


Figure 81. Files uploaded process Step 5

10.4.3.6 Step 6

This will take the user to the screen of simulations created where all simulations are stored, whether they have already been created by the file upload process or by the step-by-step process.



Figure 82. Files uploaded process Step 6

To continue, click on the "Select" button that will take the user to the last screen before performing the simulation on the tool.

10.4.3.7 Step 7

From here, we have two options if we press the "Return" button the user returns to the previous screen of simulations created and if the user presses the "Run Tool" button the operation of the tool will begin.

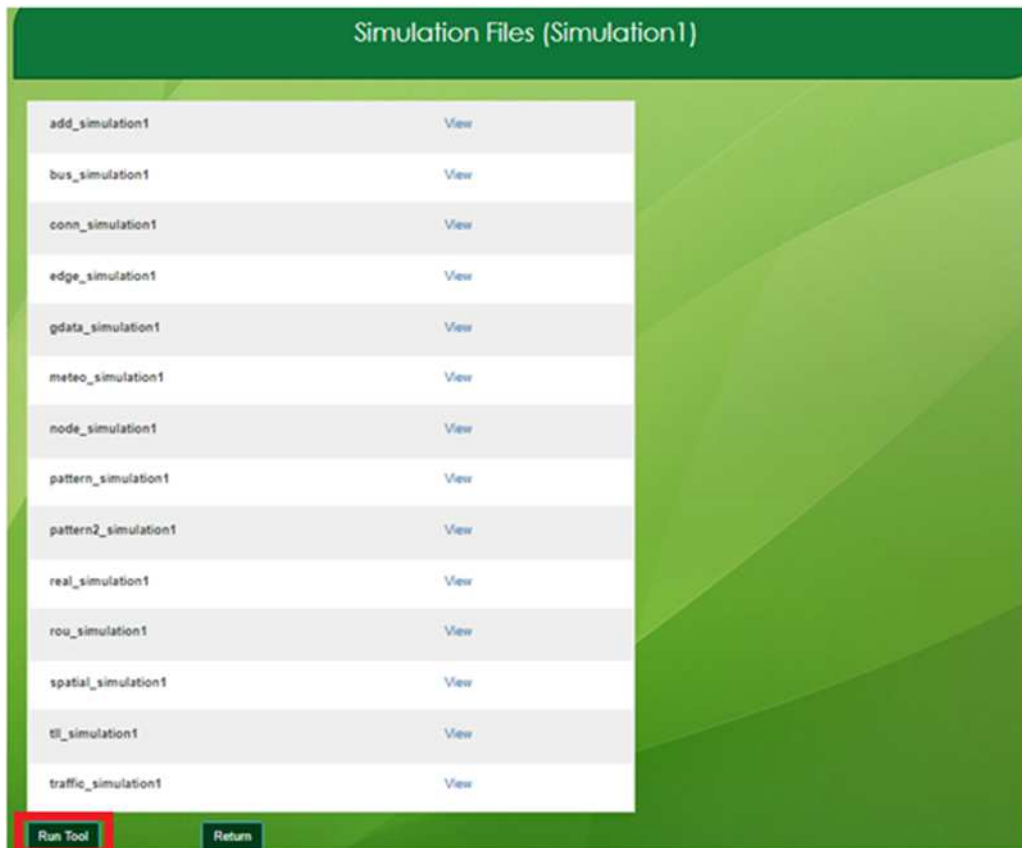


Figure 83. Files uploaded process Step 7

This last step corresponds to the step-by-step process in step 9, so it takes the user to the screen to run the modules (see 8.2.2 Modules execution).

10.4.4 Modules execution

After traffic simulation, the IMT allows to continue with the modules execution. Currently, only five modules can be run: energy, noise, emissions, dispersion and health.

The main menu is showed below:

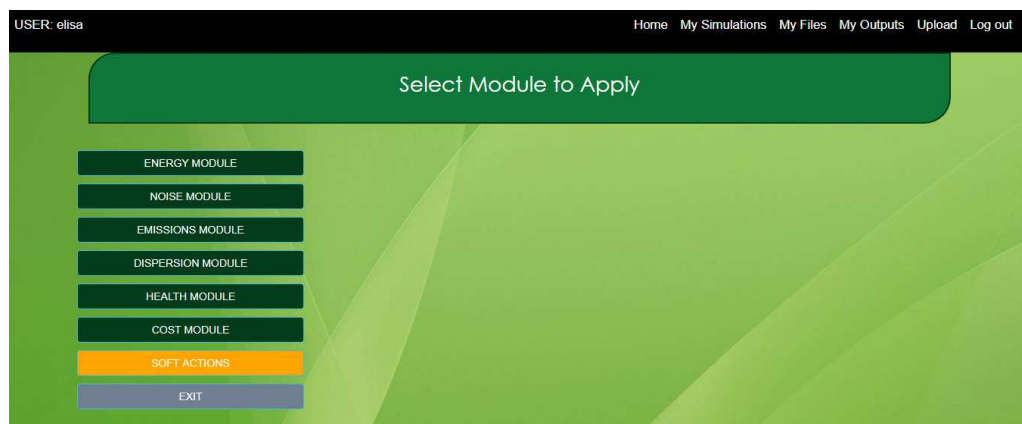


Figure 84. Module selection main menu

ENERGY MODULE:

The user can run the Energy module by clicking on “ENERGY MODULE” button:

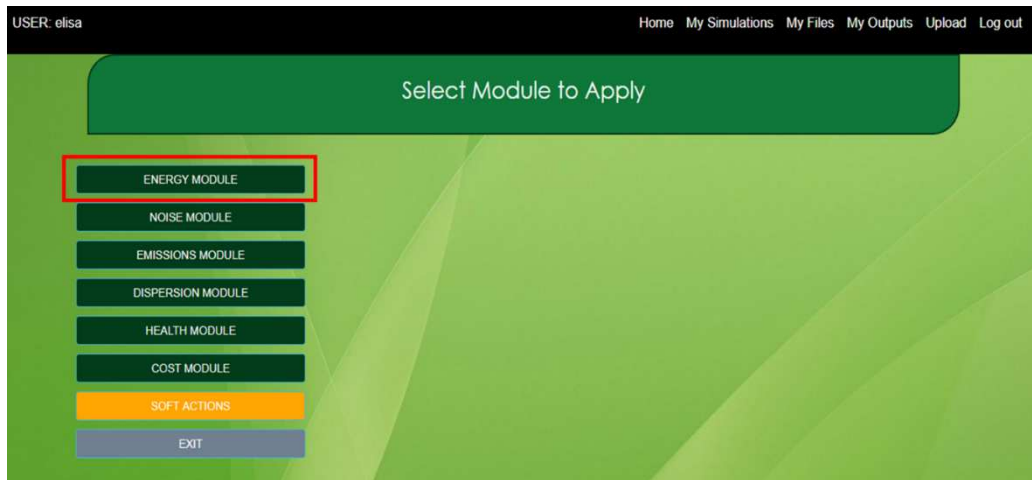


Figure 85. “Energy Module” button location in “Select Module to Apply” view

Due to Energy module only uses outputs from traffic simulator as inputs, after pressing the button, this module will be executed and results will be showed:

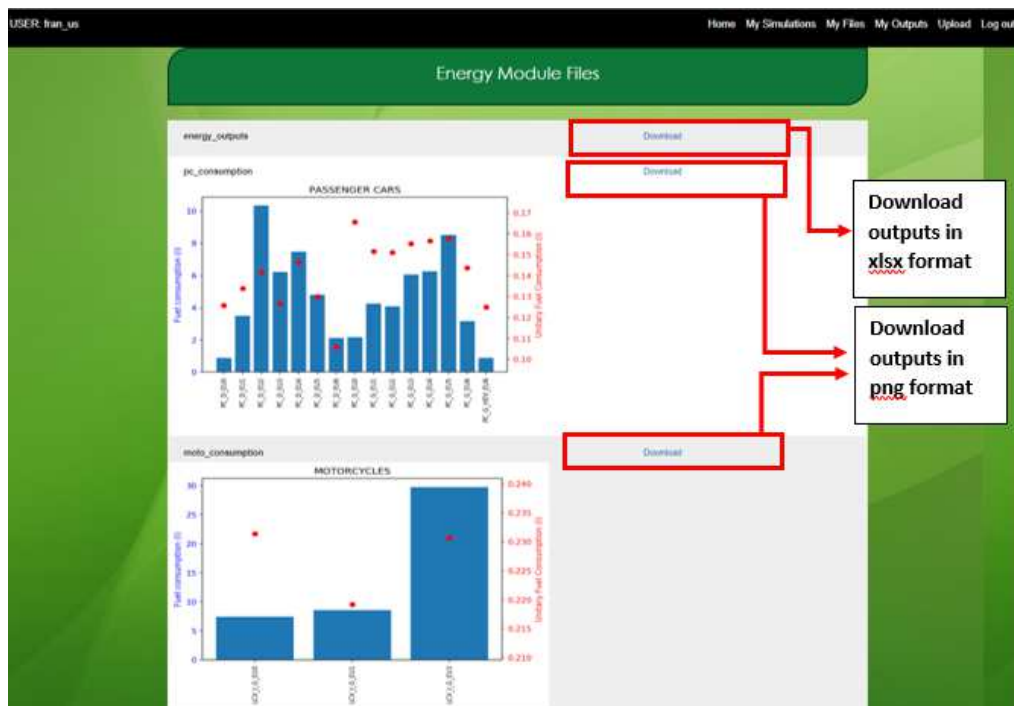


Figure 86. Energy module charts outputs

To continue with the modules execution, the user has to click on “Continue Simulation” button, located at the bottom of the view. Otherwise, click on “Finish” button.

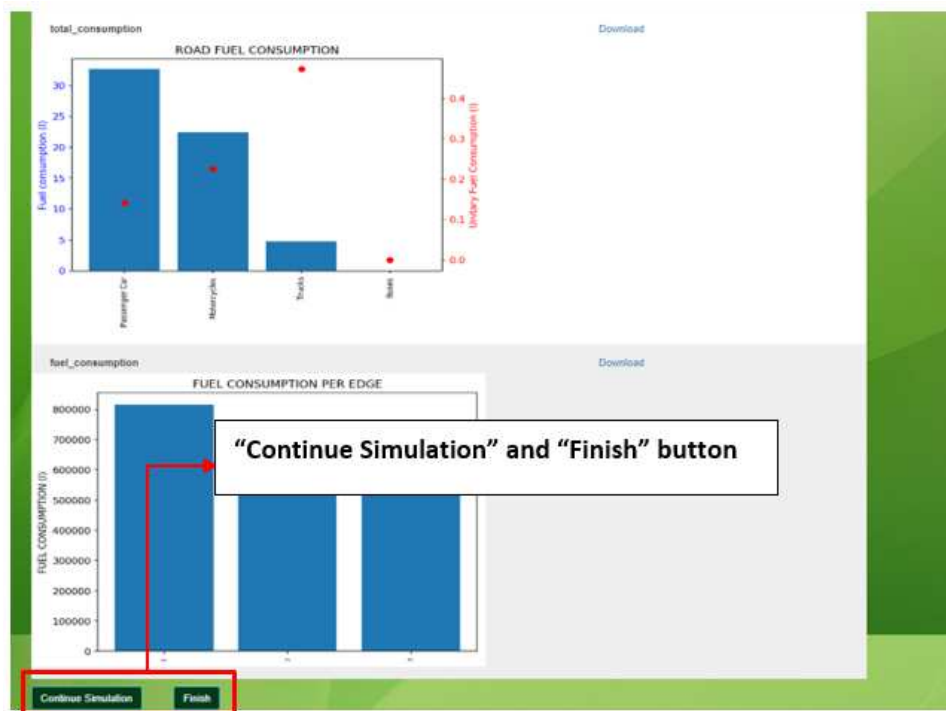


Figure 87. “Continue Simulation” and “Finish” button location

NOISE MODULE:

The user can run the Noise module by clicking on “NOISE MODULE” button:

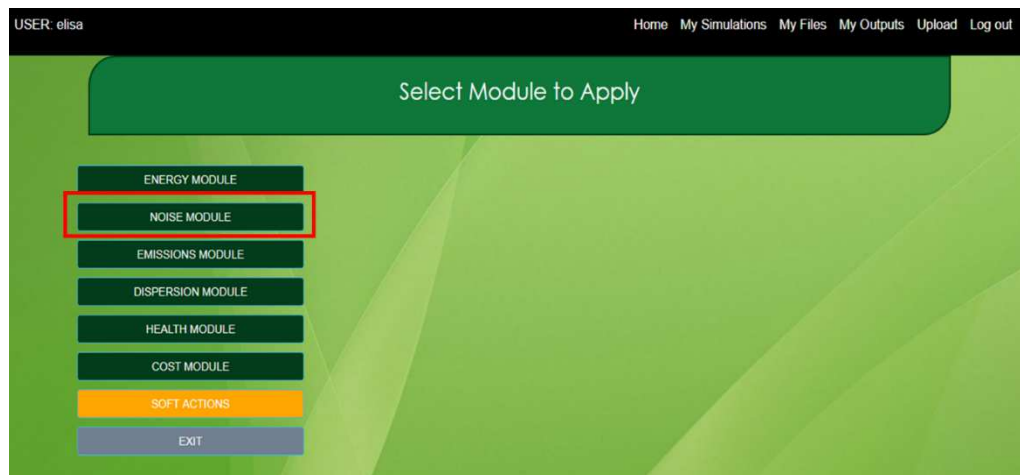


Figure 88. “Noise Module” button location in “Select Module to Apply” view

Due to Noise module only uses outputs from traffic simulator as inputs, after pressing the button, this module will be executed and results will be showed:

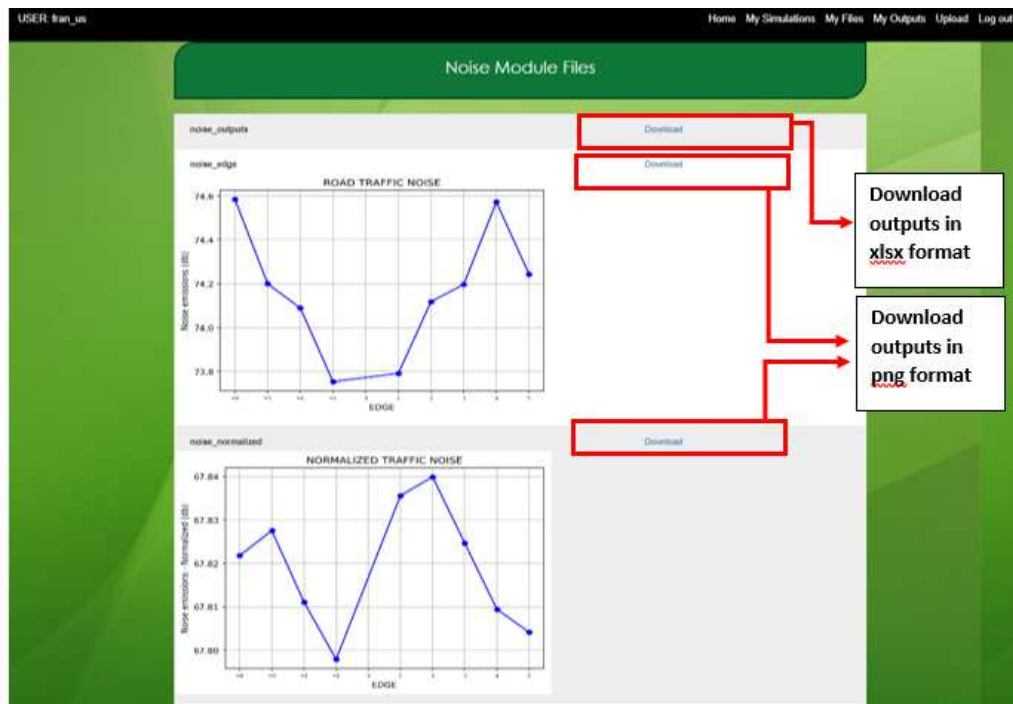


Figure 89. Noise module charts outputs

To continue with the modules execution, the user has to click on “Continue Simulation” button, locate at the bottom of the view. Otherwise, click on “Finish” button.

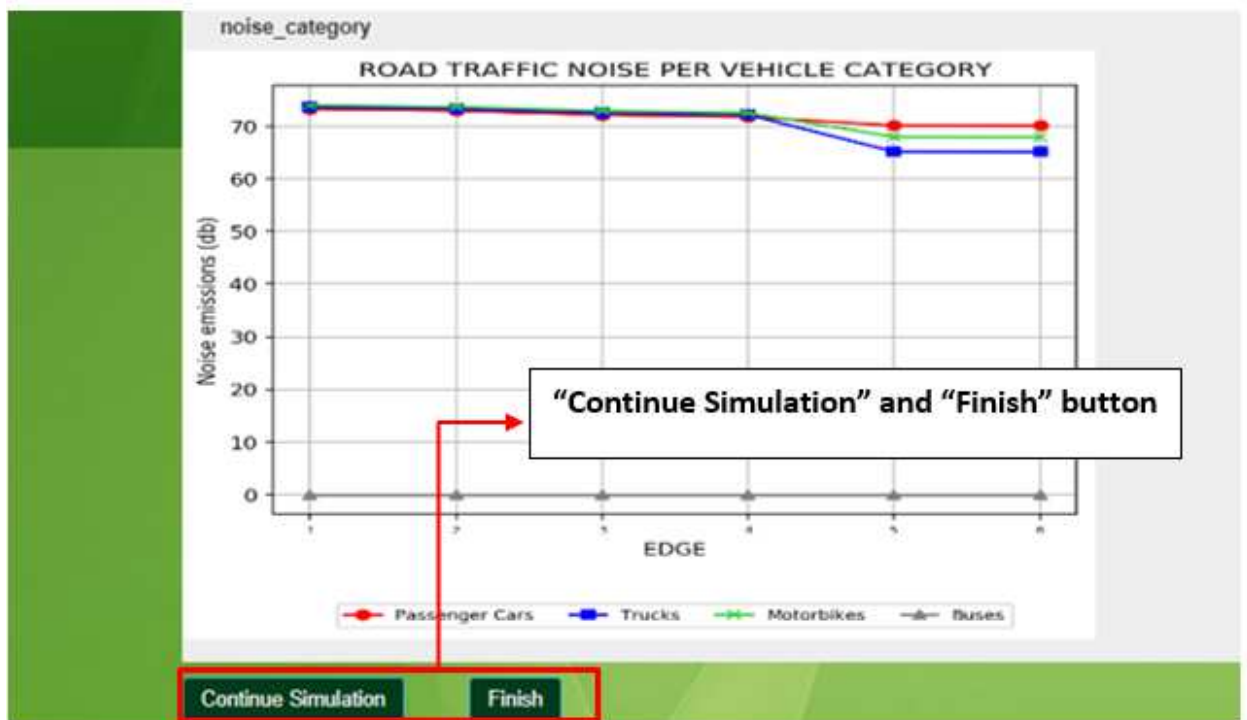


Figure 90. "Continue Simulation" and "Finish" button location

EMISSIONS MODULE:

The user can run the Emissions module by clicking on "EMISSIONS MODULE" button:

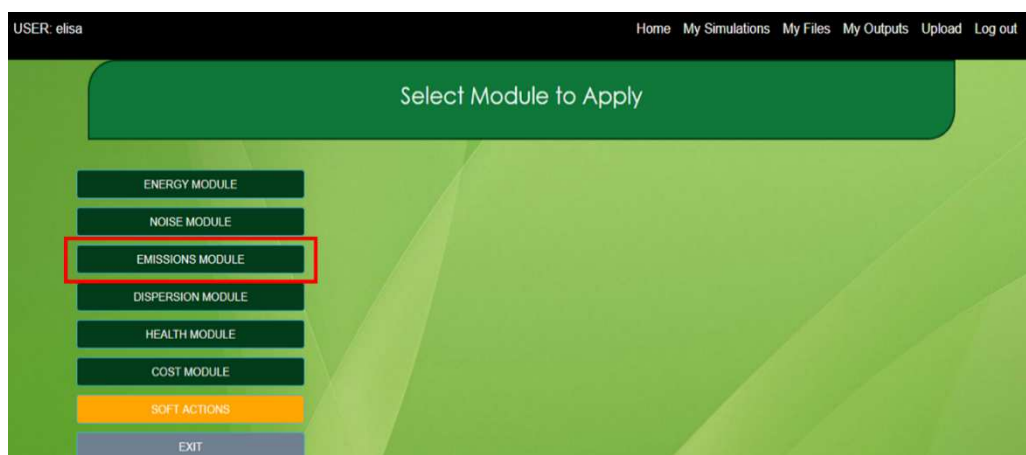


Figure 91. "Emissions Module" button location in "Select Module to Apply" view

Emission module allows the user to choose between the following options (to be shown as plots):

- Pollutant: CO, CO₂, NO_x, HC, PM_x
- Type of data: absolute and/or normalized emissions
- Temporal analysis: hourly and/or daily analysis

- Spatial Analysis: Group the results into a set of edges. For instance, if the road defined by the user includes the following edges: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, -1, -2, -3, -4, -5; the user could group this in a set of subgroups: 1-4 (edges: 1, 2, 3, 4, -1, -2, -3, -4) and 5-10 (edges: 5, 6, 7, 8, 9, 10, -5) or 1-3 (edges: 1, 2, 3, -1, -2, -3), 4-7 (edges: 4, 5, 6, 7, -4, -5) and 8-10 (edges: 8, 9, 10) or any other configuration of interest to the user.

Emissions module: Select the outputs that will be displayed

Pollutant	
CO	y
CO2	n
NOx	n
HC	n
PMx	n

Type of Data	
Absolute Emissions	y
Normalized Emissions	y

Temporal Analysis	
Hourly Analysis	y
Daily Analysis	y

Spatial Analysis	
From	To
1	4

new spatial analysis

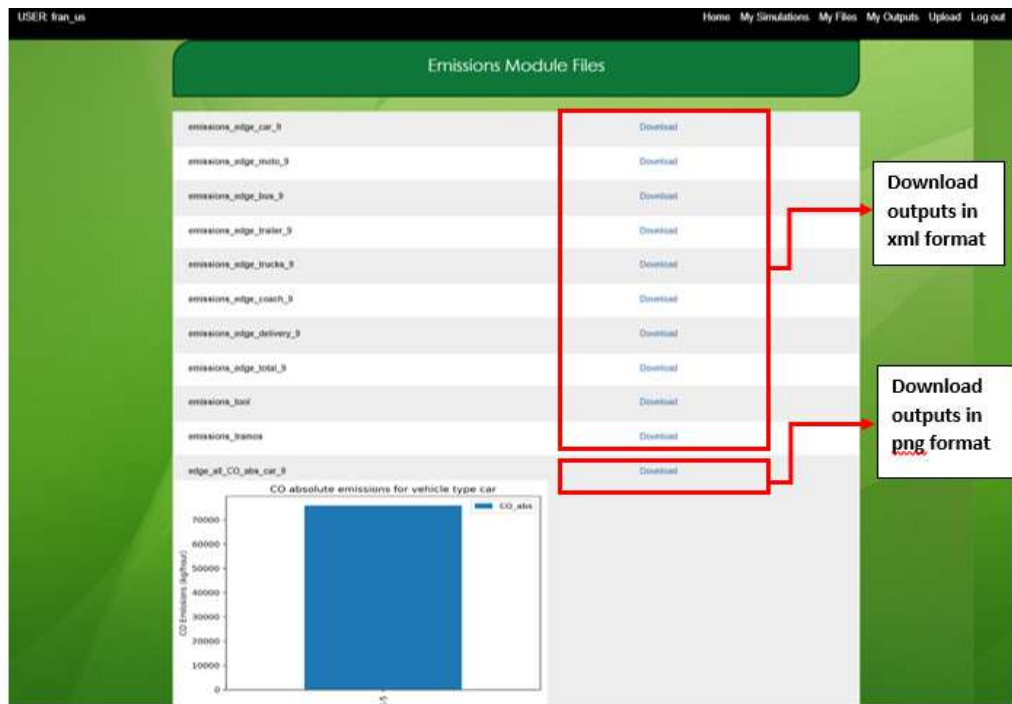
Run module

Click on "new spatial analysis" to add a new sub-group of edges

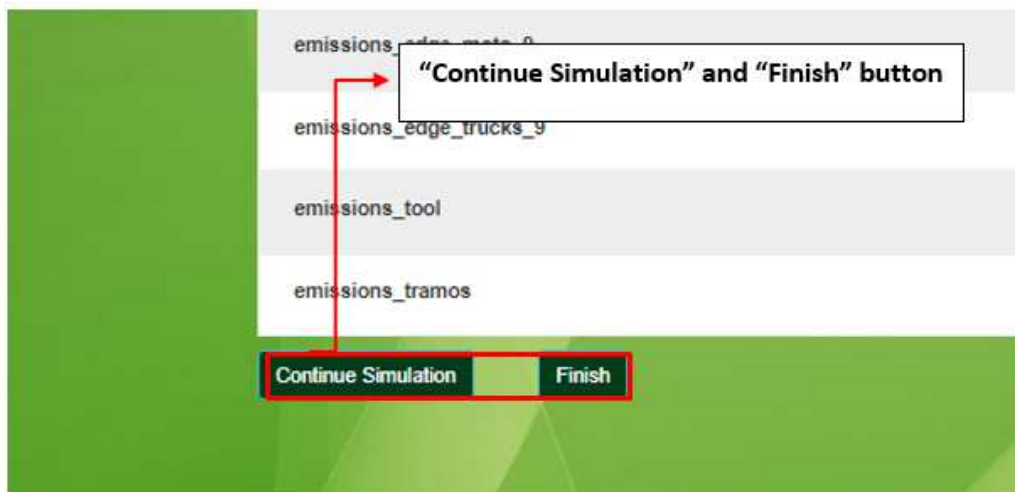
Figure 92. Emissions module files output

Due to Emissions module only uses outputs from traffic simulator as inputs, after pressing the button, this module will be executed and results will be showed:

Results will be shown as a set of xml files (per hour and vehicle type, and global files with complete information) and a set of plots. Both could be downloaded.



To continue with the modules execution, the user has to click on “Continue Simulation” button, locate at the bottom of the view. Otherwise, click on “Finish” button.



DISPERSION MODULE:

The user can run the Dispersion module by clicking on “DISPERSION MODULE” button:

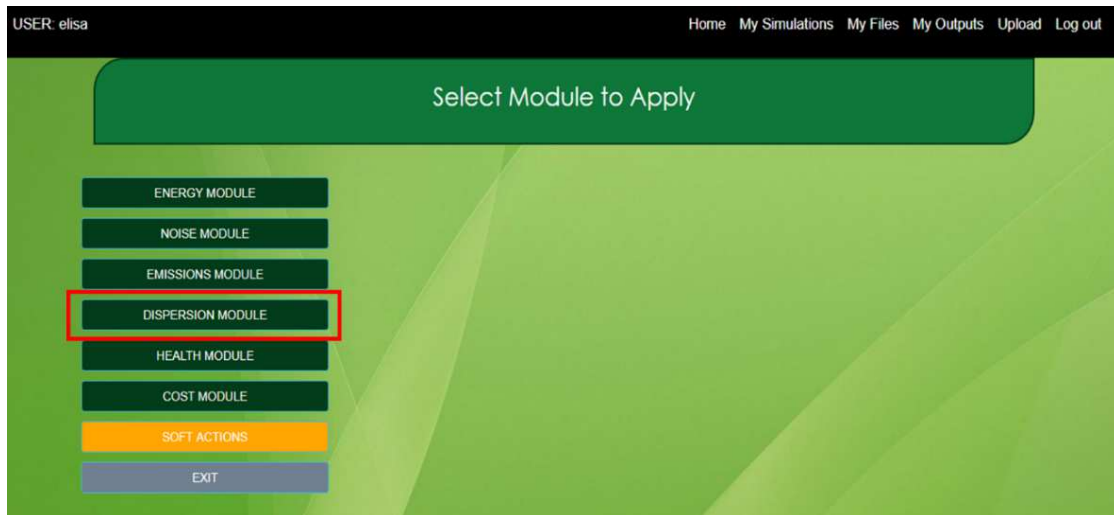


Figure 95. “Dispersion Module” button location in “Select Module to Apply” view

After Dispersion module selection, an input excel file must be downloaded and completed by the IMT user. This file collects information about building, trees and road and includes some notes on how it must be completed, apart from the important guidelines given below

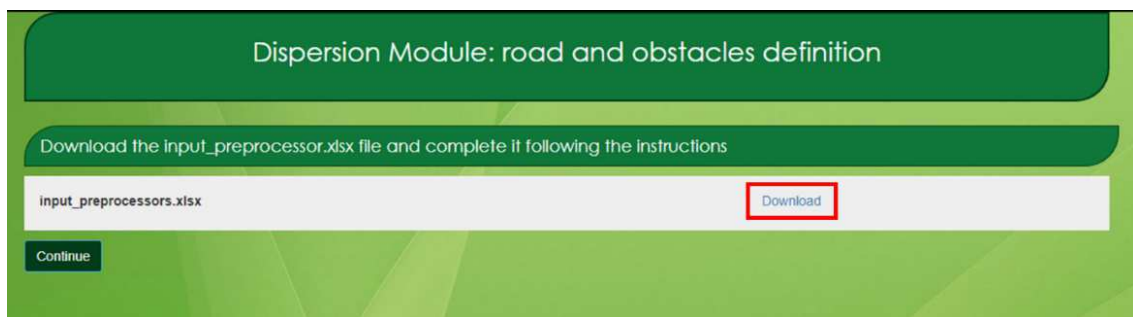


Figure 96. Download input excel file

To prepare the required information to fill in sheets “buildings”, “trees” and “roads” of the excel file, some steps have to be performed, using Geographical Information System software (ArcGIS, that requires a licence, or QGIS, available online for free) before filling in the input excel file. The following guidelines assume the use of QGIS

10.4.4.1 Download and open the QGIS software

The QGIS software can be downloaded through the following link: <https://www.qgis.org/en/site/forusers/download.html#>.

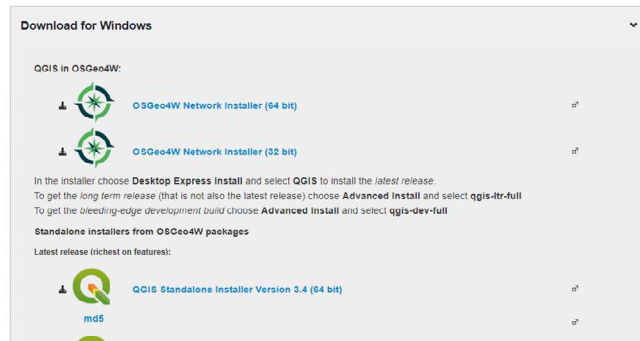
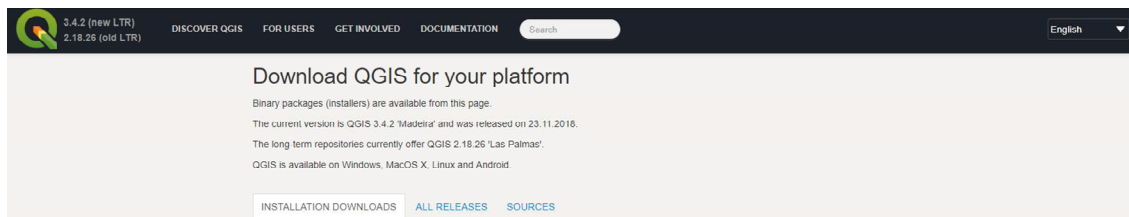


Figure 97. Download QGIS software

The user only needs to install the OSGeo4W Network Installer (64 or 32 bit according to computer processor).

Open QGIS and define the OpenStreepMap as base map

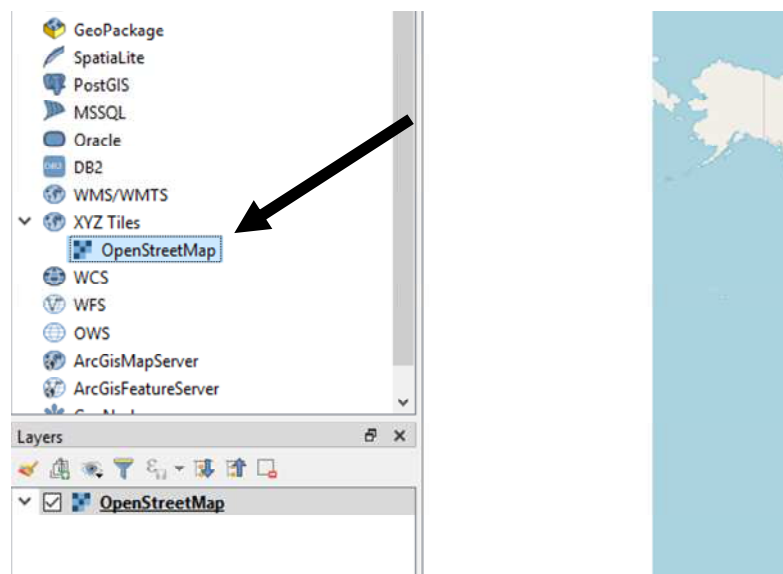


Figure 98. Open QGIS software

Zoom in to your study area

Using the scroll button of the mouse, the user can zoom in to the study area. In the image below, there is an example of several roads in Lisbon (Portugal).

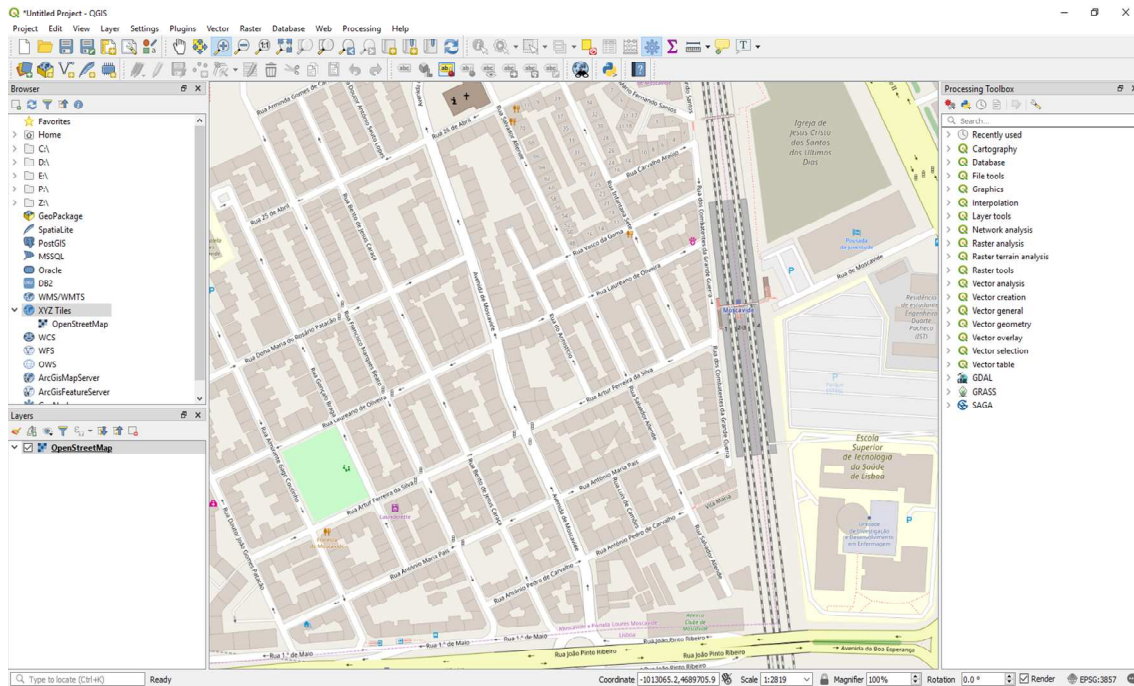


Figure 99. Zoom in to your study area

10.4.4.2 Draw the buildings

First the user needs to create a “New Shapefile Layer”:

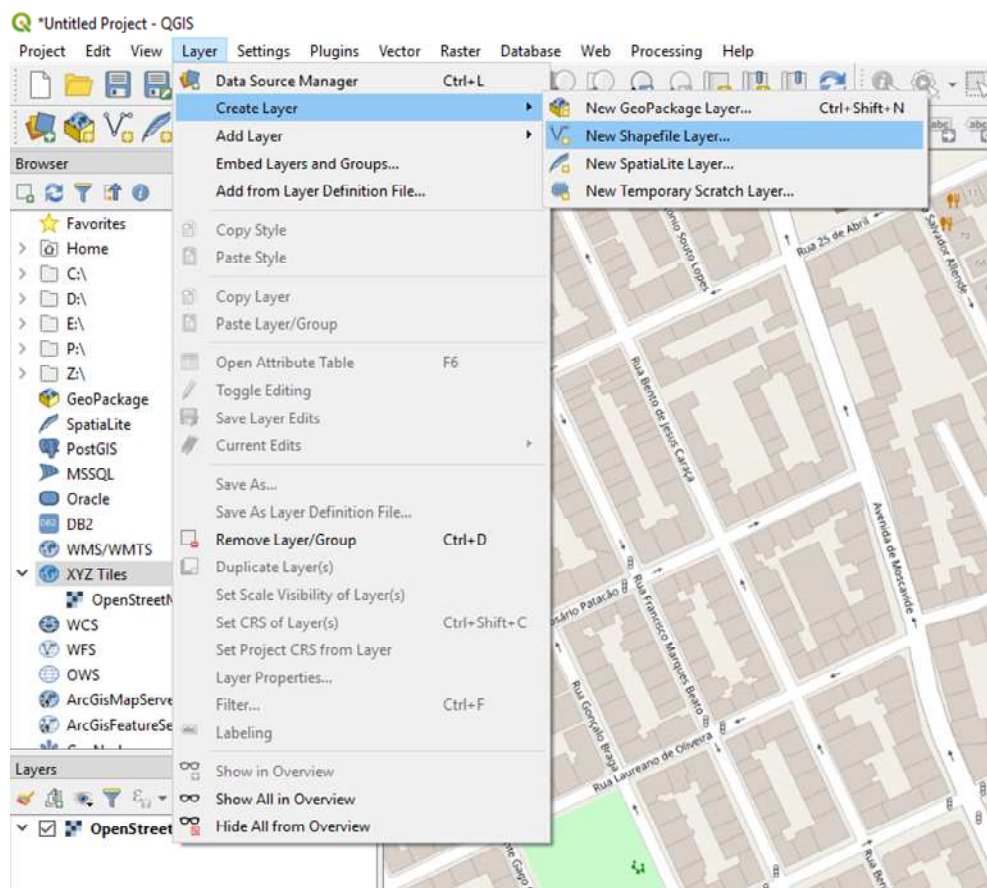


Figure 100. Draw the buildings using QGIS software – Step 1

The user needs to define the “File Name” (including location) and the “Geometry type” (Polygon) and “Ok”.

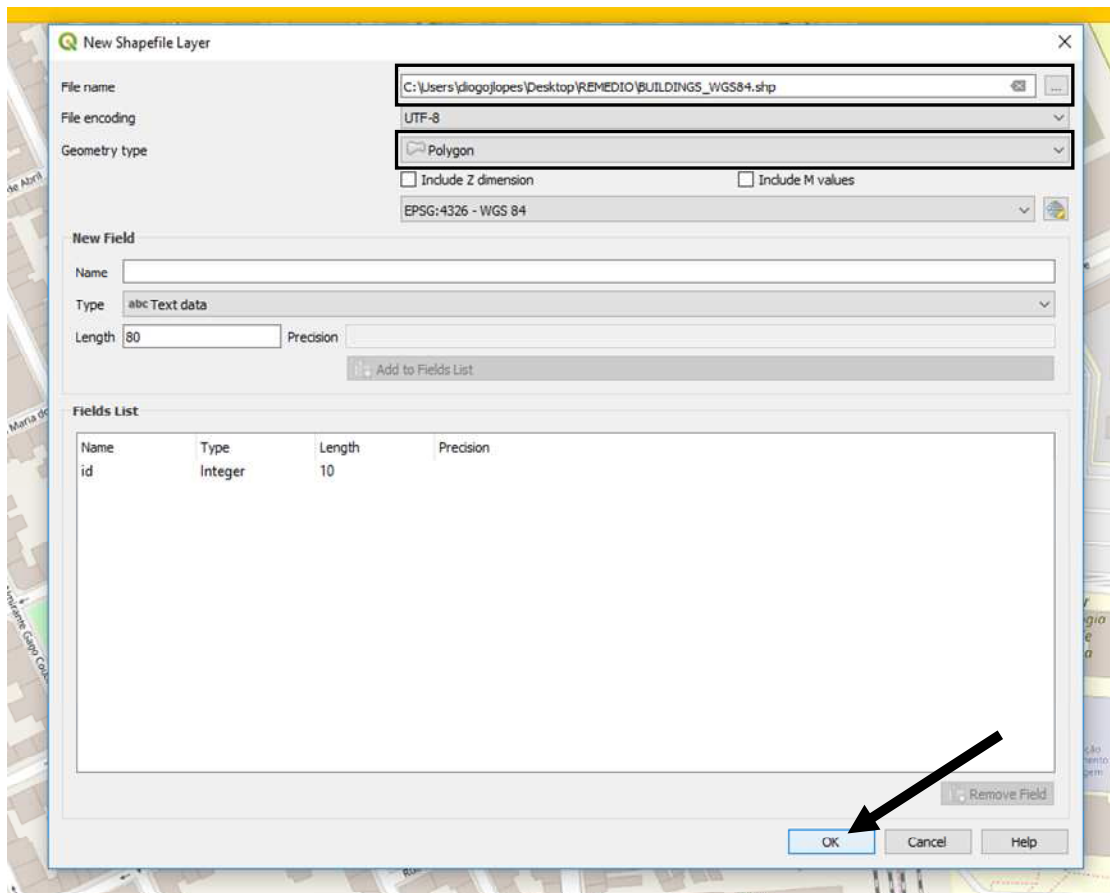


Figure 101. Draw the buildings using QGIS software – Step 2

Click in the “Toggle Editing”.

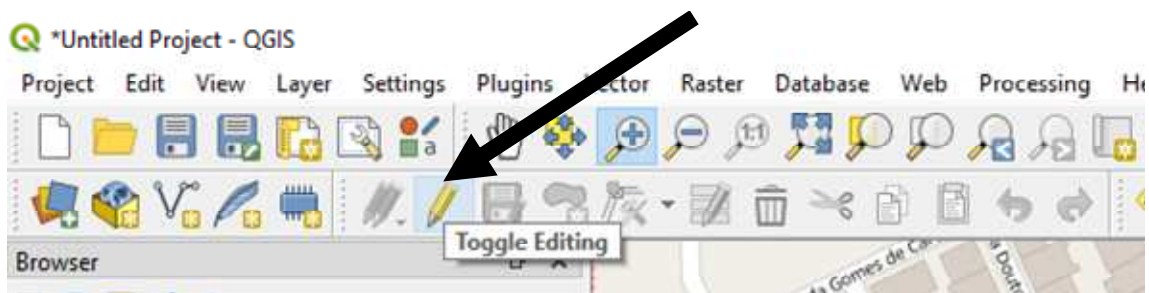


Figure 102. Draw the buildings using QGIS software – Step 3

Click in the “Add Polygon”.

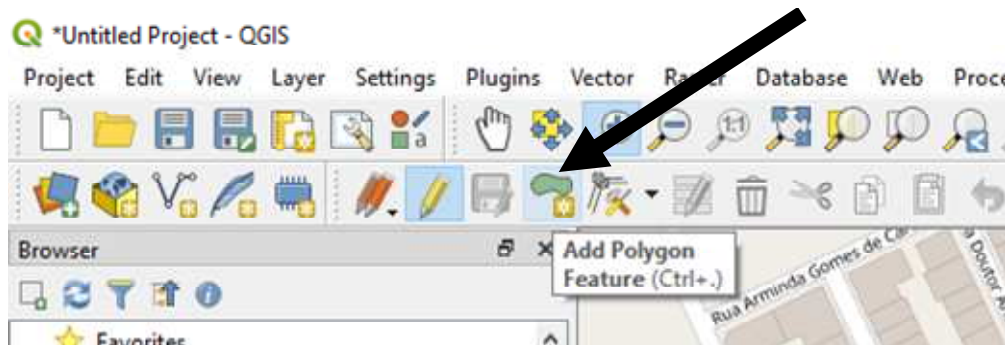


Figure 103. Draw the buildings using QGIS software – Step 4

The user needs to draw the buildings by defining the vertices. For that, click with left mouse button on the vertices and click in the right mouse button to end feature. The buildings cannot have more than 4 vertices. In the image below, there is an example of 3 building features.

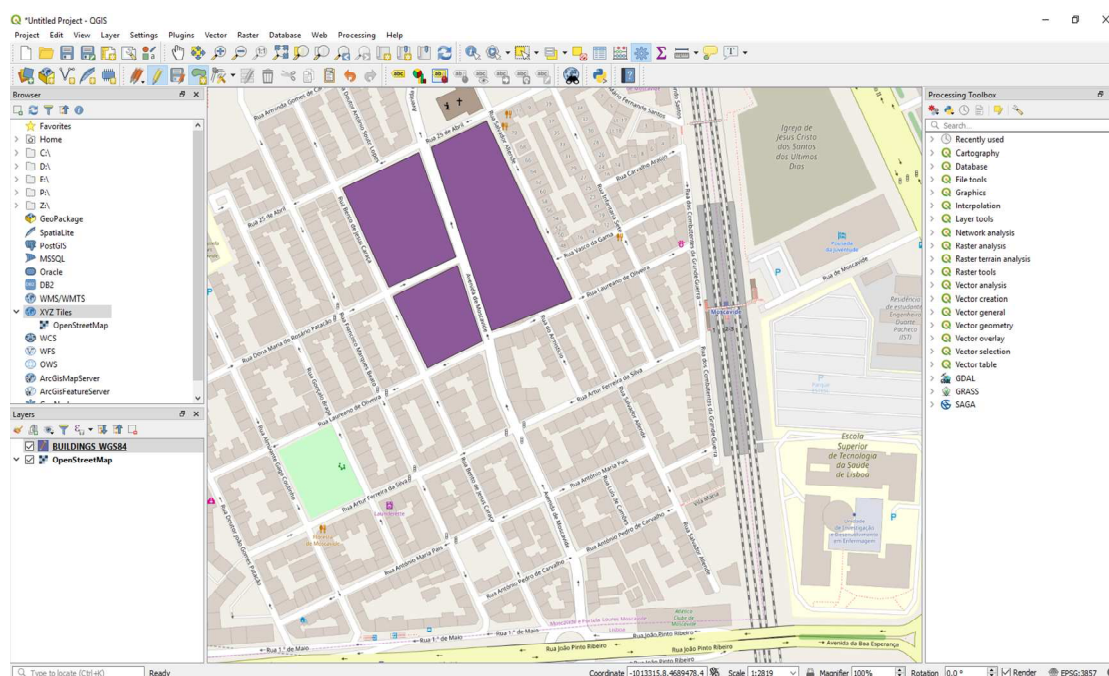


Figure 104. Draw the buildings using QGIS software – Step 5

10.4.4.3 Add the buildings height information

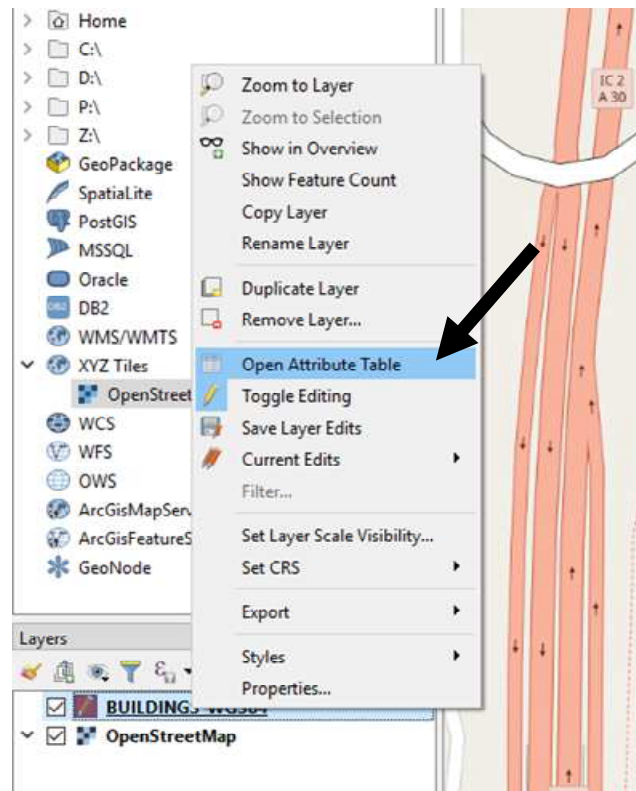


Figure 105. Add the buildings height information – Step 1

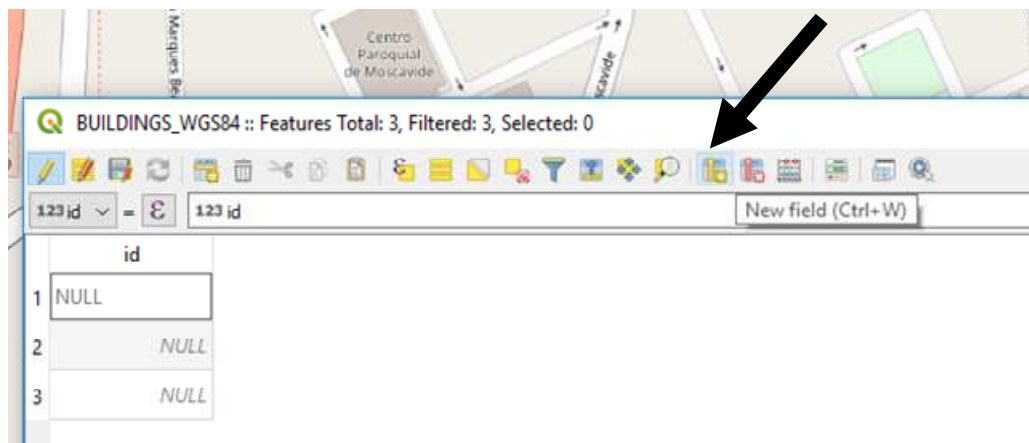


Figure 106. Add the buildings height information – Step 2

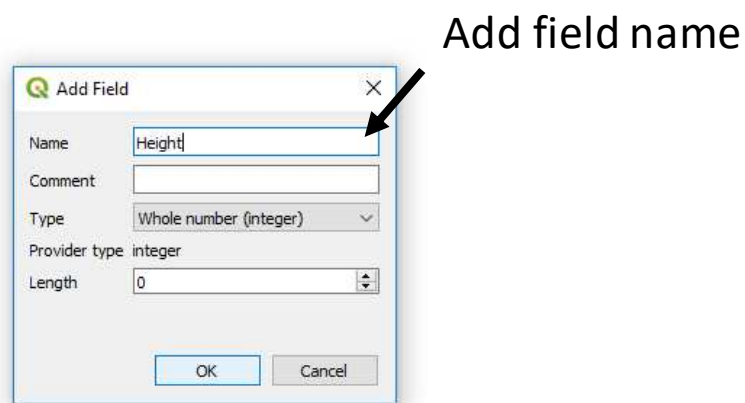


Figure 107. Add the buildings height information – Step 3

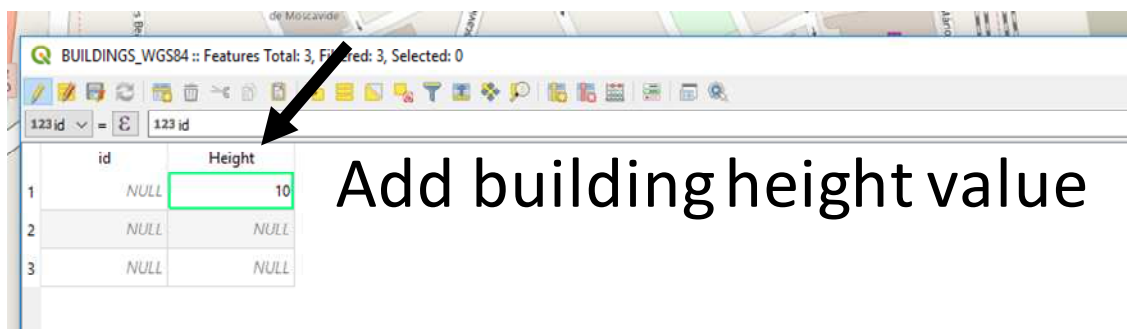


Figure 108. Add the buildings height information – Step 4

10.4.4.4 Get the coordinates of the vertices of the buildings

First, extract the vertices from the polygons.

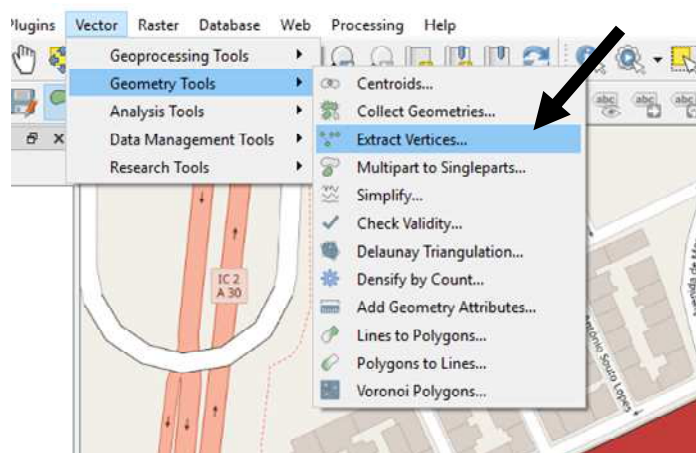


Figure 109. Get the coordinates of the vertices of the buildings – Step 1

Give a name to the file to be created (e.g. VERTICES.shp) and click in the “Run” button.

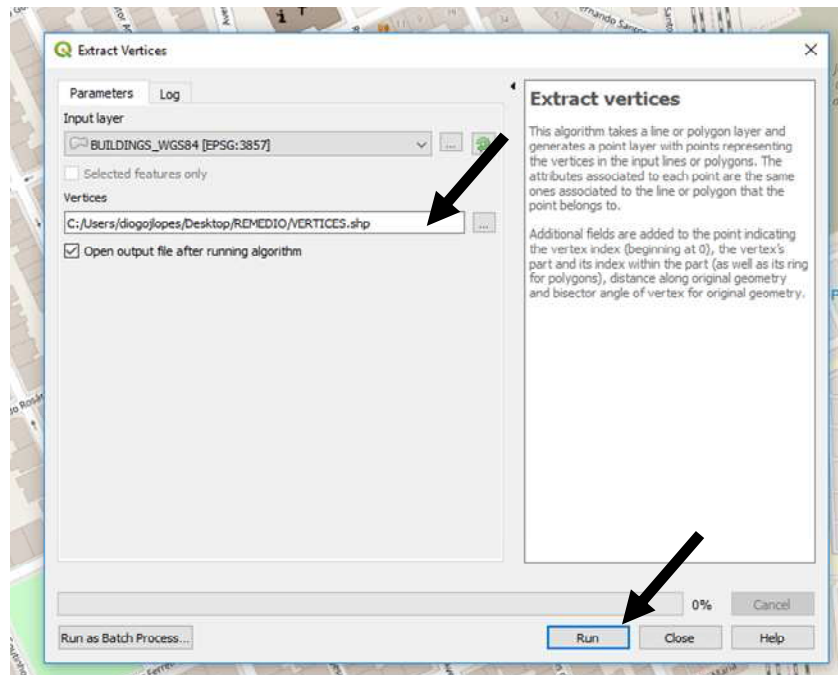


Figure 110. Get the coordinates of the vertices of the buildings – Step 2

Add the “Geometry attributes” to the file created (i.e. VERTICES.shp).

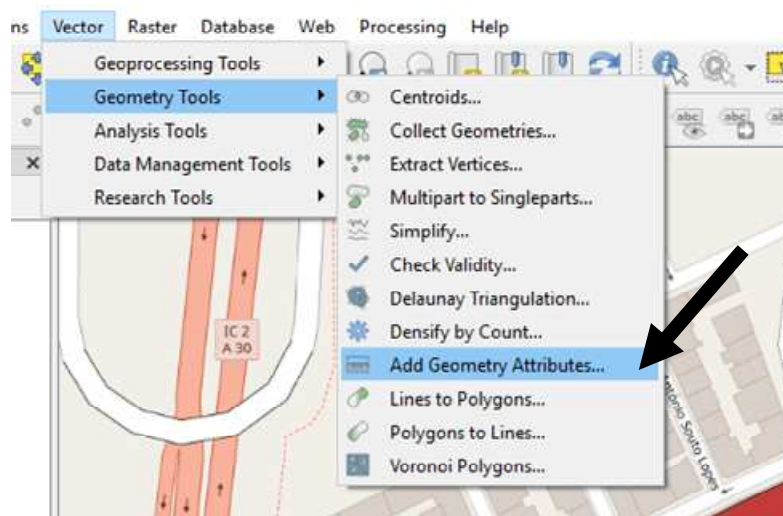


Figure 111. Get the coordinates of the vertices of the buildings – Step 3

Give a name to the file to be created (e.g. VERTICES_GEOMETRY_ATTRIBUTES.shp) and click in the “Run” button.

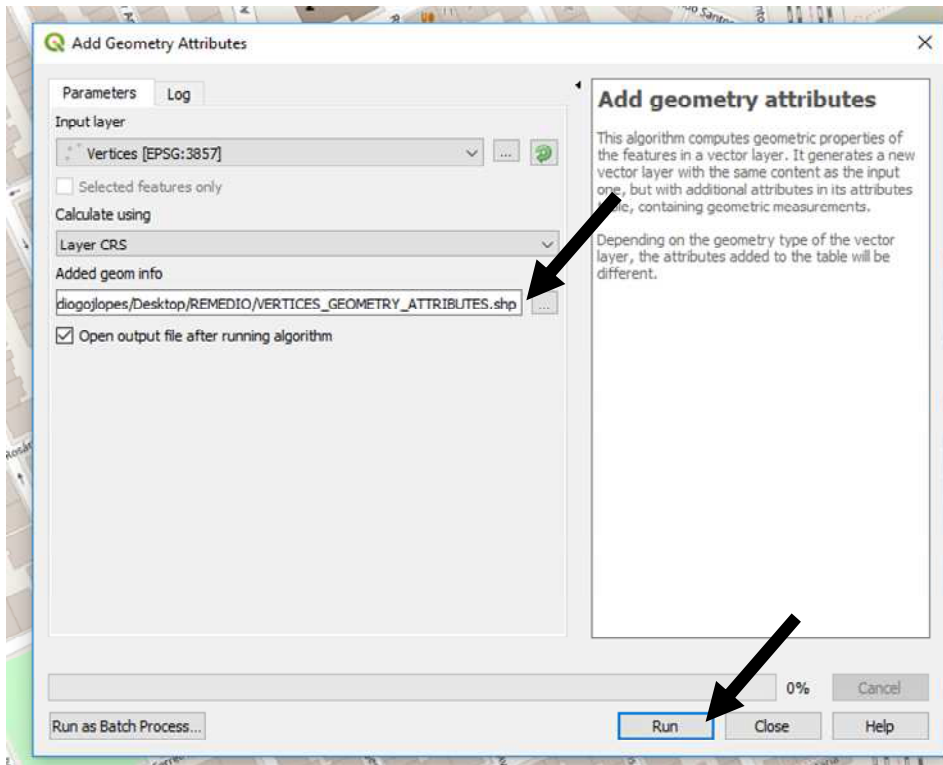


Figure 112. Get the coordinates of the vertices of the buildings – Step 4

10.4.4.5 Re-project the “added geom info” file

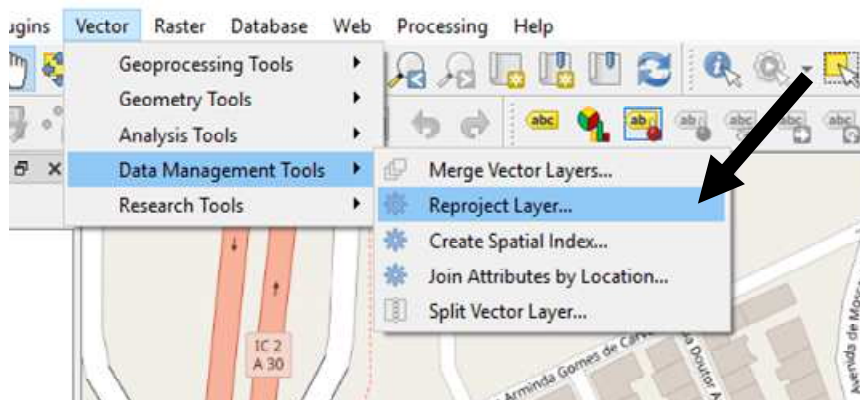


Figure 113. Re-project the “added geom info” file – Step 1

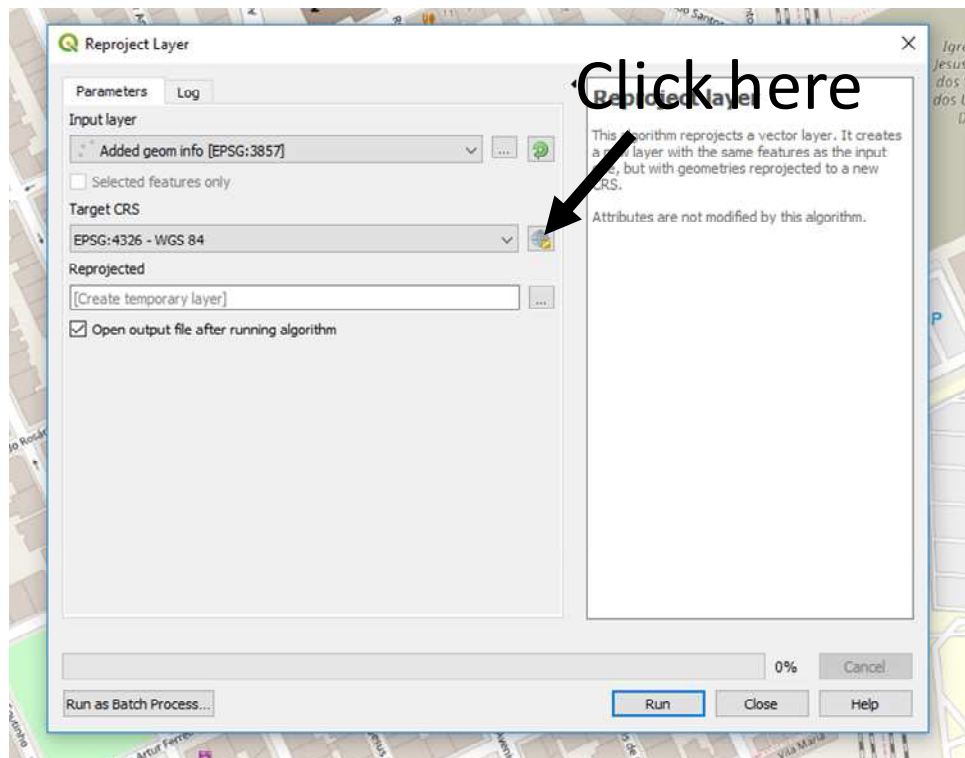


Figure 114. Re-project the “added geom info” file – Step 2

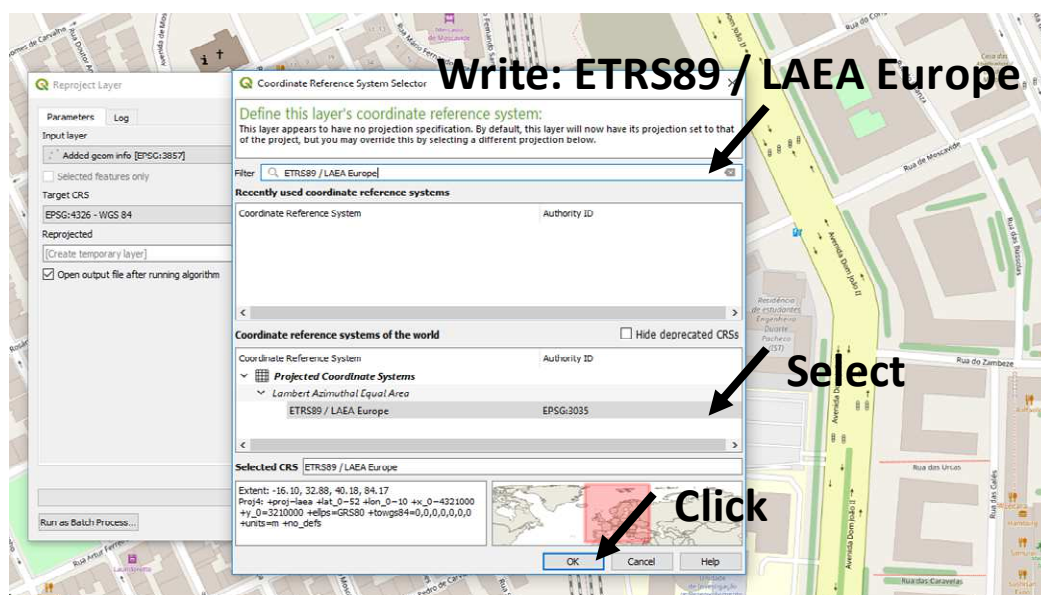


Figure 115. Re-project the “added geom info” file – Step 3

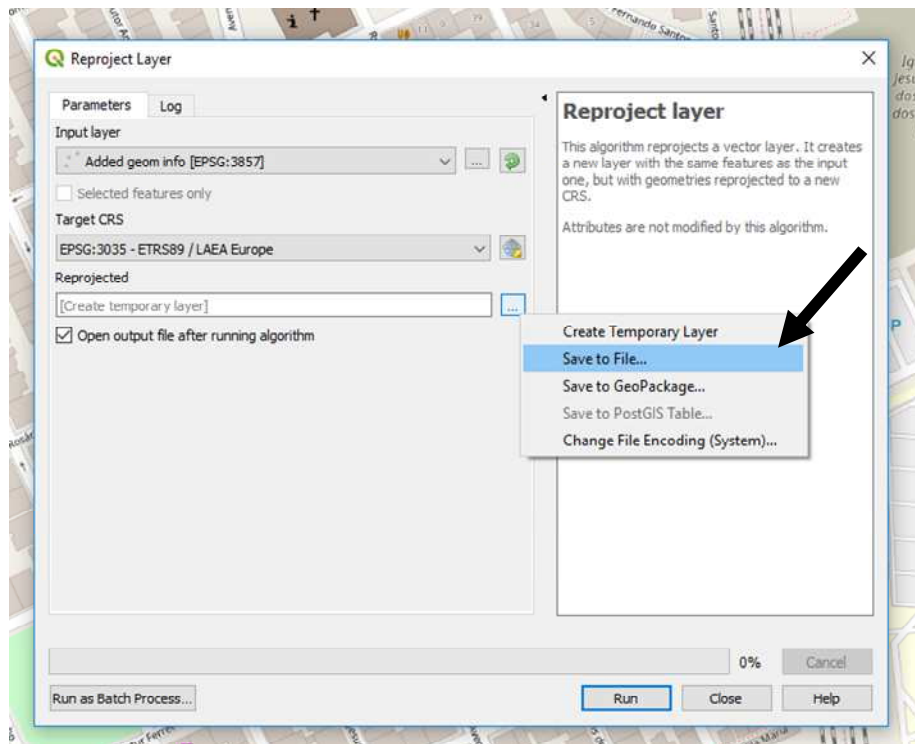


Figure 116. Re-project the “added geom info” file – Step 4

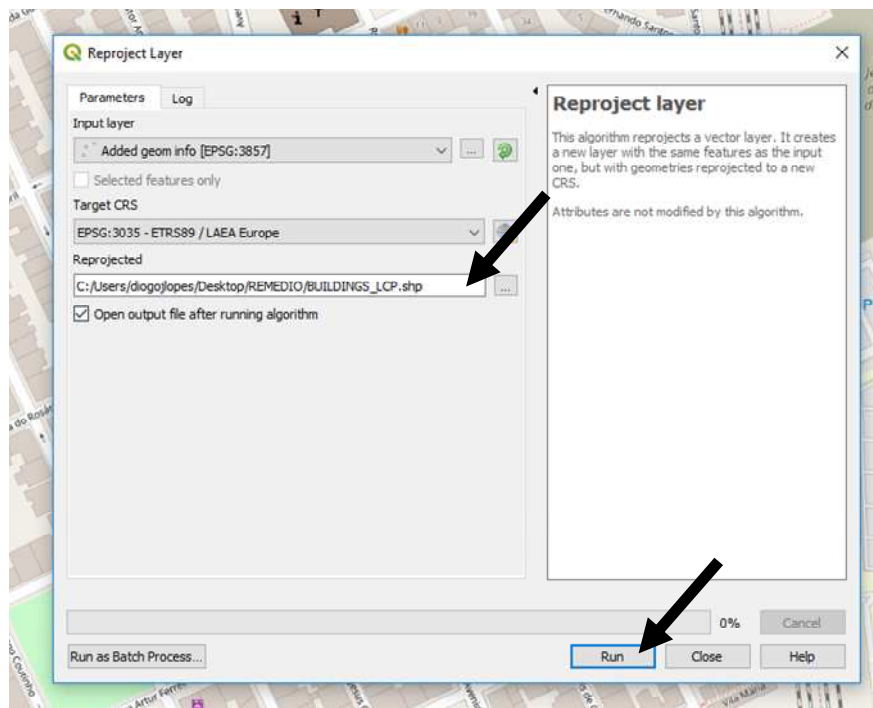


Figure 117. Re-project the “added geom info” file – Step 5

Add the “Geometry attributes” to the file created (i.e. “Reprojected.shp”).

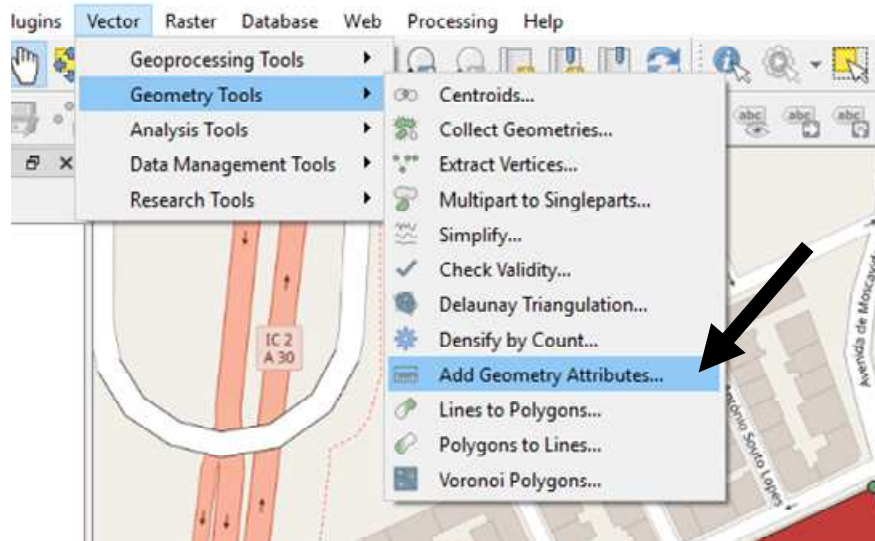


Figure 118. Re-project the “added geom info” file – Step 6

Finally, it is necessary to delete duplicate geometries.

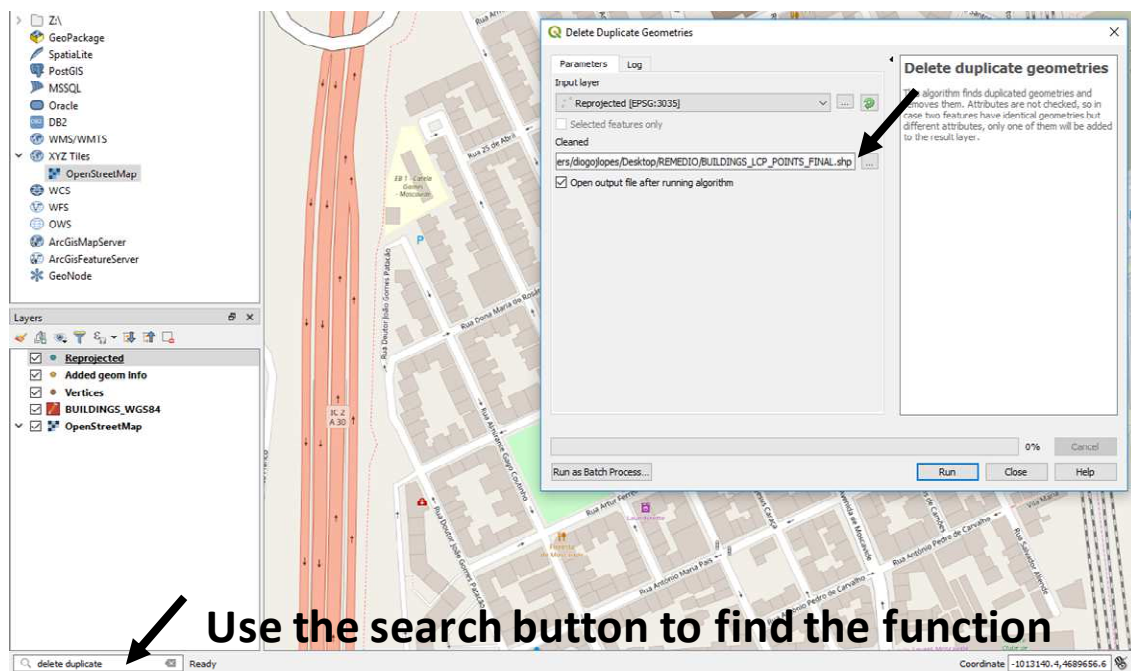


Figure 119. Re-project the “added geom info” file – Step 7

10.4.4.6 Copy the buildings coordinates to the “Input_preprocessors.xlsx” file

Open the “BUILDINGS_LCP_POINTS_FINAL.dbf” file in excel to the “Input_preprocessors.xlsx” file.

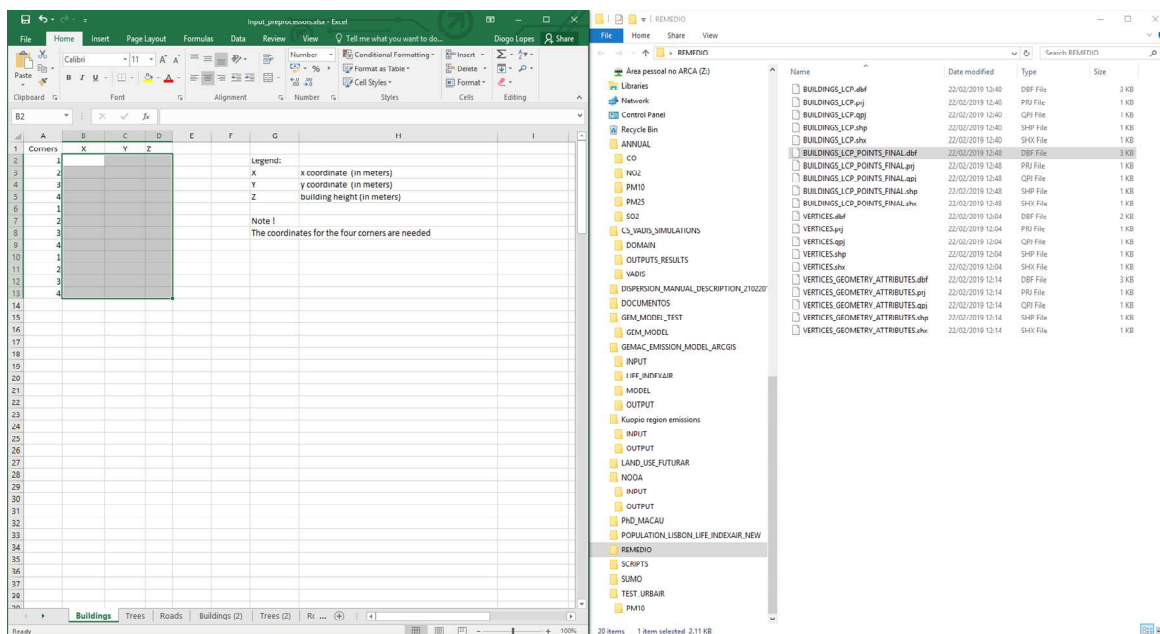


Figure 120. Copy the buildings coordinates to the “Input_preprocessors.xlsx” file – Step 1

Copy the “xcoord_2” and “ycoord_2” columns (highlighted in yellow) to the “Input_preprocessors.xlsx” file. Close the “BUILDINGS_LCP_POINTS_FINAL.dbf” file without changing it.

The image shows an Excel spreadsheet titled 'BUILDINGS_LCP_POINTS_FINAL.dbf - Excel'. It has a table with columns A, B, C, D, E, F, G, H, I, J. Column A is labeled 'id', B is 'Height', C is 'vertex_ind', D is 'vertex_par', E is 'vertex_p_1', F is 'vertex_p_2', G is 'distance', H is 'angle', I is 'xcoord', and J is 'ycoord'. The 'xcoord' and 'ycoord' columns are highlighted in yellow. The table contains 13 rows of data.

id	Height	vertex_ind	vertex_par	vertex_p_1	vertex_p_2	distance	angle	xcoord	ycoord
2	10	0	0	0	0	0.0000000000000000	20.57461858043630	-1013382.6801313700000000	4690008.9713239400000000
3	10	1	0	0	1	91.97485616587250	113.46912300300300	-1013299.3731604300000000	4690047.9498149300000000
4	10	2	0	0	2	215.72281949496400	204.69640019986900	-1013261.1589535800000000	4689930.2500578200000000
5	10	3	0	0	3	295.20836974807900	291.80189577730200	-1013334.5302307300000000	4689899.6786923400000000
6	10	0	0	0	0	0.0000000000000000	19.81133593978990	-1013327.6516735000000000	4689886.6858620100000000
7	10	1	0	0	1	81.35947335114050	115.46956391993300	-1013254.2803963400000000	4689921.8429323100000000
8	10	2	0	0	2	173.30574567649500	206.53516113664900	-1013232.8804405100000000	4689832.4216882800000000
9	10	3	0	0	3	236.6307373261700	290.87693315650600	-1013290.9660349200000000	4689807.2009117600000000
10	10	0	0	0	0	0.0000000000000000	24.09796900678400	-1013284.8517618300000000	4690057.1212245700000000
11	10	1	0	0	1	67.43914342085500	110.29857843466000	-1013222.9447467200000000	4690083.8711693700000000
12	10	2	0	0	2	288.59212450975400	200.83003248890100	-1013125.8806613200000000	4689885.1572937400000000
13	10	3	0	0	3	385.24612061248400	294.62942306102500	-1013215.3019053500000000	4689848.4716551600000000

Figure 121. Copy the buildings coordinates to the “Input_preprocessors.xlsx” file – Step 2

If there are trees in the study area the user has to repeat the same procedure, steps 1.4.4.4 to 1.4.4.7, to define the trees.

10.4.4.7 Treat the information for “roads”

Regarding the road segments, the user should use the “DISPERSION_MODULE.csv” created in the the first steps of the IMT application (sub-sections 1.2.1 to 1.2.6 of this manual) and the file should be opened with the QGIS software.

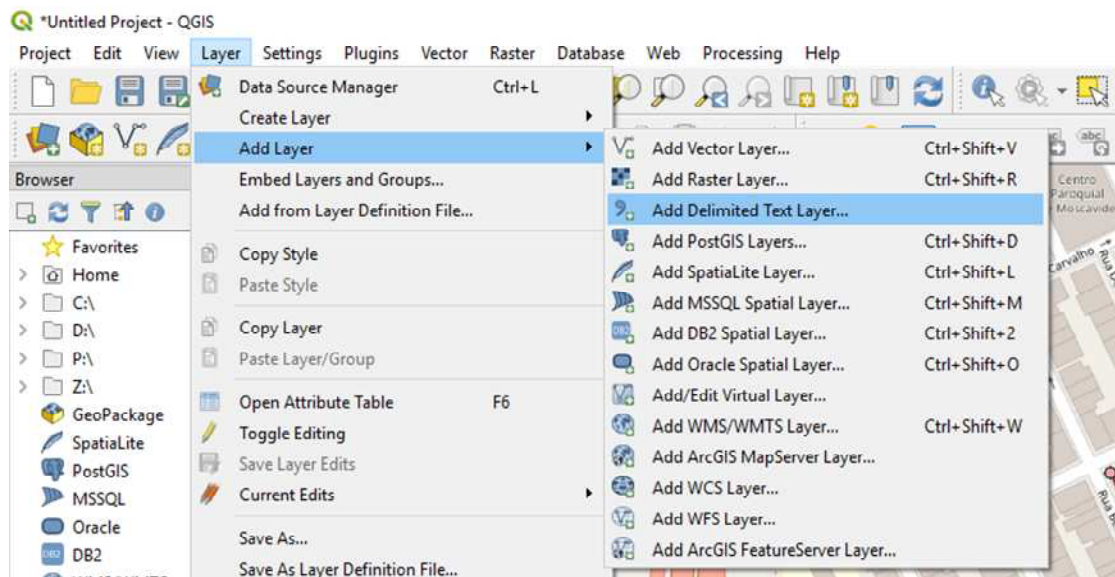


Figure 122. Treat the information for “roads” – Step 1

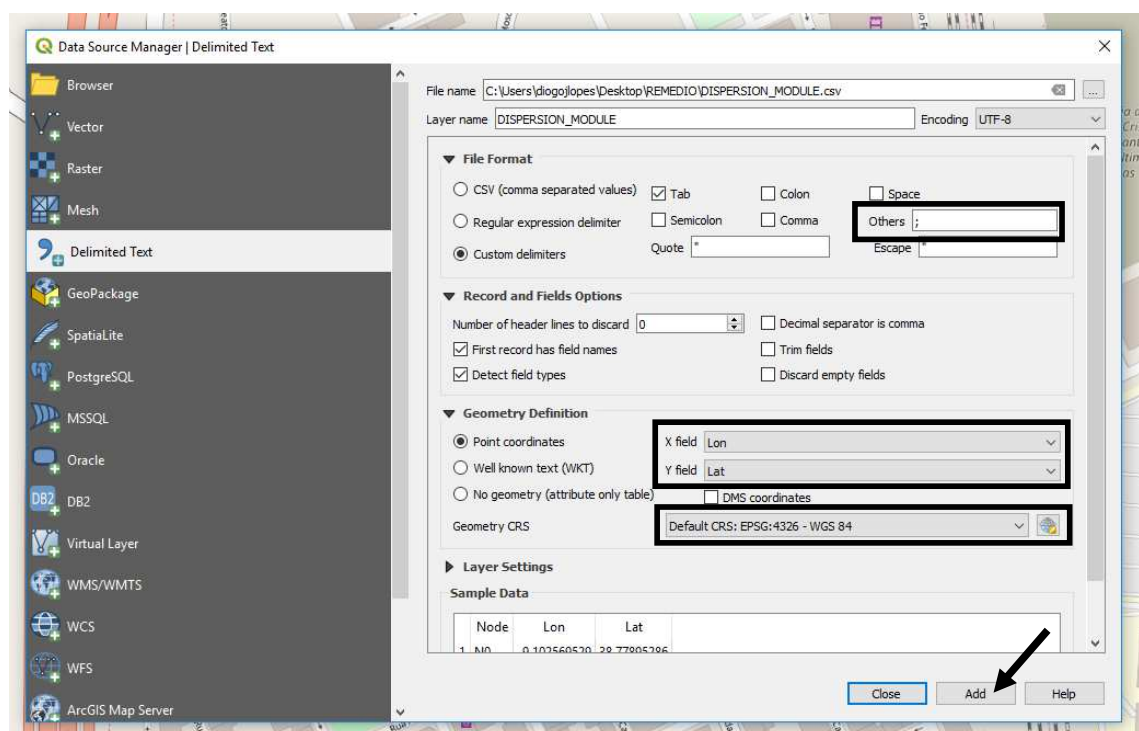


Figure 123. Treat the information for “roads” – Step 2

To convert the coordinates (of roads, traffic lights, bus stops, etc) from degrees to meters and copy the new coordinates values to the “Input_preprocessors.xlsx” file, the steps 1.4.4.6 and 1.4.4.7 described above need to be performed.

10.4.4.8 Upload input file “Input_preprocessors.xlsx” in the IMT

After this, the user has to upload the input file completed for his particular case. Click on “save” to access the next screen.

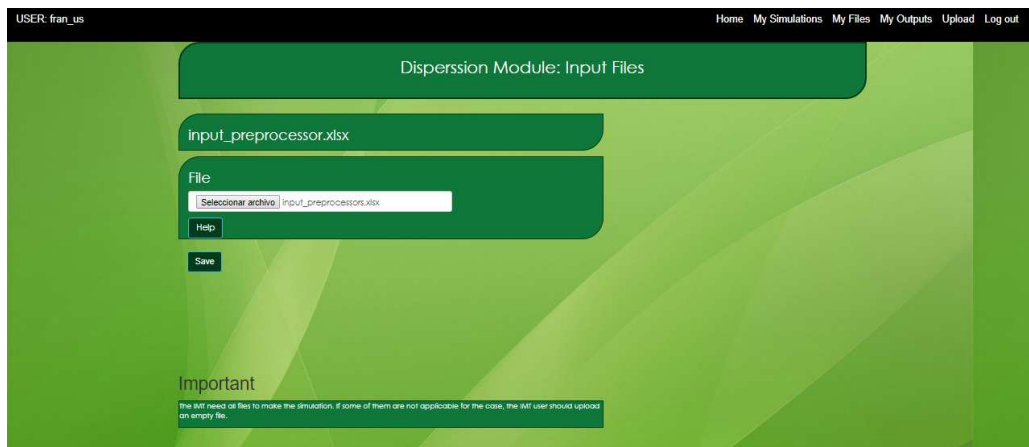


Figure 124. Selection of input file to upload

Finally, clicking on “Run Module” button, allows to execute the module.

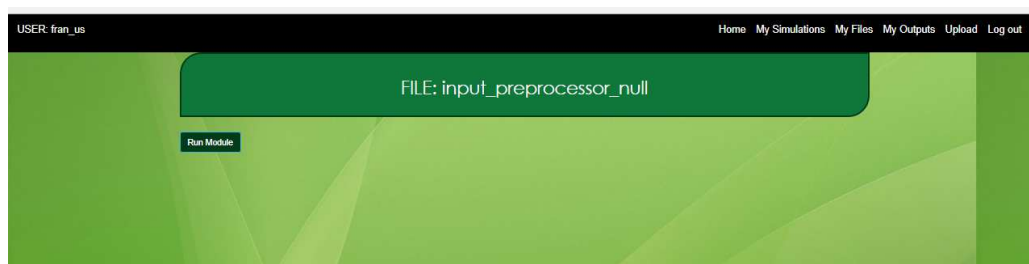


Figure 125. Module execution pre-screen

After this step, Dispersion module will be run, and results will be showed. To continue with the modules execution, the user has to click on “Continue Simulation” button, located at the bottom of the view. Otherwise, click on “Finish” button to return to Homepage.

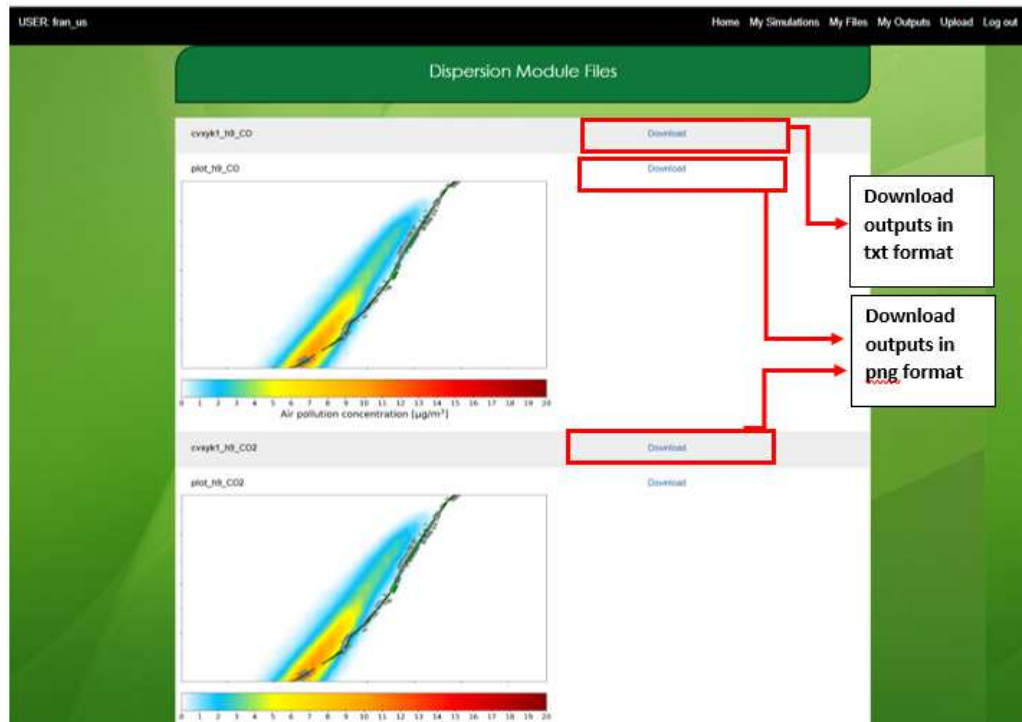


Figure 126. “Download”, “Continue Simulation” and “Finish” button location

HEALTH MODULE:

The user can run the Health module by clicking on “HEALTH MODULE” button:

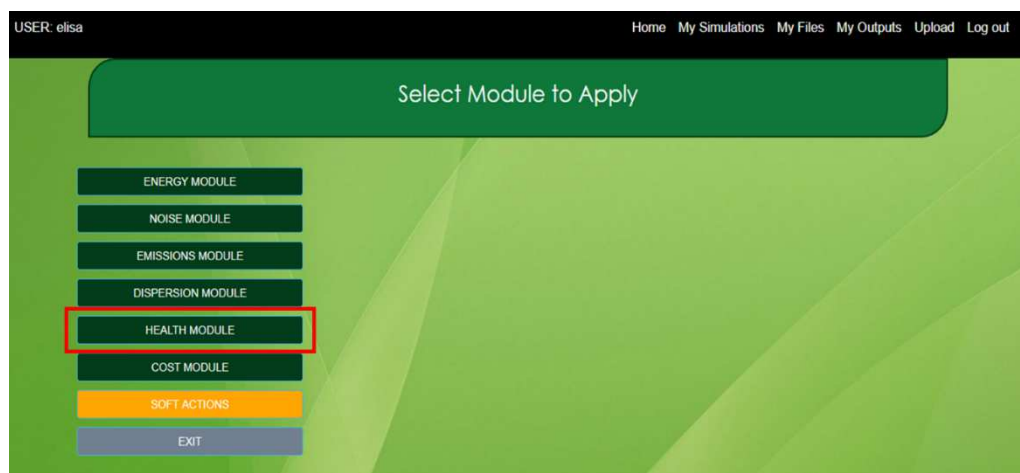


Figure 127. “Health Module” button location in “Select Module to Apply” view

Since the Health module uses outputs from traffic simulator and dispersion module and some historical data as inputs, after pressing the button, this module will be asked the user if the input files will be uploaded or automatically generated by IMT. The structure of these files could be consulted in the annex. Due to there are two kind of data for health module

(actual level of pollutant and weather conditions and historical data), the IMT will ask the user what files will be upload:

USER: fran_us Home My Simulations My Files My Outputs Upload Log out

Health module: Input options

Simulation data
Inputs from emissions module (0) or upload new input file (1)
0

Historical data
Inputs by default (0) or upload new input files (1)
0

Continue

Select "1" to upload a new file or "0" to generate automatically this file.

Figure 128. Selection box to generate input file

For example, if the user selects "1" in Simulation data, the next step is to upload a new input file of actual level of pollutants and weather conditions:

USER: fran_us Home My Simulations My Files My Outputs Upload Log out

Add Health Module: Input Files

Insert File
Actual level of pollutants and weather conditions

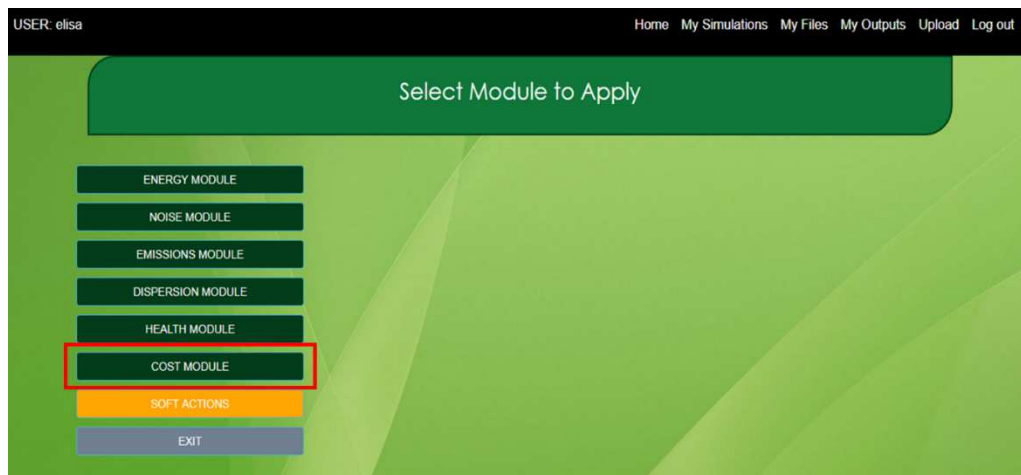
File
[Selection area] input.txt

Help Save

Important
The IMT need all files to make the simulation, if some of them are empty file.

Select the appropriate file and click on "save" button

Figure 129. Selection of input file to upload



OUTPUTS:

When a module is executed, the outputs files and charts will be also stored in “My outputs” folder. To access this folder, click on “My Outputs” in the main toolbar. **Each file contains in its name the ID of the simulation to which it belongs.**

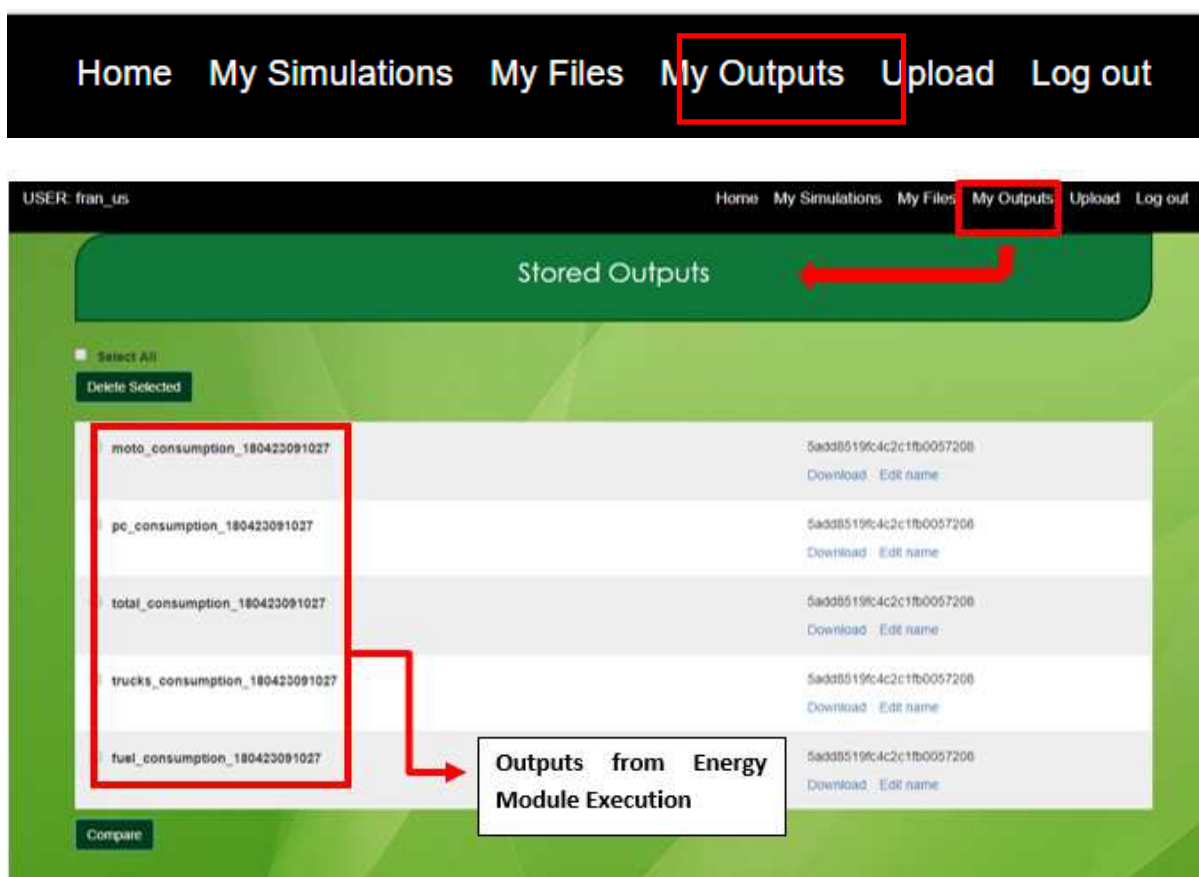


Figure 132. “My Outputs” description

10.5 Traffic files description

10.5.1.1 Node file

```
<nodes>
<node id="N0" x="-6.000589439208937" y="37.378912911567014" z="1e-7"></node>
<node id="t4" x="-5.998100349243074" y="37.38020878274759" z="1e-7" type="traffic_light"></node>
<node id="p9" x="-5.996898719604406" y="37.38061800057368" z="1e-7"></node>
<node id="N1" x="-5.995525428588862" y="37.38130002532207" z="1e-7"></node>
<node id="b7" x="-5.993894645507736" y="37.3823230508136" z="1e-7"></node>
<node id="t5" x="-5.9929505079345615" y="37.3828004579332" z="1e-7" type="traffic_light"></node>
<node id="N2" x="-5.992092201049734" y="37.383277862014076" z="1e-7"></node>
<node id="b8" x="-5.990804740722628" y="37.384096261937664" z="1e-7"></node>
<node id="t6" x="-5.989431449706995" y="37.384505458549846" z="1e-7" type="traffic_light"></node>
<node id="r10" x="-5.987972328002924" y="37.38559663859811" z="1e-7"></node>
<node id="N3" x="-5.987371513183501" y="37.38566483682436" z="1e-7"></node>
</nodes>
```

Figure 133. Node file structure

The node file indicates the points defined in the simulation. Each of the nodes or points used to characterise the road or section of the simulation is placed between nodes labels. In the id attribute the format set is one letter and one number. For the letter the following scheme is followed:

- Nodes: the letter 'N' is used
- Traffic lights: the letter 't' is used
- Bus stops: the letter 'b' is used
- Pedestrian crossings: the letter 'p' is used
- Roundabouts: the letter 'r' is used
- Stops: the letter 'x' is used

For the number, in the id attribute, there is no requirement set except that the N0 must be the beginning of the road to study.

The other attributes place the point on the map through coordinates. The attribute 'x' indicates longitude, the attribute 'y', latitude and the attribute 'z', altitude. Longitude and latitude will be given in decimal coordinates.

Finally, one more attribute must be specified for traffic lights, which is the type that will be used:

type= "traffic_light"

10.5.1.2 Edge file

```
<?xml version='1.0'?>
<edges>
  <edge id='1' from='N0' to='t4' numLanes='1'/>
  <edge id='2' from='t4' to='p9' numLanes='1'/>
  <edge id='3' from='p9' to='N1' numLanes='1'/>
  <edge id='4' from='N1' to='b7' numLanes='1'/>
  <edge id='5' from='b7' to='t5' numLanes='1'/>
  <edge id='6' from='t5' to='N2' numLanes='1'/>
  <edge id='7' from='N2' to='b8' numLanes='1'/>
  <edge id='8' from='b8' to='t6' numLanes='1'/>
  <edge id='9' from='t6' to='r10' numLanes='1'/>
  <edge id='10' from='r10' to='N3' numLanes='1'/>
  <edge id='-1' from='t4' to='N0' numLanes='1'/>
  <edge id='-2' from='p9' to='t4' numLanes='1'/>
  <edge id='-3' from='N1' to='p9' numLanes='1'/>
  <edge id='-4' from='b7' to='N1' numLanes='1'/>
  <edge id='-5' from='t5' to='b7' numLanes='1'/>
  <edge id='-6' from='N2' to='t5' numLanes='1'/>
  <edge id='-7' from='b8' to='N2' numLanes='1'/>
  <edge id='-8' from='t6' to='b8' numLanes='1'/>
  <edge id='-9' from='r10' to='t6' numLanes='1'/>
  <edge id='-10' from='N3' to='r10' numLanes='1'/>
  <roundabout edges='9 10 -9 -10'/>
</edges>
```

Figure 134. Edge file structure

The edge file establishes the sections into which the simulation to be studied is divided. It is located between labels edges. The attributes to define the edge are "id", "from", "to" and "numLanes". The "id" attribute is defined as a number from 1 to the total number of edges for the direct direction and for the reverse direction it is set from -1 to the total number of edges with the negative sign in front. The "from" attribute indicates the node where the edge begins and the "to" attribute the node where it ends. In the edge with id =1 the "from" must be "NO". The "numLanes" attribute indicates the number of lanes of this edge.

If there are roundabouts in the simulation, an additional row will be added with the edges where it is located. For example, for the structure defined above you can see that for roundabouts (whose letter is set to 'r') it is in edges 9 and 10 for the direct direction and in edges -9 and -10 for the reverse direction so you add a row with the following format:

```
<roundabout edges='9 10 -9 -10'/>
```

If there is more than one roundabout, only one row is added and not one row per roundabout.

If the user wants to indicate the existence of special lanes such as bike lanes or bus lanes, the user must add a new line for each edge on which the lanes are set. The file is completed as follows:

```
<?xml version='1.0'?>
<edges>
  <edge id='1' from='N0' to='b6' numLanes='3'>
    <lane index='1' allow='bus' />
    <lane index='0' allow='bicycle' />
  </edge>
  <edge id='2' from='b6' to='N1' numLanes='3'>
    <lane index='1' allow='bus' />
    <lane index='0' allow='bicycle' />
  </edge>
  <edge id='3' from='N1' to='b7' numLanes='3'>
    <lane index='1' allow='bus' />
  </edge>
  <edge id='4' from='b7' to='N2' numLanes='3'>
    <lane index='0' allow='bicycle' />
  </edge>
  <edge id='5' from='N2' to='b8' numLanes='3'>
    <lane index='0' allow='bicycle' />
  </edge>
  <edge id='6' from='b8' to='N3' numLanes='3' />
</edges>
```

Figure 135. Edge file structure with bus and bike lane

A new line with the lane tag containing the 'index' and 'allow' attributes is added. The 'index' attribute refers to the lane where the special lane is placed. By default, it will be zero for both bicycles and buses unless there are two lanes on the edge in which case 0 will be for bicycles and 1 for the bus. The 'allow' attribute specifies the vehicle in the lane.

10.5.1.3 Tll file

```
<?xml version='1.0'?>
<additional>
  <tlLogic id='t4' type='static' programID='0' offset='0'>
    <phase duration='30' state='GGGG'/>
    <phase duration='10' state='yyyy'/>
    <phase duration='30' state='rrr'/>
    <phase duration='10' state='yyyy'/>
  </tlLogic>
  <tlLogic id='t5' type='static' programID='0' offset='0'>
    <phase duration='30' state='GGGG'/>
    <phase duration='10' state='yyyy'/>
    <phase duration='30' state='rrr'/>
    <phase duration='10' state='yyyy'/>
  </tlLogic>
  <tlLogic id='t6' type='static' programID='0' offset='0'>
    <phase duration='30' state='GGGG'/>
    <phase duration='10' state='yyyy'/>
    <phase duration='30' state='rrr'/>
    <phase duration='10' state='yyyy'/>
  </tlLogic>
</additional>
```

Figure 136. Tll file structure

The tll file as shown above is between two additional labels because this information is needed to create the add file. Each traffic light enters a tlLogic tag in which the "id", "type", "programID", "offset" and "phase duration" of each of the traffic light phases is specified, that is the time it remains in each of the traffic light states (green, yellow, red and again yellow). The id is always defined with the letter "t" at the beginning and followed by the number we have set in the node file. The state attribute is defined taking into account the number of lanes that exist and whether it is a one-way or two-way section and in which the letter corresponding to the traffic light status colour ("G" for green, "y" for yellow, "r" for red) is always repeated.

If no traffic light information is available, the file will appear with an additional tag and no data of any kind. It will have this structure:

```
<?xml version='1.0'?>

<additional/>
```

10.5.1.4 Bus file

```
<?xml version='1.0'?>
<additional>
  <busStop id='b7' lane='1_0'/>
  <busStop id='b8' lane='1_0'/>
  <busStop id='-b7' lane='-1_0'/>
  <busStop id='-b8' lane='-1_0'/>
</additional>
```

Figure 137. Bus file structure

The bus file has a very simple structure. The stops made by the buses in the simulation are set between additional tags. The 'busStop' label indicates the "id" and "lane" attributes. The "id" has the established format of a letter and a number. The "id" is always defined with the letter "b" at the beginning and followed by the number we have set in the node file. For the reverse direction the "id" must be set with a negative sign in front of the letter "b". The "lane" attribute is divided into two parts: the first indicates the edge where the bus stop is located and the second the lane where the stop is made which will be set as standard as 1_0 for the direct direction and -1_0 for the reverse direction to travel in the lane closest to the curb. The only case in which the second part of the "lane" attribute changes is if there is a bicycle lane in which case it will change from 0 to 1. If that happened, the file would look like this:

```
<?xml version='1.0'?>
<additional>
  <busStop id='b6' lane='1_1'/>
  <busStop id='b7' lane='3_1'/>
  <busStop id='b8' lane='5_1'/>
  <busStop id='b9' lane='7_0'/>
  <busStop id='b10' lane='9_0'/>
</additional>
```

Figure 138. Bus file structure with bus and bike lane

If there is no information about the buses in the simulation to be performed, the file will appear with an additional tag and without specifying any information. It will have this structure:

```
<?xml version='1.0'?>

<additional/>
```

10.5.1.5 Conn file

Structure:

```
<?xml version='1.0'?>
<connections>
  <crossing node='p9' edges='2 -2'/>
</connections>
```

Figure 139. Conn file structure

In the conn file you specify between two connections tags the pedestrian crossings that exist in the simulation. The node, in this case it appears as a crossing node, is defined with the letter "p" and followed by the number we have set in the node file. Also, the section or "edge" where the pedestrian crossing is located is defined. In this case, it is on edge 2 for direct direction and on edge -2 for reverse direction. If there is more than one pedestrian crossing, a new column with the same attributes will be defined.

If there are no pedestrian crossings in the simulation to be performed, the file will appear with a connections tag and without specifying any information. It will have this structure:

```
<?xml version='1.0'?>
<connections/>
```

10.5.1.6 Rou file

```
<routes>
  <vTypes>
    <vTypeDistribution id="1" sigma="0" speedDev="0.1" minGap="1">
      <vType id="t1" emissionClass="PHEMlight/PC_G_EU0" probability="0.0529" vClass="passenger"></vType>
      <vType id="t2" emissionClass="PHEMlight/PC_G_EU1" probability="0.0230" vClass="passenger"></vType>
      <vType id="t3" emissionClass="PHEMlight/PC_G_EU1" probability="0.0928" vClass="passenger"></vType>
      <vType id="t4" emissionClass="PHEMlight/PC_G_EU2" probability="0.0704" vClass="passenger"></vType>
      <vType id="t5" emissionClass="PHEMlight/PC_G_EU3" probability="0.1494" vClass="passenger"></vType>
      <vType id="t6" emissionClass="PHEMlight/PC_G_EU5" probability="0.0689" vClass="passenger"></vType>
      <vType id="t7" emissionClass="PHEMlight/PC_G_EU5" probability="0.0137" vClass="passenger"></vType>
      <vType id="t8" emissionClass="PHEMlight/PC_D_EU6" probability="0.0083" vClass="passenger"></vType>
      <vType id="t9" emissionClass="PHEMlight/PC_D_EU5" probability="0.0041" vClass="passenger"></vType>
      <vType id="t10" emissionClass="PHEMlight/PC_D_EU4" probability="0.0332" vClass="passenger"></vType>
      <vType id="t11" emissionClass="PHEMlight/PC_D_EU3" probability="0.1008" vClass="passenger"></vType>
      <vType id="t12" emissionClass="PHEMlight/PC_D_EU2" probability="0.1544" vClass="passenger"></vType>
      <vType id="t13" emissionClass="PHEMlight/PC_D_EU1" probability="0.1361" vClass="passenger"></vType>
      <vType id="t14" emissionClass="PHEMlight/PC_D_EU0" probability="0.0096" vClass="passenger"></vType>
      <vType id="t15" emissionClass="PHEMlight/PC_CNG_EU5" probability="0.0755" vClass="passenger">
    </vType>
    <vType id="t16" emissionClass="PHEMlight/PC_CNG_EU5" probability="0.0040" vClass="passenger">
  </vType>
  <vTypeDistribution>
    <vTypeDistribution id="2" sigma="0" speedDev="0.1" minGap="1">
      <vType id="t17" emissionClass="PHEMlight/LCV_I_G_EU2" probability="0.40" vClass="motorcycle"></vType>
      <vType id="t18" emissionClass="PHEMlight/LCV_I_G_EU1" probability="0.16" vClass="motorcycle"></vType>
      <vType id="t19" emissionClass="PHEMlight/LCV_I_G_EU3" probability="0.14" vClass="motorcycle"></vType>
      <vType id="t20" emissionClass="PHEMlight/LCV_I_G_EU4" probability="0.3" vClass="motorcycle"></vType>
    </vTypeDistribution>
    <vTypeDistribution id="3" sigma="0" speedDev="0.1" minGap="1">
      <vType id="t21" emissionClass="PHEMlight/HDV_RT_I_D_EU0" probability="0.1277" vClass="truck"></vType>
      <vType id="t22" emissionClass="PHEMlight/HDV_RT_I_D_EU1" probability="0.0710" vClass="truck"></vType>
      <vType id="t23" emissionClass="PHEMlight/HDV_RT_I_D_EU2" probability="0.1827" vClass="truck"></vType>
      <vType id="t24" emissionClass="PHEMlight/HDV_RT_I_D_EU3" probability="0.2474" vClass="truck"></vType>
      <vType id="t25" emissionClass="PHEMlight/HDV_RT_I_D_EU4" probability="0.2383" vClass="truck"></vType>
      <vType id="t26" emissionClass="PHEMlight/HDV_RT_I_D_EU5" probability="0.1309" vClass="truck"></vType>
      <vType id="t27" emissionClass="PHEMlight/HDV_RT_I_D_EU6" probability="0.0018" vClass="truck"></vType>
    </vTypeDistribution>
    <vTypeDistribution id="4" sigma="0" speedDev="0.1" minGap="1">
      <vType id="t28" emissionClass="PHEMlight/HDV_CB_D_EU0" probability="0.1578" vClass="bus"></vType>
      <vType id="t29" emissionClass="PHEMlight/HDV_CB_D_EU1" probability="0.0493" vClass="bus"></vType>
      <vType id="t30" emissionClass="PHEMlight/HDV_CB_D_EU2" probability="0.1616" vClass="bus"></vType>
      <vType id="t31" emissionClass="PHEMlight/HDV_CB_D_EU3" probability="0.2564" vClass="bus"></vType>
      <vType id="t32" emissionClass="PHEMlight/HDV_CB_D_EU4" probability="0.1995" vClass="bus"></vType>
      <vType id="t33" emissionClass="PHEMlight/HDV_CB_D_EU5" probability="0.1662" vClass="bus"></vType>
      <vType id="t34" emissionClass="PHEMlight/HDV_CB_D_EU6" probability="0.0091" vClass="bus"></vType>
    </vTypeDistribution>
  </vTypes>
```

Figure 140. vTypeDistribution structure

```

<flow id="line4" type="4" from="1" to="5" period="1200" begin="32400" end="36000">
  <stop busStop="b4" duration="20"></stop>
  <stop busStop="b5" duration="20"></stop></flow>
<flow id="iline4" type="4" from="-5" to="-1" period="1200" begin="32400" end="36000">
  <stop busStop="-b5" duration="20"></stop>
  <stop busStop="-b4" duration="20"></stop></flow>
<flow id="1" type="2" from="-5" to="-1" vehsPerHour="100" begin="32400" end="36000" departLane="best"
departSpeed="max"></flow>
<flow id="2" type="1" from="1" to="5" vehsPerHour="250" begin="32400" end="36000" departLane="best"
departSpeed="max"></flow>
<flow id="3" type="3" from="1" to="5" vehsPerHour="10" begin="32400" end="36000" departLane="best"
departSpeed="max"></flow>
<flow id="4" type="2" from="1" to="5" vehsPerHour="100" begin="32400" end="36000" departLane="best"
departSpeed="max"></flow>
<flow id="5" type="1" from="-5" to="-1" vehsPerHour="250" begin="32400" end="36000" departLane="best"
departSpeed="max"></flow>
<flow id="6" type="3" from="-5" to="-1" vehsPerHour="10" begin="32400" end="36000" departLane="best"
departSpeed="max"></flow>
<flow id="7" type="3" from="1" to="5" vehsPerHour="10" begin="36000" end="39600" departLane="best"
departSpeed="max"></flow>
<flow id="8" type="1" from="-5" to="-1" vehsPerHour="250" begin="36000" end="39600" departLane="best"
departSpeed="max"></flow>
<flow id="9" type="1" from="1" to="5" vehsPerHour="250" begin="36000" end="39600" departLane="best"
departSpeed="max"></flow>
<flow id="10" type="3" from="-5" to="-1" vehsPerHour="10" begin="36000" end="39600" departLane="best"
departSpeed="max"></flow>
<flow id="11" type="2" from="1" to="5" vehsPerHour="100" begin="36000" end="39600" departLane="best"
departSpeed="max"></flow>
<flow id="12" type="2" from="-5" to="-1" vehsPerHour="100" begin="36000" end="39600" departLane="best"
departSpeed="max"></flow>
</routes>

```

Figure 141. Flow structure

The rou file consists of two distinct parts: one between the vTypes labels and the other between the flow labels. The first is part of the information we need to carry out the simulations and consists of the distribution of vehicles according to the fuel they use and the proportion they find. It has been obtained from a tool known as PHEMlight that gives us the distribution of the vehicles that we want to study for three countries, which will participate in the development of the project, which are: Italy (Treviso is the participating city), Greece (Thessaloniki) and Portugal (Aveiro).

In the vTypeDistribution labels, the "id" corresponding to the type of vehicle is specified (the number 1 corresponds to passengers' cars, the number 2 to motorcycles, the number 3 to trucks and the number 4 to bus). Also defined are the "sigma", "speedDev" and "minGap" attributes whose values are the same regardless of the type of vehicle and simulation to be performed (sigma = 0; speedDev = 0.1; minGap = 1).

For each of the vehicle types, another label with the name vType is opened. The attributes that define these lines are: "id", "emissionClass", "probability" and "vClass". The "id" has a defined format consisting of the letter "t" and the corresponding number in the established order. The attribute "emissionClass" presents the type of fuel, as well as the type of emissions that the vehicle has. The "probability" is given by the tool mentioned above (PHEMlight). And in "vClass" it is indicated again (because in the vtypeDistribution label it is

already specified), the type of vehicle being studied. Therefore, in the vType label we obtain the probability for each type of vehicle and according to its emissions that will be used to complete the simulation distribution.

Each country has a different distribution, therefore, the rou file changes if we choose Italy, Greece or Portugal.

The second part of the rou file corresponds to the flows, in other words, to know the variation of the vehicles and their path within the simulation. There are two types of flows: one relating to passengers' cars, motorcycles and trucks and the other relating to buses. What changes is the format of the flow.

In the case of passenger, motorcycles and trucks, the flows have the following format:

```
<flow id="1" type="1" from="1" to="7" vehsPerHour="250" begin="32400" end="36000"
      departLane="best" departSpeed="max"></flow>
```

Where, the "id" indicates the number of flow in which we are, the "type" of vehicle studied, the attribute "from" indicates the edge or section from which we start and the attribute "to" the edge or section we reach. The "vehsPerHour" indicates the number of vehicles of the indicated type that travel the indicated sections in a period of time, which is indicated in the "begin" and in the "end" attributes indicating the time in seconds. The attributes "departLane" and "departSpeed" are always defined as "best" and "max" respectively indicating that vehicles will always use the most appropriate lane for driving and the speed will be the maximum set on the road.

For simulations of two-way sections, a flow with the following format will be created:

```
<flow id="4" type="1" from="-7" to="-1" vehsPerHour="250" begin="32400" end="36000"
      departLane="best" departSpeed="max"></flow>
```

The only variation that exists in the format is that the "from" and the "to" appear as negative numbers indicating the sections through which they pass in the opposite direction to the one initially established.

As far as buses are concerned, the flows have the following format:

```
<flow id="line4" type="4" from="1" to="7" period="1200" begin="32400" end="36000">
      <stop busStop="b5" duration="20"></stop></flow>
```

Where, the "id" indicates the bus line that passes through the simulation section to be studied, the "type" is the number 4 that corresponds to the buses, the attributes "from" and "to" indicate the edge from which the journey starts and where it arrives respectively. The "period" indicates how often (in seconds) the bus line passes through the simulation section. The "begin" and "end" indicate the time period in which the buses will run through the sections defined in the simulation.

For the reverse direction the format of the buses is as follows:

```
<flow id="iline4" type="4" from="-7" to="-1" period="1200" begin="32400" end="36000">  
    <stop busStop="-b5" duration="20"></stop></flow>
```

The "id" attribute now has an "i" before the line number and the "from", "to" and "busStop" attributes appear with a negative sign in front of the edges being crossed and the stop set respectively.

For the definition of the bus flows, a new attribute is established, which is the stop tag. Here, the stop to be made by the bus ("busStop" attribute) and the duration of the stop ("duration" attribute) are indicated in seconds. The "busStop" attribute must match the "id" attribute of the selected stop in the bus file. It is not necessary for a bus to stop at all the stops established in the simulation.

In the simulations, through the tool, the flows are generated from hour to hour ("begin") to hour to hour ("end"), so it would be convenient to use this format, although it is not mandatory. If it is important that the flows are ordered by the begin attribute following this format:

```
<flow id="line4" type="4" from="1" to="7" period="1200" begin="32400" end="36000">  
    <stop busStop="b5" duration="20"></stop></flow>  
  
<flow id="iline4" type="4" from="-7" to="-1" period="1200" begin="32400" end="36000">  
    <stop busStop="-b5" duration="20"></stop></flow>  
  
<flow id="1" type="1" from="1" to="7" vehsPerHour="250" begin="32400" end="36000"  
    departLane="best" departSpeed="max"></flow>  
  
<flow id="2" type="3" from="1" to="7" vehsPerHour="10" begin="32400" end="36000"  
    departLane="best" departSpeed="max"></flow>  
  
<flow id="3" type="2" from="1" to="7" vehsPerHour="100" begin="32400" end="36000"  
    departLane="best" departSpeed="max"></flow>  
  
<flow id="4" type="1" from="-7" to="-1" vehsPerHour="250" begin="32400" end="36000"  
    departLane="best" departSpeed="max"></flow>  
  
<flow id="5" type="3" from="-7" to="-1" vehsPerHour="10" begin="32400" end="36000"  
    departLane="best" departSpeed="max"></flow>  
  
<flow id="6" type="2" from="-7" to="-1" vehsPerHour="100" begin="32400" end="36000"  
    departLane="best" departSpeed="max"></flow>  
  
<flow id="7" type="1" from="1" to="7" vehsPerHour="250" begin="36000" end="39600"  
    departLane="best" departSpeed="max"></flow>
```

```

<flow id="8" type="3" from="1" to="7" vehsPerHour="10" begin="36000" end="39600"
    departLane="best" departSpeed="max"></flow>

<flow id="9" type="2" from="1" to="7" vehsPerHour="100" begin="36000" end="39600"
    departLane="best" departSpeed="max"></flow>

<flow id="10" type="1" from="-7" to="-1" vehsPerHour="250" begin="36000" end="39600"
    departLane="best" departSpeed="max"></flow>

<flow id="11" type="3" from="-7" to="-1" vehsPerHour="10" begin="36000" end="39600"
    departLane="best" departSpeed="max"></flow>

<flow id="12" type="2" from="-7" to="-1" vehsPerHour="100" begin="36000" end="39600"
    departLane="best" departSpeed="max"></flow>

```

A valid format has been specified for a simulation of a two-way road section. If the simulation is carried out in one direction only, the flows in which the "from" and the "to" have a negative sign must be eliminated, as well as the bus flows with the "id" attribute with a letter "i".

The number of vehicles can vary from section to section. For example, in a simulation, a certain number of vehicles can pass from edge 1 to edge 2, another from edge 2 to edge 3 and so on. The generation of flows will vary and it will be necessary to define how many vehicles pass through each of the edges. The format would look something like this:

```

<flow id="1" type="1" from="1" to="3" vehsPerHour="200" begin="32400" end="36000"
    departLane="best" departSpeed="max"></flow>

<flow id="2" type="1" from="1" to="2" vehsPerHour="50" begin="32400" end="36000"
    departLane="best" departSpeed="max"></flow>

<flow id="3" type="1" from="2" to="2" vehsPerHour="50" begin="32400" end="36000"
    departLane="best" departSpeed="max"></flow>

```

In this case, it is specified that the entire simulation (only 3 edges have been set) will go through 200 passengers, that from edge 1 to edge 2 will go through 50 passengers and that edge 2 will go through another 50 passengers. If we make a table with the above values, we would have this:

Edge	Passenger
1	250
2	300
3	200

First of all, a flow will be defined with all the vehicles of the same type that will go through the whole simulation. Subsequently, the flows will be indicated as the variation of vehicles in each section. For example, for the flow with id = 2, it is indicated that only 50 passengers travel from edge 1 to edge 2. And finally, there are another 50 passengers who only travel along edge 2.

If some type of vehicle does not pass through any section (for example, no trucks do), the flow corresponding to that section will not be written to the rou file, because if you write and indicate that the attribute "vehsPerHour" is 0, the program may cause a problem.

10.5.1.7 Add file

```
<?xml version='1.0'?>
<additional>
  <edgeData id='ed' type='emissions' file='emissions_edge_car_9.xml' begin='32400' end='36000' vTypes='t1 t2 t3
t4 t5 t6 t7 t8 t9 t10 t11 t12 t13 t14 t15 t16'/>
  <edgeData id='ed' type='emissions' file='emissions_edge_car_10.xml' begin='36000' end='39600' vTypes='t1 t2 t3
t4 t5 t6 t7 t8 t9 t10 t11 t12 t13 t14 t15 t16'/>
  <edgeData id='ed' type='emissions' file='emissions_edge_moto_9.xml' begin='32400' end='36000' vTypes='t17 t18
t19 t20'/>
  <edgeData id='ed' type='emissions' file='emissions_edge_moto_10.xml' begin='36000' end='39600' vTypes='t17
t18 t19 t20'/>
  <edgeData id='ed' type='emissions' file='emissions_edge_trucks_9.xml' begin='32400' end='36000' vTypes='t21
t22 t23 t24 t25 t26 t27'/>
  <edgeData id='ed' type='emissions' file='emissions_edge_trucks_10.xml' begin='36000' end='39600' vTypes='t21
t22 t23 t24 t25 t26 t27'/>
  <edgeData id='ed' type='emissions' file='emissions_edge_bus_9.xml' begin='32400' end='36000' vTypes='t28 t29
t30 t31 t32 t33 t34'/>
  <edgeData id='ed' type='emissions' file='emissions_edge_bus_10.xml' begin='36000' end='39600' vTypes='t28 t29
t30 t31 t32 t33 t34'/>
  <edgeData id='ed' type='emissions' file='emissions_tramos.xml' begin='32400' end='39600'/>
</additional>
```

Figure 142. Add file structure

The add file is located between two additional tags and sets the emissions for each type of vehicle per hour. Within edgeData tags, there are several attributes such as "id", "type", "file", "begin", "end" and "vTypes".

The 'id' and 'type' attributes always have the same value as 'ed' and 'emissions' respectively. The "file" attribute indicates the file that is created in the following format: The first part is always repeated as "emissions_edge_", followed by the type of vehicle (car, motorcycle, trucks, bus) and the start time (24-hour format), ending with the file extension (.xml).

It also creates a single file whose "file" attribute is "emissions_tramos.xml" without specifying the time as in all other files created.

The "begin" attribute indicates in seconds the start time of the simulation and the "end" attribute specifies in seconds the finish time. As the files are created from hour to hour the difference between the "begin" and "end" will be 3600 seconds. For the "emissions_tramos.xml" file, the "begin" attribute and the "end" attribute have the value of

0 and 82800 seconds respectively, since this file is generated for a simulation that can take up to 24 hours.

Finally, the "vType" attribute corresponds to the "id" of the PHEMligh values of the country selected for the simulation. They can be viewed in the vTypeDistribution section of the above-mentioned rou file.

10.5.1.8 Real file

```
<?xml version='1.0'?>
<configuration>
  <input>
    <net-file value='net_tool.xml'/>
    <route-files value='rou_tool.xml'/>
    <additional-files value='bus_tool.xml,add_tool.xml'/>
  </input>
  <time>
    <begin value='32400'/>
    <end value='39600'/>
  </time>
  <output>
    <emission-output value='emissions_tool.xml'/>
  </output>
</configuration>
```

Figure 143. Real file Structure

The real file shows, between "configuration" labels, the inputs that the program uses and needs and the outputs that are generated from the application of the tool.

Within the "configuration" labels there are 3 divisions with different tags: the first is "input", the second is "time" and the last is "output". Within the "input" tags it indicates the necessary files for the simulation to be carried out correctly. They are divided into net-file whose "value" attribute is "net_tool.xml", route-file whose "value" attribute is "rou_tool.xml" and additional-files whose "value" attribute is "bus_tool.xml, add_tool.xml". These are the files needed as inputs for the simulation.

Then, inside the "time" tags, the values of the begin and end are indicated, whose "value" attribute will be the time in seconds from the beginning to the end of the simulation.

On the "output" tags, the emission-output is indicated, which is the file to be generated when the simulation is performed, whose "value" attribute is "emissions_tool.xml".

10.5.1.9 Spatial file

```
<?xml version='1.0'?>
<edges>
  <edge id='1' slope='0' d='0' road_surface='0'/>
  <edge id='2' slope='0' d='0' road_surface='0'/>
  <edge id='3' slope='0' d='0' road_surface='0'/>
  <edge id='4' slope='0' d='0' road_surface='0'/>
  <edge id='5' slope='0' d='0' road_surface='0'/>
  <edge id='-1' slope='0' d='0' road_surface='0'/>
  <edge id='-2' slope='0' d='0' road_surface='0'/>
  <edge id='-3' slope='0' d='0' road_surface='0'/>
  <edge id='-4' slope='0' d='0' road_surface='0'/>
  <edge id='-5' slope='0' d='0' road_surface='0'/>
</edges>
```

Figure 144. Spatial file structure

The spatial file is used primarily for the resolution of the noise module and is between edges labels. A row is created for each edge that is studied in the simulation but in this case the attribute "id" will only be a positive number, that is, even if the lane is in the reverse direction it will not be necessary to add the negative sign as it only takes into account the number of edges. The "slope" attribute indicates the slope of that section or edge of the road. The attribute 'd' indicates the distance between the source of the noise and the receiver. This value is considered by default to be '0'. And finally, the 'road_surface' attribute is specified to determine the type of surface area travelled on that section of the road. The value of the attribute corresponds to the following surfaces specified in the tool:

- Average dense 0/11: if the surface is this the value of the 'road_surface' attribute is '0'.
- Transversely brushed concrete: value of the 'road_surface' attribute is '1'.
- Concrete with Surface dressing 2/4: value of the 'road_surface' attribute is '2'.
- Exposed aggregated: value of the 'road_surface' attribute is '3'.
- Drain asphalt 6/16: value of the 'road_surface' attribute is '4'.
- 2 layer drain asphalt 4/8-11/16: value of the 'road_surface' attribute is '5'.
- SMA 0/6: value of the 'road_surface' attribute is '6'.
- Surface dressing 4/8: value of the 'road_surface' attribute is '7'.

10.5.1.10 *Gdata file*

```
<?xml version='1.0'?>
<Period>
  <Day hours='12' T='20'/>
  <Evening hours='4' T='20'/>
  <Night hours='8' T='20'/>
</Period>
```

Figure 145. Gdata file structure

The gdata file is used for the noise module and has a very simple structure, as you can see in Figure 145. The "hours" attribute, which indicates the number of hours for each of the phases of the day, is set within the "Period" tags and divided into the "Day", "Evening" and "Night" tags. The values, generally, will always be the same. For "Day" it will be "12", for "Evening" it will be "4" and for "Night" it will be "8". The attribute 'T' indicates the ambient temperature. The average temperature is considered by default to be the value of 20°C.

10.5.1.11 Traffic file

```
<?xml version='1.0'?>
<edges>
  <edge id='1'>
    <Passenger_Car m='1' Qm='250'/>
    <Medium_Heavy_Vehicles m='2' Qm='0'/>
    <Heavy_Vehicles m='3' Qm='10'/>
    <Powered_Two_Wheelers m='4' Qm='100'/>
    <Line_Bus id_bus='line 1' period='20' v='30' stop_lane='1'/>
    <Line_Bus id_bus='Line 4' period='20' v='30' stop_lane='0'/>
  </edge>
  <edge id='2'>
    <Passenger_Car m='1' Qm='250'/>
    <Medium_Heavy_Vehicles m='2' Qm='0'/>
    <Heavy_Vehicles m='3' Qm='10'/>
    <Powered_Two_Wheelers m='4' Qm='100'/>
    <Line_Bus id_bus='line 1' period='20' v='30' stop_lane='0'/>
    <Line_Bus id_bus='Line 4' period='20' v='30' stop_lane='0'/>
  </edge>
  <edge id='-1'>
    <Passenger_Car m='1' Qm='250'/>
    <Medium_Heavy_Vehicles m='2' Qm='0'/>
    <Heavy_Vehicles m='3' Qm='10'/>
    <Powered_Two_Wheelers m='4' Qm='100'/>
    <Line_Bus id_bus='line 1' period='20' v='30' stop_lane='0'/>
    <Line_Bus id_bus='Line 4' period='20' v='30' stop_lane='0'/>
  </edge>
  <edge id='-2'>
    <Passenger_Car m='1' Qm='250'/>
    <Medium_Heavy_Vehicles m='2' Qm='0'/>
    <Heavy_Vehicles m='3' Qm='10'/>
    <Powered_Two_Wheelers m='4' Qm='100'/>
    <Line_Bus id_bus='line 1' period='20' v='30' stop_lane='1'/>
    <Line_Bus id_bus='Line 4' period='20' v='30' stop_lane='0'/>
  </edge>
  <time_type h_begin='9' h_end='10' />
</edges>
```

Figure 146. Traffic file structure

It is defined between edges labels and is divided into two parts: firstly, the section through which the vehicle is driven and secondly, the type of vehicle. For the tag edge, whose only attribute is the "id" obtained from the edge file, so here the negative symbol is added for the reverse direction of travel in front of the section number. For each of the edges, the following tags are defined:

- Passenger_Car: The attribute "m" indicates the value for this type of vehicle which is "1". The attribute 'Qm' indicates the number of passenger cars passing through this edge.

- **Medium_Heavy_Vehicles:** The attribute "m" indicates the value for this type of vehicle which is "2". The attribute 'Qm' indicates the number of such vehicles passing through this edge. This type of vehicle is not covered by the programme and therefore the value of the attribute 'Qm' is '0'.
- **Heavy_Vehicles:** The attribute "m" indicates the value for this type of vehicle which is "3". The attribute 'Qm' indicates the number of such vehicles (trucks) passing through this edge.
- **Powered_Two_Wheelers:** The attribute "m" indicates the value for this type of vehicle which is "4". The attribute 'Qm' indicates the number of such vehicles (motorcycles) passing through this edge.
- **Line_bus:** It indicates the number of buses that run the simulation. It consists of 4 attributes: "id_bus" which corresponds to the bus line number defined in the simulation, "period" which is defined as the time (in minutes) it takes a bus to pass through the established stop, "v" is the speed of the bus set to "30" and the "stop_lane" attribute which has only two values: the value '0' if the bus stop is not defined at the current edge or the value '1' if the bus stop is located at the current edge. A new row with information is added for each bus line that has been defined. If there are no stops or no bus lines defined, the line is completely eliminated.

Finally, when all the information corresponding to the types of vehicles that run along each edge has been defined, a last row is added with the tag "time_type" and containing the following attributes: "h_begin" where the start of the simulation is defined (in 24-hour format), "h_end" where the end of the simulation is defined (in 24-hour format).

Note: the user must indicate in the attribute 'Qm' the number of vehicles at peak time, that is, the maximum number of vehicles of each type during the hour with the highest traffic on that road.

10.5.1.12 *Pattern file*

```
<patrones>
  <patron id="1" begin="0" end="3600" prob="0.10"/>
  <patron id="2" begin="3600" end="7200" prob="0.15"/>
  <patron id="3" begin="7200" end="10800" prob="0.20"/>
  <patron id="4" begin="10800" end="14400" prob="0.25"/>
  <patron id="5" begin="14400" end="18000" prob="0.30"/>
  <patron id="6" begin="18000" end="21600" prob="0.35"/>
  <patron id="7" begin="21600" end="25200" prob="0.40"/>
  <patron id="8" begin="25200" end="28800" prob="0.45"/>
  <patron id="9" begin="28800" end="32400" prob="0.50"/>
  <patron id="10" begin="32400" end="36000" prob="0.55"/>
  <patron id="11" begin="36000" end="39600" prob="0.60"/>
  <patron id="12" begin="39600" end="43200" prob="0.65"/>
  <patron id="13" begin="43200" end="46800" prob="0.70"/>
  <patron id="14" begin="46800" end="50400" prob="1"/>
  <patron id="15" begin="50400" end="54000" prob="0.75"/>
  <patron id="16" begin="54000" end="57600" prob="0.80"/>
  <patron id="17" begin="57600" end="61200" prob="0.85"/>
  <patron id="18" begin="61200" end="64800" prob="0.90"/>
  <patron id="19" begin="64800" end="68400" prob="0.82"/>
  <patron id="20" begin="68400" end="72000" prob="0.62"/>
  <patron id="21" begin="72000" end="75600" prob="0.42"/>
  <patron id="22" begin="75600" end="79200" prob="0.22"/>
  <patron id="23" begin="79200" end="82800" prob="0.32"/>
  <patron id="24" begin="82800" end="86400" prob="0.52"/>
</patrones>
```

Figure 147. Pattern file structure

The user must upload a file indicating the distribution of the traffic, that is, a file indicating the patterns that have been used or followed. This file is defined between “patrones” label.

The “patron” tag consists of four attributes: "id", "begin", "end" and "prob". The attribute "id" is sorted from 1 to 24. The "begin" attribute indicates the time in seconds in which it starts and is ordered from 0 to 23 hours. The "end" attribute indicates the time in seconds at which it finishes and is ordered from 1 hour to 24 hours. The difference for each "id" attribute is that the "begin" and "end" are 1 hour (3600 seconds) apart. The "begin" of the next row will coincide with the "end" of the previous row. Finally, the probability of vehicles running on the road for each hour is indicated by the attribute "prob". The user must take into account at what time is the period with the most traffic and give the value of 1 to the attribute "prob". This value corresponds to the number of vehicles in the traffic file. Even so, it is necessary to know the rest of the probabilities in order to carry out the simulation.

10.5.1.13 *Pattern2 file*

```
<?xml version='1.0'?>
<patterns>
  <pattern id='0' begin='00:00' end='01:00' prob='0.190'/>
  <pattern id='1' begin='01:00' end='02:00' prob='0.170'/>
  <pattern id='2' begin='02:00' end='03:00' prob='0.147'/>
  <pattern id='3' begin='03:00' end='04:00' prob='0.135'/>
  <pattern id='4' begin='04:00' end='05:00' prob='0.131'/>
  <pattern id='5' begin='05:00' end='06:00' prob='0.165'/>
  <pattern id='6' begin='06:00' end='07:00' prob='0.210'/>
  <pattern id='7' begin='07:00' end='08:00' prob='0.236'/>
  <pattern id='8' begin='08:00' end='09:00' prob='0.858'/>
  <pattern id='9' begin='09:00' end='10:00' prob='1.000'/>
  <pattern id='10' begin='10:00' end='11:00' prob='0.743'/>
  <pattern id='11' begin='11:00' end='12:00' prob='0.813'/>
  <pattern id='12' begin='12:00' end='13:00' prob='0.856'/>
  <pattern id='13' begin='13:00' end='14:00' prob='0.838'/>
  <pattern id='14' begin='14:00' end='15:00' prob='0.897'/>
  <pattern id='15' begin='15:00' end='16:00' prob='0.763'/>
  <pattern id='16' begin='16:00' end='17:00' prob='0.671'/>
  <pattern id='17' begin='17:00' end='18:00' prob='0.875'/>
  <pattern id='18' begin='18:00' end='19:00' prob='0.924'/>
  <pattern id='19' begin='19:00' end='20:00' prob='0.833'/>
  <pattern id='20' begin='20:00' end='21:00' prob='0.740'/>
  <pattern id='21' begin='21:00' end='22:00' prob='0.566'/>
  <pattern id='22' begin='22:00' end='23:00' prob='0.313'/>
  <pattern id='23' begin='23:00' end='24:00' prob='0.236'/>
</patterns>
```

Figure 148. Pattern file structure

The second pattern is used for the freight module and follows the same format as the first pattern. This pattern will apply to light commercial vehicles, trailers and trucks.

10.5.1.14 Traffic file

```
<?xml version='1.0'?>
<edges>
  <edge id='1'>
    <Passenger_Car m='1' Qm='250'/>
    <Medium_Heavy_Vehicles m='2' Qm='0'/>
    <Heavy_Vehicles m='3' Qm='10'/>
    <Powered_Two_Wheelers m='4' Qm='100'/>
    <Line_Bus id_bus='4' period='20' v='30' stop_lane='1'/>
  </edge>
  <edge id='2'>
    <Passenger_Car m='1' Qm='250'/>
    <Medium_Heavy_Vehicles m='2' Qm='0'/>
    <Heavy_Vehicles m='3' Qm='10'/>
    <Powered_Two_Wheelers m='4' Qm='100'/>
    <Line_Bus id_bus='4' period='20' v='30' stop_lane='0'/>
  </edge>
  <edge id='-1'>
    <Passenger_Car m='1' Qm='250'/>
    <Medium_Heavy_Vehicles m='2' Qm='0'/>
    <Heavy_Vehicles m='3' Qm='10'/>
    <Powered_Two_Wheelers m='4' Qm='100'/>
    <Line_Bus id_bus='4' period='20' v='30' stop_lane='0'/>
  </edge>
  <edge id='-2'>
    <Passenger_Car m='1' Qm='250'/>
    <Medium_Heavy_Vehicles m='2' Qm='0'/>
    <Heavy_Vehicles m='3' Qm='10'/>
    <Powered_Two_Wheelers m='4' Qm='100'/>
    <Line_Bus id_bus='4' period='20' v='30' stop_lane='1'/>
  </edge>
  <time_type h_begin='9' h_end='11' patern='0'/>
</edges>
```

Figure 149. Traffic file structure

It is defined between edges labels and is divided into two parts: firstly, the section through which the vehicle is driven and secondly, the type of vehicle. For the tag edge, whose only attribute is the "id" obtained from the edge file, so here the negative symbol is added for the reverse direction of travel in front of the section number. For each of the edges, the following tags are defined:

- Passenger_Car: The attribute "m" indicates the value for this type of vehicle which is "1". The attribute 'Qm' indicates the number of passenger cars passing through this edge.
- Medium_Heavy_Vehicles: The attribute "m" indicates the value for this type of vehicle which is "2". The attribute 'Qm' indicates the number of such vehicles passing through this edge. This type of vehicle is not covered by the programme and therefore the value of the attribute 'Qm' is '0'.

- **Heavy_Vehicles:** The attribute "m" indicates the value for this type of vehicle which is "3". The attribute 'Qm' indicates the number of such vehicles (trucks) passing through this edge.
- **Powered_Two_Wheelers:** The attribute "m" indicates the value for this type of vehicle which is "4". The attribute 'Qm' indicates the number of such vehicles (motorcycles) passing through this edge.
- **Line_bus:** It indicates the number of buses that run the simulation. It consists of 4 attributes: "id_bus" which corresponds to the bus line number defined in the simulation, "period" which is defined as the time (in minutes) it takes a bus to pass through the established stop, "v" is the speed of the bus set to "30" and the "stop_lane" attribute which has only two values: the value '0' if the bus stop is not defined at the current edge or the value '1' if the bus stop is located at the current edge. A new row with information is added for each bus line that has been defined. If there are no stops or no bus lines defined, the line is completely eliminated.

Finally, when all the information corresponding to the types of vehicles that run along each edge has been defined, a last row is added with the tag "time_type" and containing the following attributes: "h_begin" where the start of the simulation is defined (in 24-hour format), "h_end" where the end of the simulation is defined (in 24-hour format) and the "patern" indicates the pattern used in the simulation. If the pattern to be used is not known, it is set to "0".

10.5.1.15 *Meteo file*

```
<?xml version='1.0'?>
<meteorological>
  <meteorological date='2018-07-30' temp='20' press='1' wind_vel='2' wind_dir='4'/>
</meteorological>
```

Figure 150. Meteo file structure

The user has to upload a file in which the weather data is specified. This file is defined between "meteorological" label.

The "meteorological" tag consists of five attributes: "date", "temp", "press", "wind_vel" and "wind_dir". The attribute "date" is the date from which the weather data is displayed. You have to follow the format 'yyyy-mm-dd'. The "temp" attribute indicates the average temperature of that date in degrees centigrade. The "press" attribute indicates the average pressure of the date in bar. The "wind_vel" attribute indicates the average speed of the wind in meter per second and the "wind_dir" attribute indicates the direction of the wind in degrees.

4	roundabout	45.670500, 12.228082	1
5	bus stop	45.671974, 12.231281	1
6	traffic light	45.672661, 12.232478	1
7	traffic light	45.676889, 12.237022	1
8	bus stop	45.677896, 12.238083	1
9	crossroad	45.678235, 12.238422	1
10	crossroad	45.679491, 12.239709	1
11	bus stop	45.679616, 12.239896	1
12	bus stop	45.680179, 12.240357	1
13	crossroad	45.680638, 12.240905	1
14	traffic light	45.682013, 12.242294	1
15	bus stop	45.683087, 12.243142	1
16	traffic light	45.683377, 12.243340	1
17	bus stop	45.683750, 12.243764	1
18	crossroad	45.686888, 12.246081	1
19	bus stop	45.689338, 12.248275	1
20	bus stop	45.693082, 12.251827	1
21	bus stop	45.693576, 12.252132	1
22	traffic light	45.693813, 12.252438	1
23	crossroad	45.696811, 12.255249	1
24	roundabout	45.698917, 12.258553	1

The monitoring campaign in Treviso took place from the 19th October to the 13th of November 2017.

A subset of data from the 20th to 21st October 2017 has been used as testing data.

Data collected is composed by:

- traffic flows for the 2 directions of the road (Table 27)
- gas air pollutants
- noise measurements (Table 28)

Table 27. Treviso traffic data per direction per hour

Hour	East direction				West direction			
	<i>Passenger cars</i>	<i>Medium heavy vehicle</i>	<i>Heavy vehicles</i>	<i>Powered two wheels</i>	<i>Passenger cars</i>	<i>Medium heavy vehicle</i>	<i>Heavy vehicles</i>	<i>Powered two wheels</i>
0-1	179	6	1	0	175	4	0	3
1-2	65	1	4	0	121	1	0	0
2-3	29	3	1	0	93	6	4	1
3-4	31	5	6	0	54	11	3	0
4-5	40	2	4	0	60	24	9	0
5-6	94	15	16	0	92	54	14	0
6-7	203	41	41	0	209	29	22	2
7-8	623	47	62	0	579	47	36	16
8-9	818	41	45	0	682	44	37	29
9-10	715	45	47	0	712	44	34	17
10-11	745	42	39	0	742	45	46	7
11-12	753	59	35	0	732	38	42	22
12-13	808	47	27	0	705	27	21	34
13-14	726	42	41	0	751	53	23	20
14-15	741	30	36	0	705	48	31	15
15-16	745	36	41	0	767	32	34	19
16-17	838	55	24	0	716	40	18	17
17-18	813	39	22	0	724	35	19	21
18-19	829	32	15	0	539	24	13	51
19-20	855	23	8	0	763	18	7	26
20-21	756	13	14	0	710	15	5	21

21-22	555	12	3	0	432	8	12	6
22-23	464	18	3	0	408	4	3	5
23-0	458	9	2	0	421	5	2	3

Table 28. Noise level measurements per hour

Inizio periodo	Leq	Lmin	Lmax	L95	L90	L50	L10	L5
20/10/2017 0:00	65,7	50,5	77,7	51,2	51,8	59,9	70,3	71,6
20/10/2017 1:00	63,4	50,8	78,7	51,1	51,3	54,8	68,5	70,1
20/10/2017 2:00	62,8	48,5	80,5	48,9	49	53	67,2	69,8
20/10/2017 3:00	62	48,3	78,1	48,6	48,8	51,2	66,4	69,7
20/10/2017 4:00	63,5	48,6	79	49,2	49,4	52,7	68,4	71
20/10/2017 5:00	66,2	48,7	78,5	49,6	50	58,7	71	72,7
20/10/2017 6:00	68,4	48,4	83,4	50,6	52,5	64,9	72,3	73,8
20/10/2017 7:00	69,5	51	85,9	59,3	61,6	68,3	72,1	73,3
20/10/2017 8:00	68,3	54,6	82,7	60,9	62,6	67,2	71	71,9
20/10/2017 9:00	69,3	56,3	86,8	61,4	63,1	68,3	71,5	72,4
20/10/2017 10:00	68,6	55,9	79,1	62,2	63,6	67,9	71,1	72,1
20/10/2017 11:00	68,8	52,9	80,7	61,4	63,2	67,8	71,2	72,4
20/10/2017 12:00	67,5	56,3	84,3	60,6	61,9	66,6	69,9	71,1
20/10/2017 13:00	69,4	51,4	91,6	62	63,7	68,2	71,3	72,3
20/10/2017 14:00	69,9	51,5	93	60,6	62,8	67,9	71,3	72,5
20/10/2017 15:00	68,4	55,5	82,3	61,1	62,5	67,4	70,9	71,9
20/10/2017 16:00	67,6	53,8	84,6	59,4	61,8	66,8	69,9	70,7
20/10/2017 17:00	67,7	54,5	83,3	61,1	62,6	66,9	70	71
20/10/2017 18:00	66,1	55,5	79	59,8	60,8	65,1	68,6	69,5
20/10/2017 19:00	68,1	57,1	79	61,6	63,1	67,4	70,5	71,3
20/10/2017 20:00	68,7	51,2	80,5	60	62,5	68,1	71,4	72,1
20/10/2017 21:00	68,1	51,1	77,5	54,7	57,2	67,1	71,3	72,4

20/10/2017 22:00	68,1	50,6	88,1	54,8	56,7	66,6	71,2	72,2
20/10/2017 23:00	68,3	51,8	80,3	55,7	57,6	66,8	71,7	72,7
21/10/2017 0:00	68,1	51	82,4	54,9	56,9	66,5	71,6	72,5
21/10/2017 1:00	67,3	49,8	81,5	52,1	53,3	63	71,3	72,7
21/10/2017 2:00	65,8	48,2	85,4	50,6	51,3	58,3	70	71,6
21/10/2017 3:00	63,6	47,6	78,3	48,5	48,9	54,6	68,6	70,9
21/10/2017 4:00	63,9	47	80,9	48	48,6	54,7	68,6	70,9
21/10/2017 5:00	63,9	47	81,4	47,5	47,9	55,1	68,8	70,9
21/10/2017 6:00	66	46,7	78,8	47,6	48,4	59,1	70,6	72,1
21/10/2017 7:00	68,2	47,8	83,6	52,9	55,3	66,8	71,5	72,5
21/10/2017 8:00	68,7	48,2	82,7	55,9	58,7	67,6	71,7	72,6
21/10/2017 9:00	68,7	52,3	83,3	59	61,1	67,8	71,7	72,4
21/10/2017 10:00	67,6	54,8	79	60,2	62,2	67	70,1	71
21/10/2017 11:00	69,2	55,1	94,4	61,1	62,6	66,6	69,9	70,9
21/10/2017 12:00	67,8	51,9	78,5	59,6	61,6	66,8	70,5	71,3
21/10/2017 13:00	68,9	50,7	90,3	58,9	61,6	67,4	71,2	72,2
21/10/2017 14:00	69,2	49,4	91,5	57,1	60	67,6	71,4	72,2
21/10/2017 15:00	68	51,1	76,5	59,5	61,6	67,3	70,6	71,4
21/10/2017 16:00	67,7	54,1	77,4	60,2	61,6	66,8	70,4	71,2
21/10/2017 17:00	67,3	52,6	75,1	60,1	62	66,7	69,9	70,6
21/10/2017 18:00	67,3	56,8	84,2	60,5	62	66,3	69,2	70,1
21/10/2017 19:00	68,1	56,2	81,4	61,3	63	67,3	70,5	71,4
21/10/2017 20:00	68,1	50,5	87,6	59,2	61,6	67	70,1	70,9
21/10/2017 21:00	67,8	50,2	81,8	54,6	56,9	66,7	71,1	72
21/10/2017 22:00	69,6	50,6	95,8	55,7	58,4	67	70,9	72
21/10/2017 23:00	68	50,8	80,8	55,4	57,4	66,8	71,3	72,2
Globali	67,7	46,7	95,8	50,5	53,2	66,2	70,8	71,9

11.2 Noise module validation

Noise model described in chapter 5 is validated based on noise level (Leq) measured on 20th October in Treviso. The noise model provides us noise level per edge but the real noise data from Treviso is measured by detector located in a specific point. As can be seen in the noise detector is placed in the edge 12 of SUMO model, therefore we only consider the level noise from this area.

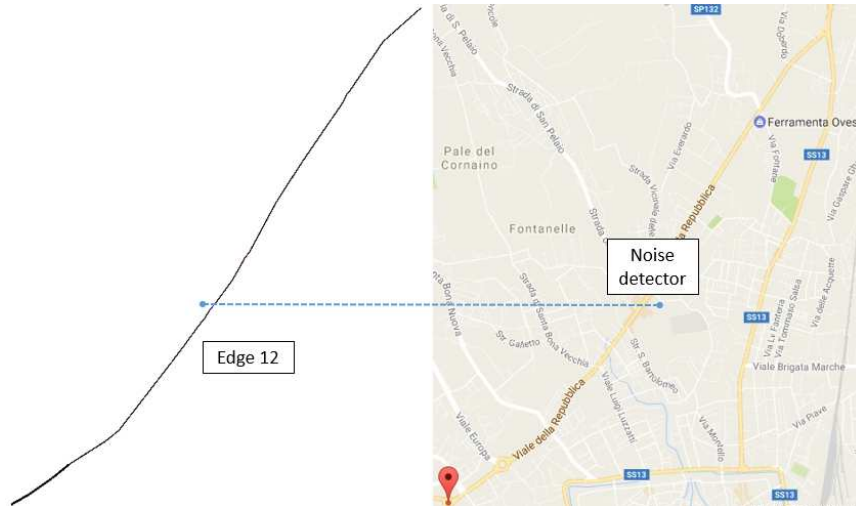


Figure 152. Noise detector position vs model

Due to Viale de la Repubblica is a two-way road, the noise model calculates the noise level to each direction and a logarithmic sum is executed to obtain the global value. These values are the following:

Table 29. Noise model results

	model noise level (dB)		
hour	west direction	east direction	logarithmic sum (dB)
0:00	60,0	60,3	63,1
1:00	58,0	57,1	60,6
2:00	58,8	54,0	60,0
3:00	57,9	57,0	60,5
4:00	60,6	56,0	61,9
5:00	63,3	61,5	65,5
6:00	63,7	65,4	67,6
7:00	66,6	68,1	70,4

8:00	67,3	67,8	70,6
9:00	67,3	67,8	70,5
10:00	67,8	67,3	70,5
11:00	67,6	67,6	70,6
12:00	66,7	67,0	69,8
13:00	67,3	67,4	70,3
14:00	67,2	66,9	70,1
15:00	67,3	67,2	70,3
16:00	66,8	67,0	69,9
17:00	66,8	66,4	69,6
18:00	65,6	65,6	68,6
19:00	66,2	64,8	68,6
20:00	65,9	64,5	68,3
21:00	64,6	64,9	67,8
22:00	63,6	64,5	67,1
23:00	63,7	64,1	66,9

Table 30. Comparison real data versus model results from Treviso

hour	real data (dB)	model (dB)	error (%)
0:00	65,7	63,1	3,924
1:00	63,4	60,6	4,446
2:00	62,8	60,0	4,410
3:00	62,0	60,5	2,431
4:00	63,5	61,9	2,451
5:00	66,2	65,5	1,036
6:00	68,4	67,6	1,225
7:00	69,5	70,4	1,503

8:00	68,3	70,6	3,354
9:00	69,3	70,5	1,846
10:00	68,6	70,5	2,796
11:00	68,8	70,6	2,553
12:00	67,5	69,8	3,391
13:00	69,4	70,3	1,407
14:00	69,9	70,1	0,253
15:00	68,4	70,3	2,779
16:00	67,6	69,9	3,293
17:00	67,7	69,6	2,748
18:00	66,1	68,6	3,914
19:00	68,1	68,6	0,678
20:00	68,7	68,3	0,853
21:00	68,1	67,8	0,484
22:00	68,1	67,1	1,513
23:00	68,3	66,9	2,057

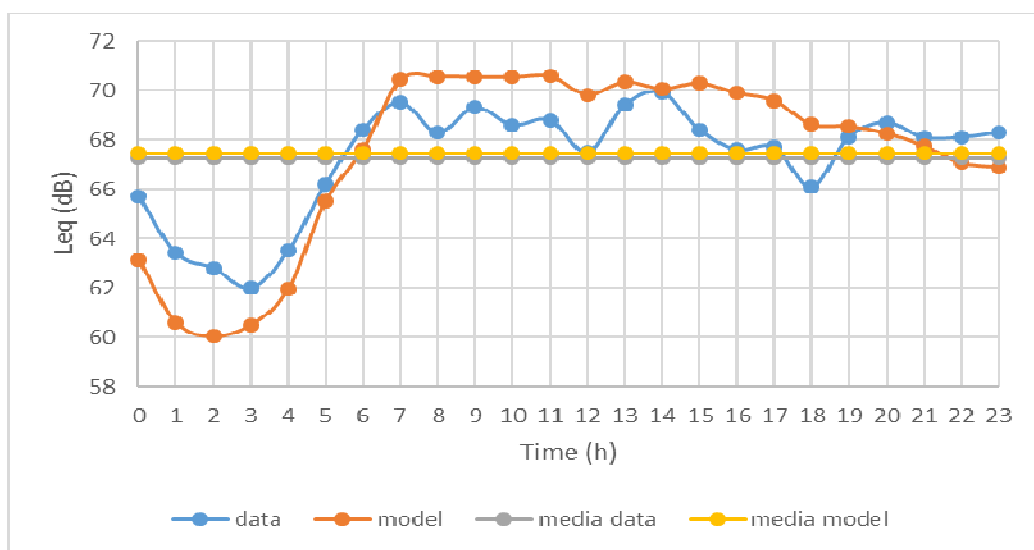


Figure 153. Comparison real data versus model results from Treviso

As Figure 113 shows, accurate results can be achieved calculating the noise caused by traffic within the REMEDIO IMT. A relative error of less than 5% appears for all the analysed hours.

11.3 Atmospheric Pollution Emission & carbon footprint module validation

For the validation of the atmospheric pollution emission and carbon footprint modules of IMT, the emission model COPERT Street level (COPERT SL user's manual v2.2.53) was implemented for the pilot area of the municipality of Treviso. COPERT SL is an emission model which is widely used on a European level for the estimation of road transport emissions. The emissions and carbon footprint results of IMT (based on the more dynamic modeling system of the SUMO traffic model coupled with the Phemlight vehicle emission model) were compared with those of COPERT SL for a 24 hours simulation period.

COPERT SL is a static model which calculates emissions from road transport on a single street or on a full city street network on an hourly basis requiring the following input data:

- Coordinates of nodes/edges,
- Length of edges (in km),
- Average speed of vehicles per hour (in km/hr) across the pilot zone,
- Number of vehicles per hour,
- Vehicle type distribution according to category, fuel and emission standard.

COPERT SL can be used for the estimation of emissions for the pollutants CO, NO_x, CO₂, PM and VOC. In COPERT SL, vehicles are classified in the following categories: Passenger cars, Light commercial vehicles, Heavy duty trucks, Buses, Motorcycles and Mopeds. The vehicle categories are further classified based on technology (gasoline, diesel, CNG etc. fuel used) and emission standards (EU1, EU2 etc.) similarly to IMT (i.e. PHEMlight) classification.

The main input data for the application of the pollutant emissions and carbon footprint modules of IMT and for the application of the COPERT SL for the pilot area of Treviso (e.g. zone description, traffic data in two directions per hour etc) have already been described in epigraph 11.1. Figure 154 illustrates the vehicle type distribution per hour in the Treviso pilot area, which was further classified according to the IMT pollutant and carbon footprint modules classification. Figure 155 presents the overall traffic load through the day along the road axis of Treviso where it can be seen that it presents its peak the hour 16:00-17:00. It should be noticed that the average vehicle speed at each road segment (edge) derived from the hourly IMT simulation outputs was used as input for the application of the

COPERT SL. The validation was performed for CO, PM (practically PM2.5), NOx, VOC (for COPERT SL) and HC (for IMT) and carbon footprint (CO2) emissions.

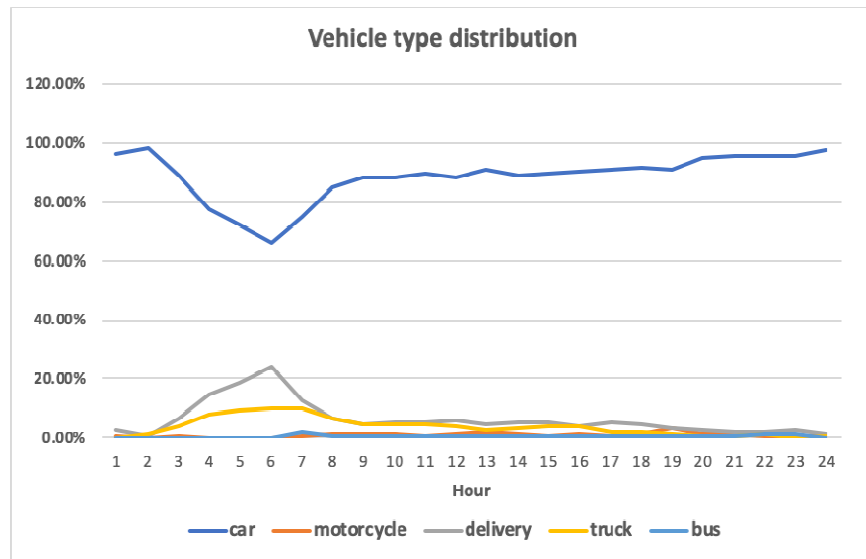


Figure 154. Vehicle type distribution in Treviso pilot area.

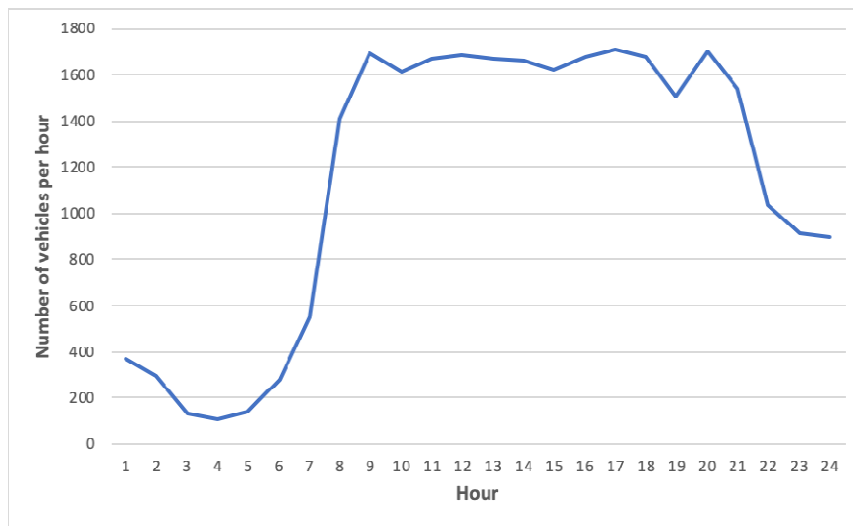


Figure 155. Hourly traffic load in Treviso pilot area.

In Figures 156 to 160, the carbon footprint (i.e. CO2 emissions) and pollutant hourly emissions results from the IMT and COPERT SL simulations are presented for the pilot area of Treviso. It seems that both models present a similar hourly distribution of NOx, PM, HC/VOC and carbon footprint emissions. Also, the correlation between the aforementioned daily emission values of the two models is very high (0.9) indicating a good model performance. Large differences between both model results have been estimated for CO emissions and further research is necessary to understand the reasons.

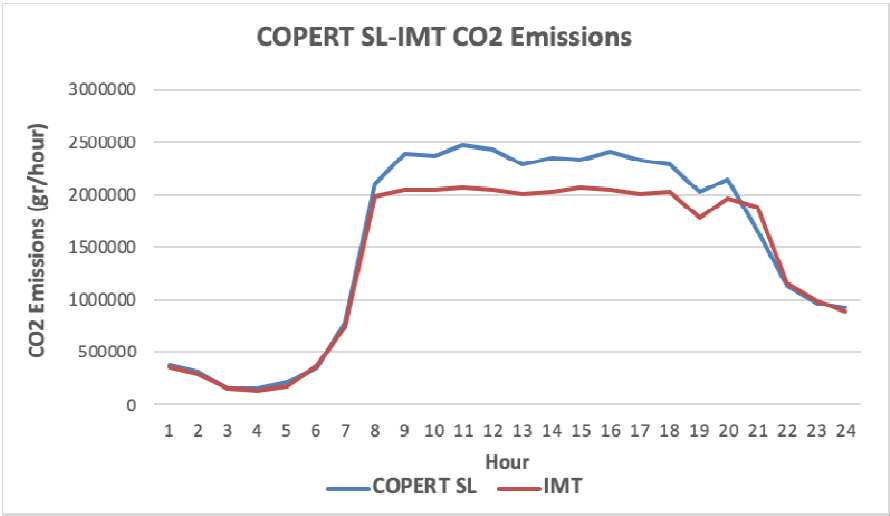


Figure 156. Comparison between the IMT and COPERT SL hourly results for carbon footprint emissions

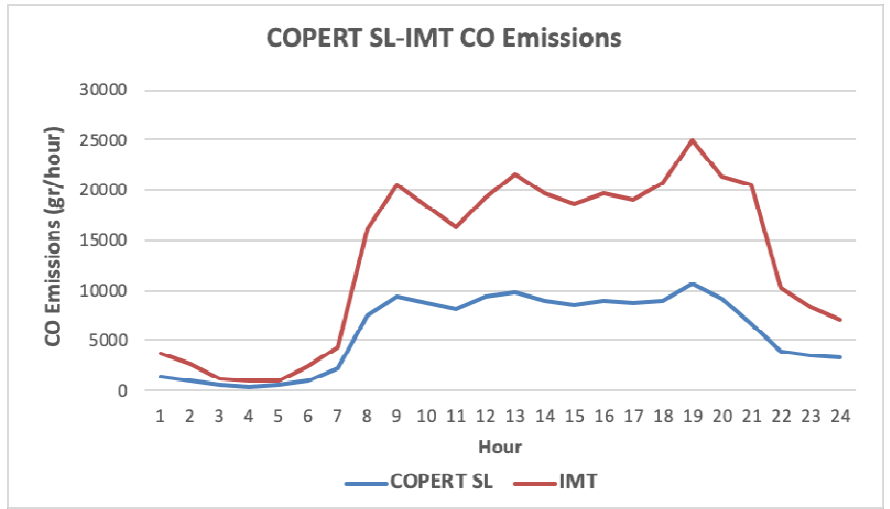


Figure 157. Comparison between the IMT and COPERT SL hourly CO emissions

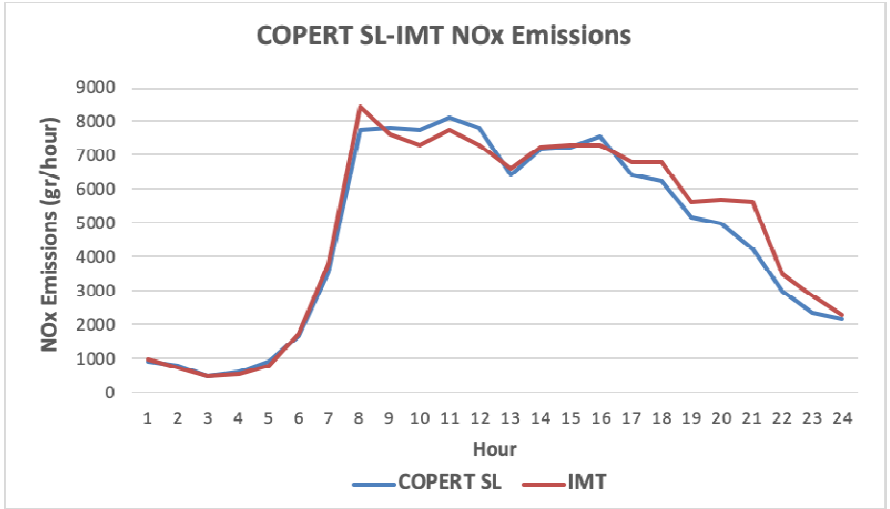


Figure 158. Comparison between the IMT and COPERT SL hourly NOx emissions

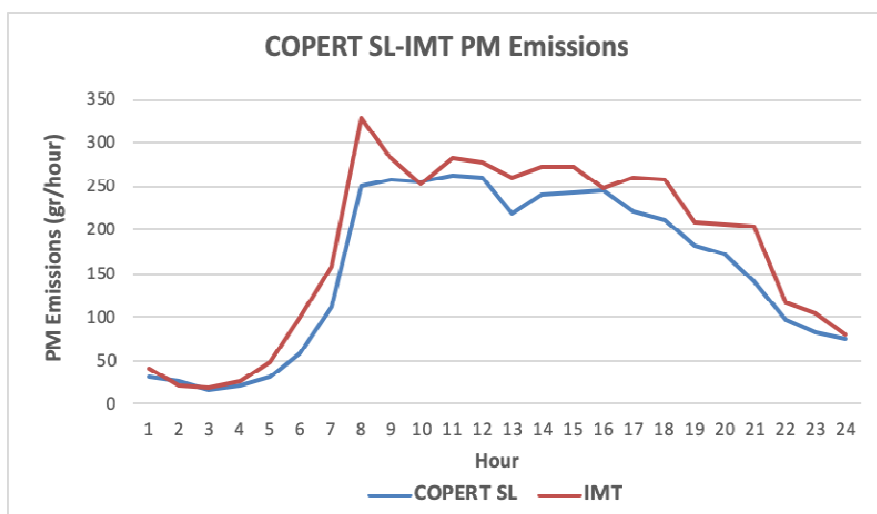


Figure 159. Comparison between the IMT and COPERT SL hourly PM emissions

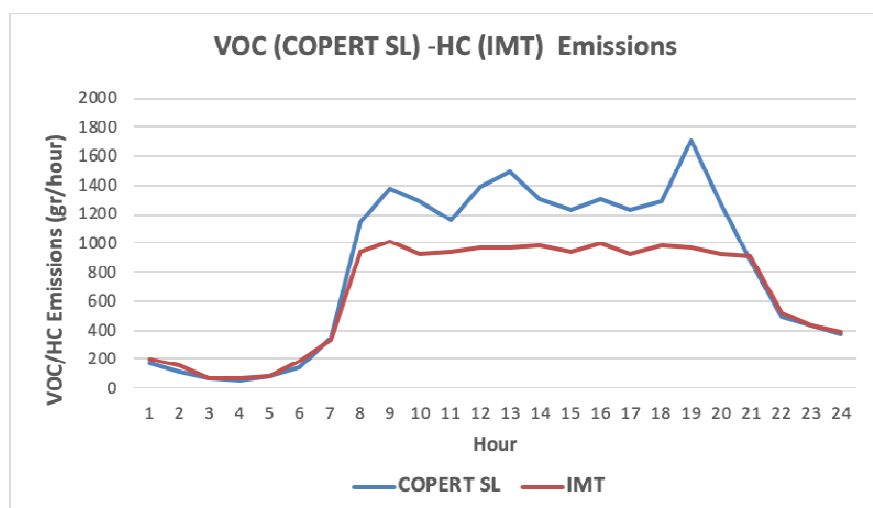


Figure 160. Comparison between the IMT and COPERT SL hourly HC/VOC emissions

In Figures 161 and 162, the % differences between the IMT and COPERT SL carbon footprint and pollutant emission results are presented. The differences are defined as following:

$$\% \text{ Difference} = \frac{(\text{IMT} - \text{COPERT SL})}{\text{COPERT SL}} \%$$

Figure 161 illustrates the % differences between the IMT and COPERT SL daily carbon footprint (i.e. CO₂ emissions) and pollutant emissions. Figure 162 shows % differences between models in hourly CO₂ and pollutant emissions for the hour of peak traffic (i.e. 16:00-17:00).

The IMT performance seems to be satisfactory for the estimation of CO₂, NO_x, PM and HC/VOC emissions since the differences with respect to COPERT SL results are in most cases small. IMT estimation for the daily carbon footprint is -2.3% in comparison with COPERT SL; the difference is +7.8% for peak hour. The differences in NO_x, PM and HC daily emissions are +7.7% and +23.1%, respectively. The differences between both models in hourly emissions at the hour of peak traffic are larger estimated as 26% and 43% for NO_x and PM respectively. Regarding HC and VOC, estimated by IMT and COPERT SL, respectively, it seems that although the values between the models are comparable, any effort for direct comparison is very difficult because of the different chemical speciation used in the two models. Previous studies have been shown that there are expected differences in the results of static and dynamic traffic emissions models. Wismans et al. 2012 found absolute differences in NO_x emissions between static and dynamic models that could be up to 45%, with the differences being larger for CO₂. Borge et al. 2012 estimated a 20% difference in NO_x emissions estimated with the COPERTv8.1 and HBEFAv3.1 emissions models, representative of the 'average-speed' and 'traffic situation' model types respectively. Thus, it could be stated that the IMT presents good performance in the estimation of traffic-related carbon footprint and NO_x, PM and HC emissions since the estimated differences with respect to the COPERT SL model results falls within an expected range.

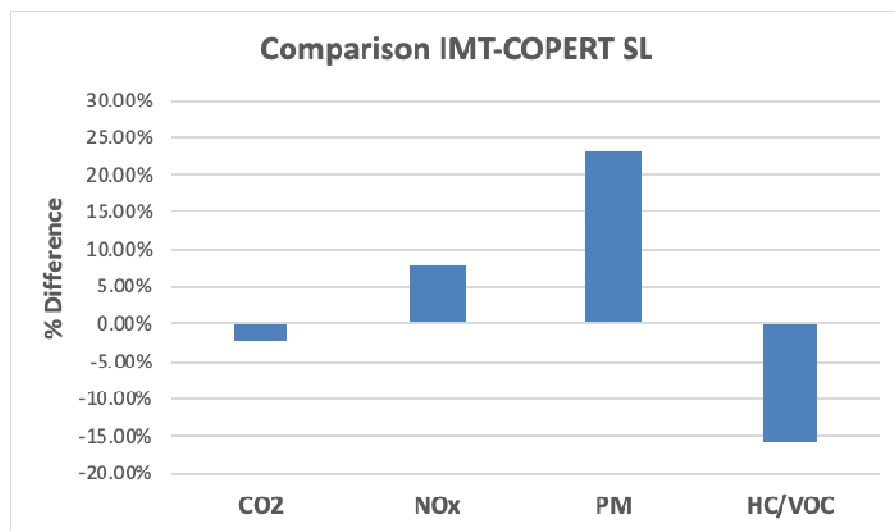


Figure 161. Percentage differences between IMT and COPERT SL daily simulation results.

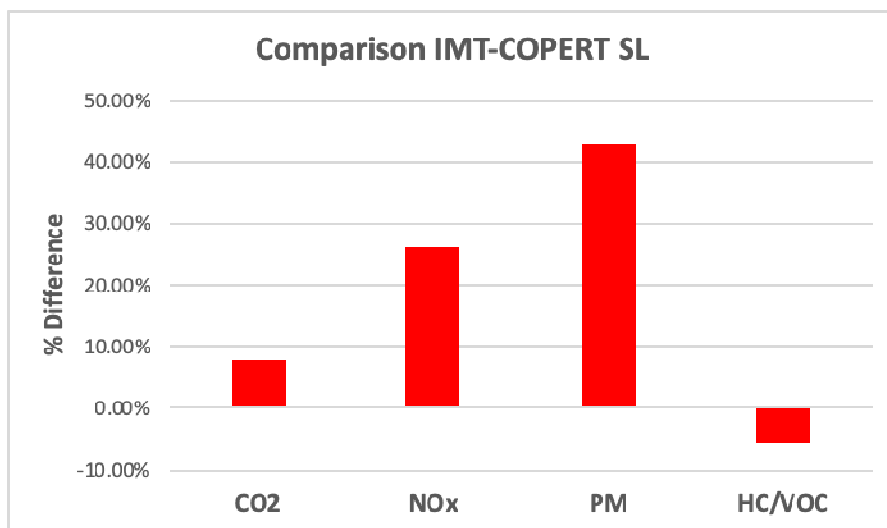


Figure 162. Percentage differences between IMT and COPERT SL simulation results at the peak hour of traffic data (16:00-17:00).

References:

- Borge R., de Miguel I., de la Paz D., Lumbreras J., Perez J., Rodriguez E. Comparison of road traffic emission models in Madrid (Spain) (2012). ATMOSENV Volume 62, December 2012, Pages 461-471. <https://doi.org/10.1016/j.atmosenv.2012.08.073>
- COPERT Street Level user's manual v2.2.53. Emisia Mission for Environment (www.emisia.com)
- Wismans L., van den Brink M., Brederode L., Zantema K., van Berkum E. Comparison of estimation of emissions based on static and dynamic traffic assignment models. Proceedings of 92th Annual Meeting of the Transportation Board, 13-17 January 2013, Washington DC, USA

12 Soft actions

12.1 Introduction

One of the main goals of the REMEDIO IMT is the capacity to estimate how a certain mobility action would affect to the study area. Thus, after simulating a complete test over the pilot zone under analysis, different mobility actions of interest can be studied and their impact can be assessed. These actions involve changes in the simulation process within the IMT tool. In this document, a selected set of mobility actions is summarized and how they are implemented is within a step-by-step guide for IMT users. The conceptual scheme for this process is shown in Figure 163. It reflects how the IMT user can analyze the feasibility of the action and their impact from different perspectives (noise, emissions, cost, etc.), as a fundamental basis for the decision-making process.

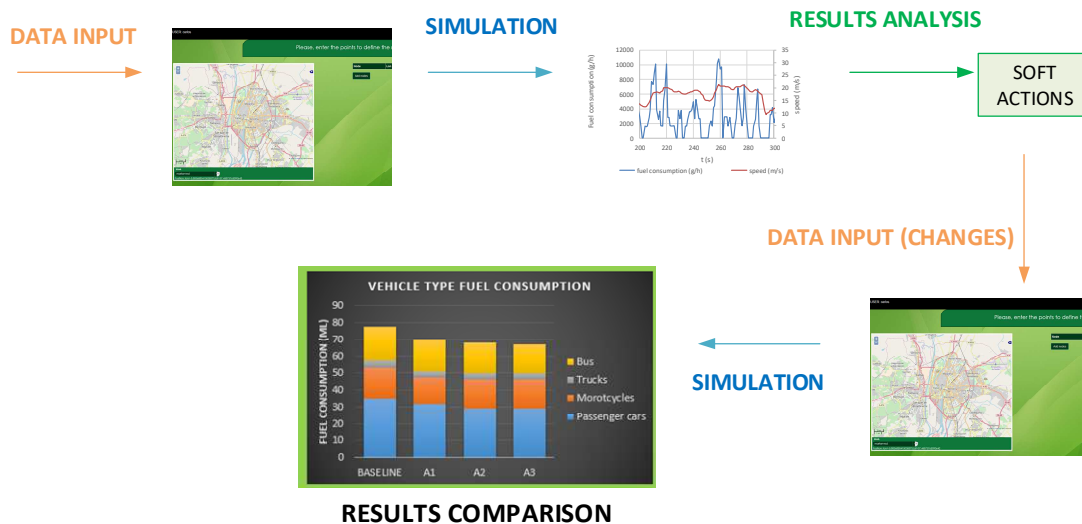


Figure 163: Mobility actions analysis. Conceptual scheme

The overall simulation procedure is:

1. Base case simulation. Once the base case has been simulated, case results are taken as reference baseline.
2. After this, the IMT user must click the button “soft actions analysis”. An excel file appear in the IMT. It must be downloaded and completed with the info about the base case reference results.

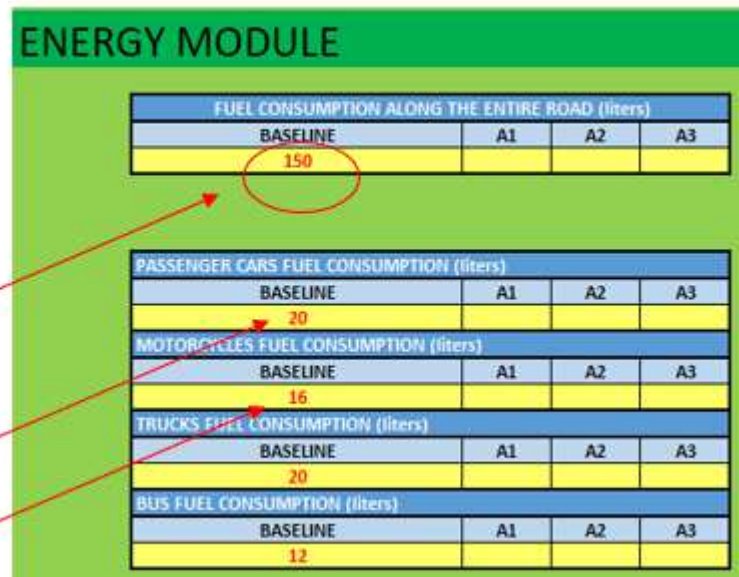


Figure 164: Completing the information about the reference case

3. The IMT modelling process is launched again. Note that some step do not imply any change and therefore the inputs of the base case must be maintained. Within the description of each mobility actions the user can find the specific steps that must be changes in the new scenario.
4. Finally, the user can simulate the IMT modules for the new scenario as in the base case. Results of the modules can be inserted in the previously downloaded excel file which is used as comparator.



Figure 165: Comparison about the fuel consumption after simulating 3 different actions

The set of mobility actions includes within the IMT is the following:

1. Add a bus lane
2. Add one or more bus lines
3. Add a bike lane. Bike sharing
4. Changes about traffic light
5. Remove/add a road lane
6. Change vehicle type distribution
7. Select/change a traffic pattern (24-hour tests)

Note that similar mobility actions not included in the list could be analyzed. For this, the user is referred to the IMT user manual, which can be directly downloaded from the IMT platform.

12.2 Actions 1: Add a bus lane

In order to reduce the traffic congestion in a certain road, a possible action to be taken by those responsible for mobility is increasing the public transport service in the zone. Separating public transport vehicles from other traffic is usually an effective way of enhancing public transport. The addition of a bus lane would reduce the time taken to get from one point to another using public transportation, which would make the use of public transport more attractive for the users, with the consequent reduction in the number of private cars. Taking the traffic effect results from the base case simulation within the IMT, this section allows achieve a first estimation about the benefits of introduce a new bus lane.

12.2.1 Pre-defined values

A number of predefined values will be included by each of the soft mobility actions. To achieve further reliable data, an analysis of how the action would affects to traffic in the zone could be carried out by traffic experts. In this case, once known the effect of the action in the particular case, user-defined data can be introduced in the IMT for a better approach to real benefits.

12.2.2 Specific simulation procedure

The simulation procedure is as follows:

1. Take note of the numeric results after simulate the base case scenario.
2. The IMT user must click the button “soft actions analysis”. Download the excel file and complete with the results for the base case.
3. The IMT modelling process start again. Since a new bus line will be introduced in the new scenario, steps from 1 to 7 don't changes. Thus, the user should continue the process through these screens without making modifications.
4. Step 8 (edge information): In this step changes are required. In the column “Bus Lane position” you should indicate what edges have a bus lane and its position. The enumeration of the lanes considers that the value 0 is the rightmost lane and the rest takes value from 1 (Figure 166). For instance, if the new bus line is introduced along the entire road in the right side (as usually) the user should select “0” in all the boxes within the above -mentioned column.

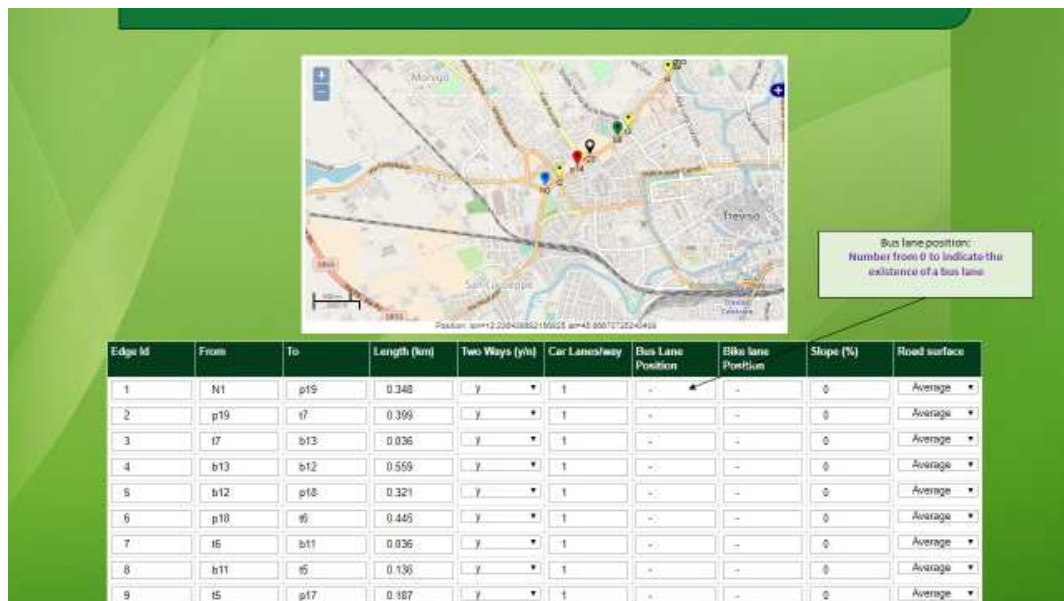


Figure 166: Step 8: how to add a bus lane

5. In the traffic definition step, the user can either accept the proposed values related to the traffic variation caused by the new action or introduced user-defined values. Thus, the user must vary the total number of vehicles by the selected factor. Recommended value: number of vehicles decreases x% caused by the application of the soft actions.
6. As last step, the user can simulate the IMT modules for the new scenario as in the base case. Results of the modules can be inserted in the previously downloaded excel file which is used as comparator.

Table of figures

Figure 1: Overall conceptual modelling approach	9
Figure 2: Schematics of data handling for road definition within the IMT	11
Figure 3. Road file created internally from the data introduced by the user	12
Figure 4. Model inputs (Vehicle and engine)	15
Figure 5. Model inputs (Rolling resistance coefficients, transmission and power nominal values)	16
Figure 6. Model inputs (Operative conditions)	16
Figure 7. PC_G_EU4 driving along the road. Driving cycle.....	17
Figure 8. PC_G_EU4 Output power associated to a deceleration and acceleration period (first traffic light)	17
Figure 9. PC_G_EU4 Fuel consumption over driving cycle. Sumo and theoretical model results comparison.....	19
Figure 10. Road traffic noise methodology.....	21
Figure 11. Input data per period, per vehicle and per edge of the road – Excel files.....	28
Figure 12. Methodology for calculating the directional sound power per category of vehicle per edge – Excel file (example)	29
Figure 13. Road surface – Rolling correction coefficients - Example	29
Figure 14. Traffic light and roundabouts - Rolling correction coefficients – Example.....	30
Figure 15– Road gradient - Propulsion correction coefficients – Example	30
Figure 16. Traffic light and roundabouts - Propulsion correction coefficients – Example.....	30
Figure 17. Rolling and propulsion correction factors.....	31
Figure 18. The directional sound power per category of vehicle and per fleet of the traffic flow under day conditions – Excel example.....	32
Figure 19. The directional sound power per category of vehicle and per fleet of the traffic under day, evening and night conditions – Excel example	33
Figure 20. Followed procedure for implementing noise model in IMT.	34
Figure 21. Inputs data for traffic simulation in Thessaloniki.....	39

Figure 22. Noise by edge – IMT noise results for day, evening and night period.....	39
Figure 23. Noise module results – Road noise emission per edge	41
Figure 24. Noise module results – Normalized road noise emission per edge.....	41
Figure 25. Noise module results – Road noise emission per edge and typology of vehicle ..	42
Figure 26 – Input and Output variables for the freight module	48
Figure 27 – Schematics of the freight module	49
Figure 28. Input-output structure of VADIS - Pollutant dispersion in the atmosphere under variable wind conditions.....	50
Figure 29. Definition of obstacles and sources coordinates.	52
Figure 30. IMT platform concept	64
Figure 31. MVC pattern diagram (extracted from https://developer.chrome.com/apps/app_frameworks).....	65
Figure 32. A general schema of Noise and Energy module operation.....	66
Figure 33. Proposed patterns.....	70
Figure 34. Sevilla vs Pattern 4	71
Figure 35. Thessaloniki vs Pattern 1.....	71
Figure 36. IMT simulation time	72
Figure 37. 24 hours simulation	72
Figure 38. IMT web application homepage	73
Figure 39. IMT Toolbar	73
Figure 40. IMT execution schema	74
Figure 41. Step-by-step traffic characterization	75
Figure 42. “Run tool” button location in step 9 view	76
Figure 43. “My files” folder description.....	76
Figure 44. “My Simulations” folder description.....	77
Figure 45. “Upload” view description	78

Figure 46. Description of how to create a new simulation	79
Figure 47. Files-Upload process execution.....	80
Figure 48. Modules Execution: options menu	81
Figure 49. Example of module outputs after energy module execution	81
Figure 50. “My Outputs” view description.....	82
Figure 51. Welcome page of the IMT.....	83
Figure 52. Register new user screen	84
Figure 53. Register new user screen	84
Figure 54. Step 1 description and ways to add new nodes in the step-by-step process	85
Figure 55. Nodes coordinates – Step 1	86
Figure 56. Step 2 description in the step-by-step process.....	86
Figure 57. Nodes coordinates – Step 1 and 2	87
Figure 58. Step 3 description in the step-by-step process.....	88
Figure 59. Nodes coordinates – Step 1, 2 and 3.....	88
Figure 60. Step 4 description in the step-by-step process.....	89
Figure 61. Nodes coordinates – Step 1, 2, 3 and 4.....	89
Figure 62. Step 5 description in the step-by-step process.....	90
Figure 63. Nodes coordinates – Step 1, 2, 3, 4 and 5.....	90
Figure 64. Step 6 description in the step-by-step process.....	91
Figure 65. Nodes coordinates – Step 1, 2, 3, 4, 5 and 6.....	92
Figure 66. Step 7 description in the step-by-step process.....	93
Figure 67. Step 8 view in the step-by-step process	94
Figure 68. Step 8 description.....	95
Figure 69. Step 9 view in the step-by-step process	96
Figure 70. “Total Vehicles” table (step 9).....	97
Figure 71. “Vehicle type” and “Pattern” tables (step 9)	98

Figure 72. “My Simulations” folder description (user manual)	99
Figure 73. “My Files” folder options: Download, View or delete	99
Figure 74. “My Simulations” folder description.....	100
Figure 75. Files upload process Step 1	101
Figure 76. Files uploaded process Step 2	102
Figure 77. Step 2, help button operation.....	103
Figure 78. Step 2 to Step 3 screens.....	103
Figure 79. Files upload process Step 3	104
Figure 80. Files uploaded process Step 4	105
Figure 81. Files uploaded process Step 5	106
Figure 82. Files uploaded process Step 6	106
Figure 83. Files uploaded process Step 7	107
Figure 84. Module selection main menu	107
Figure 85. “Energy Module” button location in “Select Module to Apply” view	108
Figure 86. Energy module charts outputs.....	108
Figure 87. “Continue Simulation” and “Finish” button location.....	109
Figure 88. “Noise Module” button location in “Select Module to Apply” view	109
Figure 89. Noise module charts outputs.....	110
Figure 90. “Continue Simulation” and “Finish” button location.....	111
Figure 91. “Emissions Module” button location in “Select Module to Apply” view.....	111
Figure 92. Emissions module files output	112
Figure 93. “Continue Simulation” and “Finish” button location.....	113
Figure 94. “Continue Simulation” and “Finish” button location.....	113
Figure 95. “Dispersion Module” button location in “Select Module to Apply” view	114
Figure 96. Download input excel file	114
Figure 97. Download QGIS software.....	115

Figure 98. Open QGIS software.....	115
Figure 99. Zoom in to your study area	116
Figure 100. Draw the buildings using QGIS software – Step 1.....	116
Figure 101. Draw the buildings using QGIS software – Step 2.....	117
Figure 102. Draw the buildings using QGIS software – Step 3.....	117
Figure 103. Draw the buildings using QGIS software – Step 4.....	118
Figure 104. Draw the buildings using QGIS software – Step 5.....	118
Figure 105. Add the buildings height information – Step 1	119
Figure 106. Add the buildings height information – Step 2	119
Figure 107. Add the buildings height information – Step 3	120
Figure 108. Add the buildings height information – Step 4	120
Figure 109. Get the coordinates of the vertices of the buildings – Step 1	120
Figure 110. Get the coordinates of the vertices of the buildings – Step 2	121
Figure 111. Get the coordinates of the vertices of the buildings – Step 3	121
Figure 112. Get the coordinates of the vertices of the buildings – Step 4	122
Figure 113. Re-project the “added geom info” file – Step 1	122
Figure 114. Re-project the “added geom info” file – Step 2	123
Figure 115. Re-project the “added geom info” file – Step 3	123
Figure 116. Re-project the “added geom info” file – Step 4	124
Figure 117. Re-project the “added geom info” file – Step 5	124
Figure 118. Re-project the “added geom info” file – Step 6	125
Figure 119. Re-project the “added geom info” file – Step 7	125
Figure 120. Copy the buildings coordinates to the “Input_preprocessors.xlsx” file – Step 1	126
Figure 121. Copy the buildings coordinates to the “Input_preprocessors.xlsx” file – Step 2	126

Figure 122. Treat the information for “roads” – Step 1.....	127
Figure 123. Treat the information for “roads” – Step 2.....	127
Figure 124. Selection of input file to upload.....	128
Figure 125. Module execution pre-screen.....	128
Figure 126. “Download”, “Continue Simulation” and “Finish” button location	129
Figure 127. “Health Module” button location in “Select Module to Apply” view.....	129
Figure 128. Selection box to generate input file.....	130
Figure 129. Selection of input file to upload.....	130
Figure 130. Input file content	131
Figure 131. “Download”, “Continue Simulation” and “Finish” button location	131
Figure 132. “My Outputs” description.....	132
Figure 133. Node file structure	133
Figure 134. Edge file structure	134
Figure 135. Edge file structure with bus and bike lane.....	135
Figure 136. Tll file structure	136
Figure 137. Bus file structure	137
Figure 138. Bus file structure with bus and bike lane.....	137
Figure 139. Conn file structure	138
Figure 140. vTypeDistribution structure	139
Figure 141. Flow structure	140
Figure 142. Add file structure	144
Figure 143. Real file Structure.....	145
Figure 144. Spatial file structure	146
Figure 145. Gdata file structure	147
Figure 146. Traffic file structure.....	148
Figure 147. Pattern file structure.....	150

Figure 148. Pattern file structure	151
Figure 149. Traffic file structure.....	152
Figure 150. Meteo file structure	153
Figure 151. Treviso study area	155
Figure 152. Noise detector position vs model	160
Figure 153. Comparison real data versus model results from Treviso	162
Figure 154. Vehicle type distribution in Treviso pilot area.	164
Figure 155. Hourly traffic load in Treviso pilot area.....	164
Figure 156. Comparison between the IMT and COPERT SL hourly results for carbon footprint emissions.....	165
Figure 157. Comparison between the IMT and COPERT SL hourly CO emissions.....	165
Figure 158. Comparison between the IMT and COPERT SL hourly NOx emissions	166
Figure 159. Comparison between the IMT and COPERT SL hourly PM emissions.....	166
Figure 160. Comparison between the IMT and COPERT SL hourly HC/VOC emissions	166
Figure 161. Percentage differences between IMT and COPERT SL daily simulation results.	167
Figure 162. Percentage differences between IMT and COPERT SL simulation results at the peak hour of traffic data (16:00-17:00).....	168
Figure 163: Mobility actions analysis. Conceptual scheme	169
Figure 164: Completing the information about the reference case	170
Figure 165: Comparison about the fuel consumption after simulating 3 different actions	170
Figure 166: Step 8: how to add a bus lane	172

Table of tables

Table 1. Vehicle type definition	11
Table 2. Vehicle flow definition	11
Table 3. Output power associated to a deceleration and acceleration period (first traffic light)	18
Table 4. Accumulate fuel consumption values over the driving cycle.....	19
Table 5: Variables of influence in the acoustical source model	23
Table 6 A-weighting correction according to IEC-61672-1	24
Table 7 Rolling noise coefficients per category of vehicle	25
Table 8 Propulsion noise coefficients per category	26
Table 9. Testing 1. Inputs.	34
Table 10. Testing 1. Results.....	35
Table 11. Testing 2. Inputs	35
Table 12. Testing 2. Results m2.....	35
Table 13. Testing 2. Results m3.....	35
Table 14. Testing 3. Inputs	36
Table 15. Testing 3. Results m4a.....	36
Table 16. Testing 3. Results m4b	36
Table 17. Testing 4. Inputs	37
Table 18. Testing 4. Results m4a.....	37
Table 19. Testing 4. Results m4b	37
Table 20. Testing 5. Inputs	37
Table 21. Testing 5. Results.....	38

Table 22. Testing 6. Inputs	38
Table 23. Testing 6. Results.....	38
Table 24. Comparing IMT module and Sumo. Testing Treviso	40
Table 25. Costs for CHD and Stroke	59
Table 26. Treviso zone description.....	155
Table 27. Treviso traffic data per direction per hour.....	157
Table 28. Noise level measurements per hour	158
Table 29. Noise model results.....	160
Table 30. Comparison real data versus model results from Treviso.....	161