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First Version of Micro-Simulator

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Executive Summary

Project and work package goals

SPEEDD will develop prototypes for proactive event-driven decision making and robust forecasting. The motivation for proactive computing stems from social and economic factors, and is based on the fact that prevention is often more active effective than cure. SPEEDD will contribute to the state of the art by:

1. Developing novel methods for real time event recognition and forecasting;
2. Providing innovative techniques for proactive event-driven decision-making;
3. Developing techniques for real-time visualization and explanation of large quantities of data.

WP8–Proactive Traffic Management Use Case–aims to forecast traffic congestions before they happen and to make decisions in order to attenuate them. Task 8.3 concerns the development of a microscopic simulator for the selected use-case, involving Grenoble peripheral and urban area.

Work presented in the deliverable

This document presents the first version of a micro-simulator for Grenoble area, which includes two significant portions of the area:

1. Grenoble South Ring, the 12km-long highway that is the main connection from South-West to North-East;
2. A sector of Grenoble downtown area, selected for being crucial for traffic and often affected by congestions.

The simulator is based on commercial software called Aimsun, and this deliverable describes how the Grenoble simulator has been produced using Aimsun tools.

How SPEEDD benefits from the work

The reason why this simulator is essential for SPEEDD is twofold. First, it will provide synthetic data for the urban area, for which detailed sensor data are not available. Second, it will enable testing proactive decision-making by allowing us to close the loop and see in real time the effect of decisions; clearly such tests need to be performed in simulation, so as to avoid perturbing real traffic for testing purposes.

Work to follow

- The portion of urban area in the simulator will be extended;
- An interface will be designed, to connect the micro-simulator of Grenoble with the SPEEDD architecture. Currently data can already be exported from Aimsun and be analyzed by partners, e.g., for event recognition. The interface with the SPEEDD prototype, which will allow for closed feedback loop from the decision making algorithms (or from humans), will be a feature to be developed in v2.

1. Introduction

1.1 History of the document

Version	Date	Author	Change Description
0.1	12/01/2015	Rohit Singhal (CNRS)	Set up the document
0.2	14/01/2015	Rohit Singhal (CNRS)	Main document
0.3	15/01/2015	Federica Garin (CNRS)	Minor changes
0.4	16/01/2015	Anton Andreev (CNRS)	Some adjustments
0.5	30/01/2015	F. Garin, A. Andreev (CNRS)	Addressing comments from reviewer
0.6	30/01/2015	Rohit Singhal (CNRS)	Output of simulator
0.7	31/01/2015	Anton Andreev (CNRS)	Output of simulator
1.0	31/01/2015	Federica Garin (CNRS)	Minor adjustments

1.2 Purpose and scope of the document

Context

Transportation and traffic congestion are crucial aspects of human civilization, especially starting from the second half of the last century when the latter became predominant due to the rapid increase in the number of vehicles. Traffic congestion results in excess delays, reduced safety, and increased environmental pollution. Traffic analysis and forecasting, necessary for a good management of transportation systems, require the analysis of massive data streams storming from various sensors, and this brings further difficult tasks (mainly about real-time processing of big quantities, geographically distributed and noisy data).

As a major tool for research on traffic estimation and control, CNRS is developing a simulator of Grenoble traffic. This is based on AIMSUN simulator for traffic systems. Version 1 of Grenoble simulator concerns two portions of the area: Grenoble South Ring, a 12km highway and a portion of Grenoble downtown which is particularly critical for traffic congestion.

Deliverable purpose

This document gives detailed information about the first version of the micro-simulator for Grenoble traffic.

1.3 Relationship with other documents

D8.2 is delivered at month 12th of the project, and describes a first version of a simulator; this is work in progress towards a final version due at month 24th (D8.4). This simulator is based on the scenario described in D8.1.

2. Micro-Simulator

2.1 AIMSUN simulator

The CNRS simulator of Grenoble town is based on AIMSUN (<http://www.aimsun.com/wp/>). CNRS is having legal license to use AIMSUN micro-simulator with professional edition, which covers all the functionalities of this software.

AIMSUN (www.aimsun.com) is a widely used commercial transport modeling software, developed and marketed by TSS- Transport Simulation Systems based in Barcelona, Spain. Microscopic simulators are the components of AIMSUN, which allow for dynamic simulations. They can deal with different traffic networks: urban networks, freeways, highways, ring roads, arterials and any combination.

The microscopic model simulates the movement of individual vehicles, based on statistical laws from car-following and lane-changing theories. Typically, vehicles enter a transportation network using a statistical distribution of arrivals. The microscopic model incorporates sub-models for acceleration, speed adaptation, lane-changing etc., to describe how vehicles move and interact with each other and with the infrastructure. This simulation is microscopic in the sense that it is at the individual car level (in analogy with simulations in physics at the molecules level), as opposed to macroscopic models which use a fluid-dynamic description of the traffic flow as a whole, with partial differential equations for flows and densities.

Aimsun provides the tools to carry out traffic operations assessment of any scale and complexity. The applications are many, some of the most common are:

- Impact analysis of infrastructure design such as highway corridor improvement/construction
- Evaluation of travel demand management (TDM) strategies
- Signal control plan optimisation (Aimsun-TRANSYT link) and adaptive control evaluation
- Evaluation of Variable Speed policies and other Intelligent Transportation Systems (ITS)

Even on a laptop, the Aimsun microsimulator can run a model of the whole town of Singapore with 10,580 intersections and 4,483 km of lanes 2-3 times faster than real time. High speed simulation makes it possible to:

- Simulate larger areas without leaving out problem zones
- Test a greater number of scenarios in the time available allowing for broader 'what if' analysis for a variety of traffic conditions
- Deal with time-critical situations

2.1.1 Input required by AIMSUN

The input data required by AIMSUN Dynamic simulators is a simulation scenario and a set of simulation parameters that define the experiment. The scenario is composed of three types of data:

a. *Network description*

The network is a collection of links connected to each other by nodes (intersections) and may have different traffic features. In order to build the network in AIMSUN, the user needs the following data:

1. Map of the area
2. Details of the number lanes for each section, reserved and side lanes.
3. Possible turning movement for every junction, including details about the lanes from which each turning is allowed and solid lines marked on the road surface.
4. Detectors

b. *Traffic control*

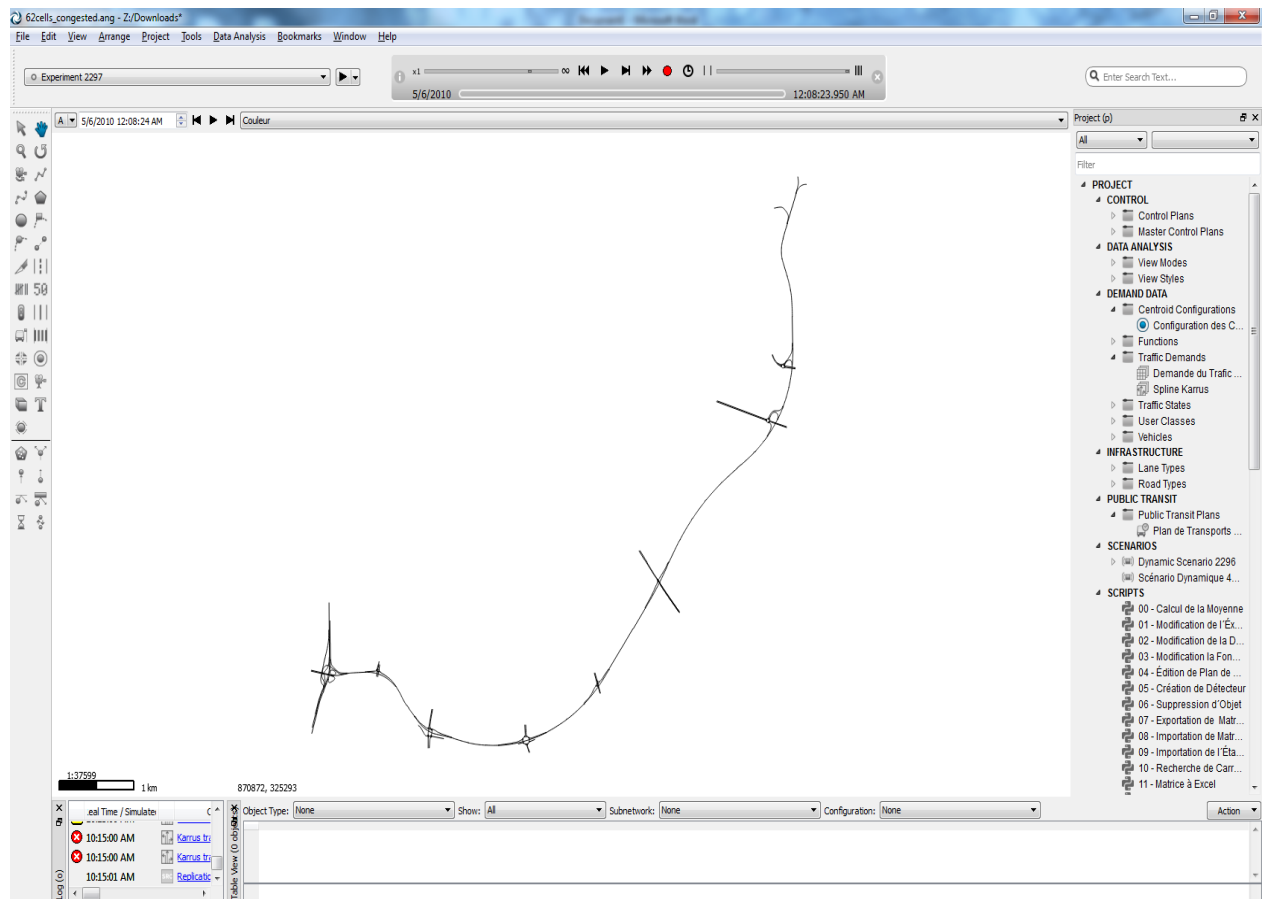
There are several types of traffic control taken into account by AIMSUN: signals, give-way signs and ramp meters. Traffic signals and give-way signs are used for junction nodes, while ramp meters is for sections that end at join node.

c. *Traffic demand data*

Traffic demand data in AIMSUN can be defined in two different ways, by the traffic flows at the sections or by an origin/destination (O/D) matrix. Several O/D matrices or Traffic states will be grouped into a traffic demand. The following data must be provided for those different types of traffic demand data:

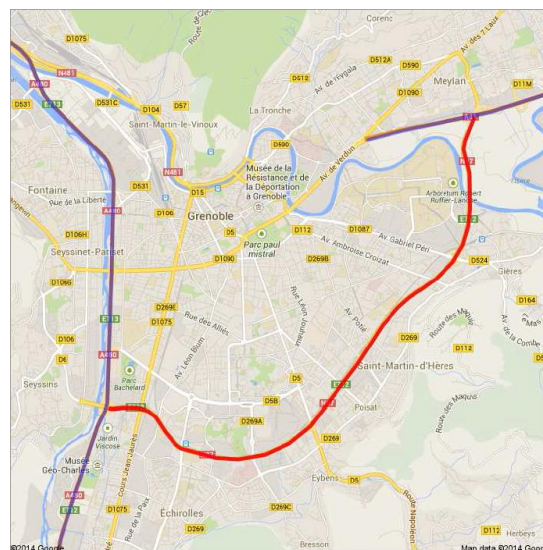
1. Traffic flows
 - a. Vehicle type and the attributes
 - b. Vehicle classes
 - c. Flow in the input section for each vehicle
 - d. Turning proportion at all section for each vehicle type
2. O/D Matrix
 - a. Centroids definition: traffic sources and sinks
 - b. Vehicle type and attributes
 - c. Vehicle classes
 - d. Number of trips going from every origin centroid to any destination one.

Figure 1 shows the screen for AIMSUN highway tool. In this screen, we can see the different tools available in the AIMSUN simulator for the developer.



[Figure: 1]

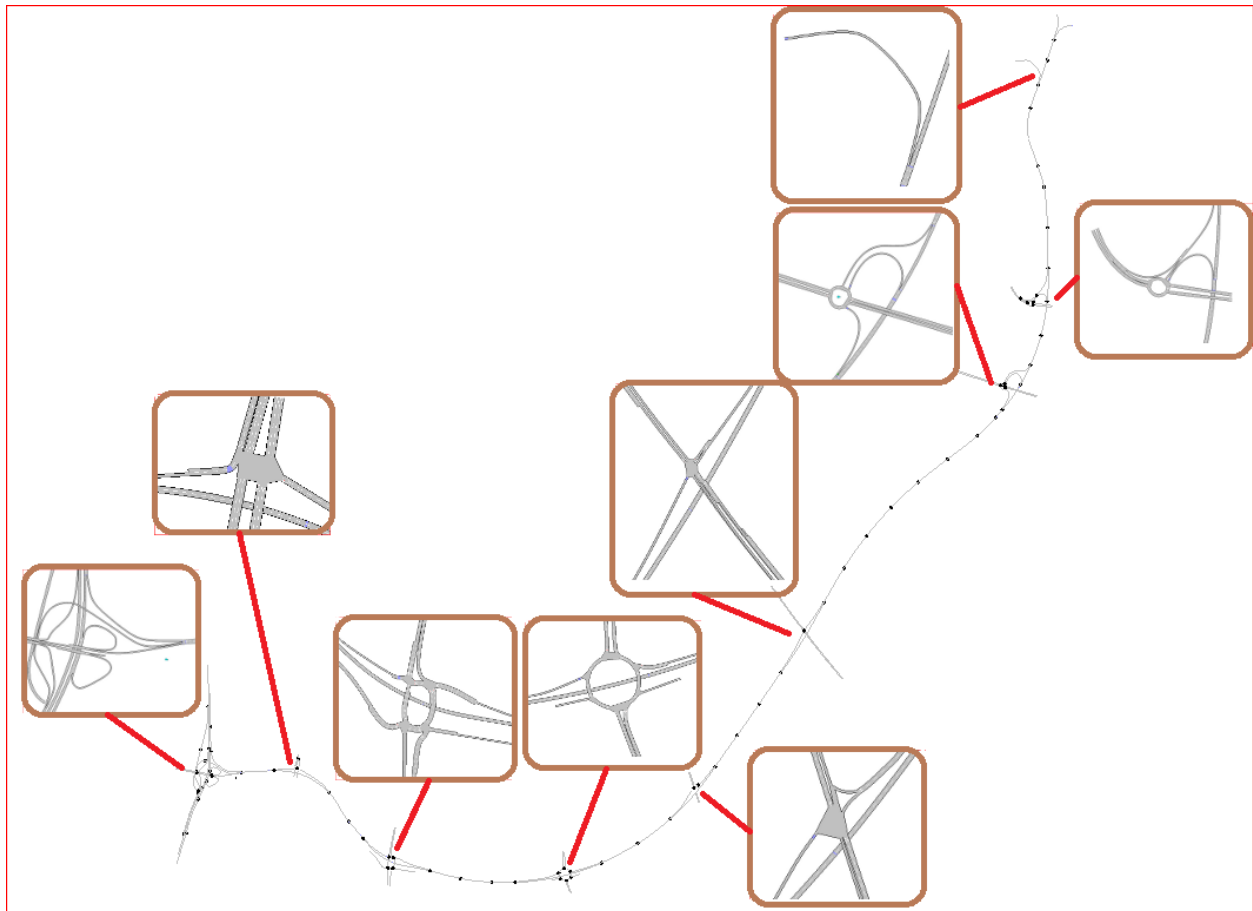
2.2 Grenoble South Ring simulator



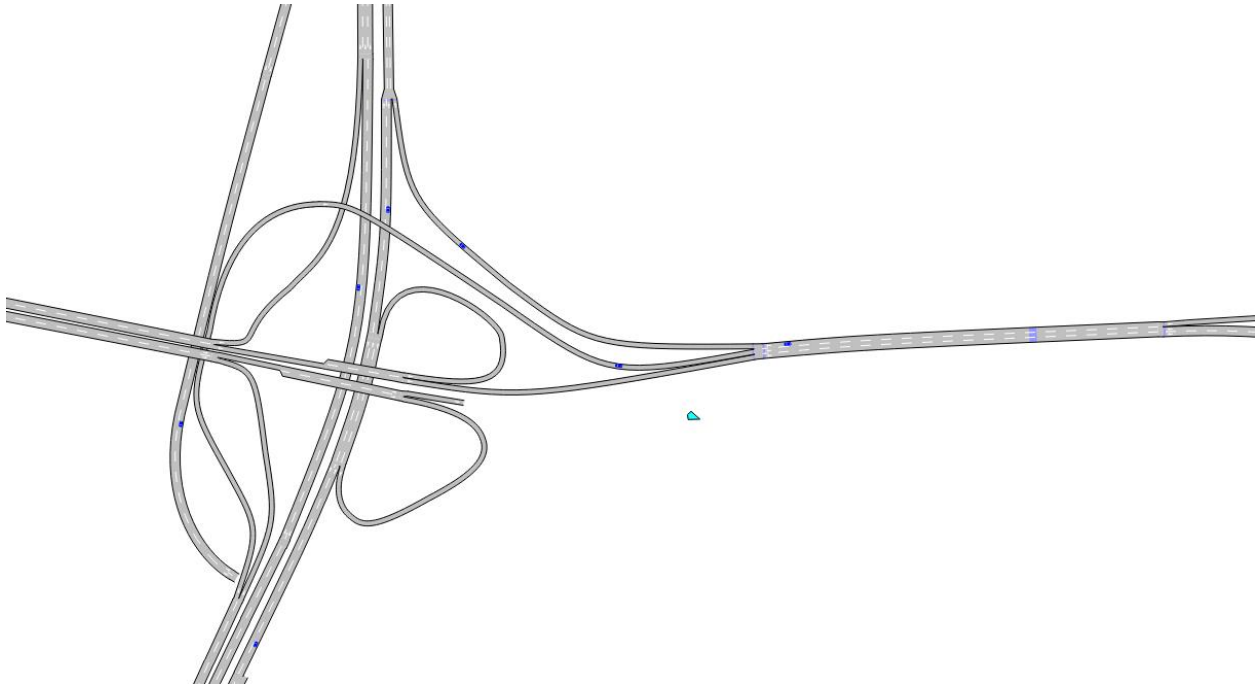
[Figure: 2]

Figure 2 shows a map of Grenoble South Ring, a highway which is 12 km long, and Figures 1 and 3 show the corresponding AIMSUN map. On this ring road, in the east-west direction, CNRS has a rich set of sensors providing real traffic data (Grenoble Traffic Lab, <http://necs.inrialpes.fr/pages/grenoble-traffic-lab.php>, also see Deliverable D8.1). CNRS has created an AIMSUN simulator model for the same east-west direction of the highway, with the purpose of testing control algorithms in a closed loop, which is not possible in the real-world setup.

To create this model, the first step has been to import a map, and also to make sure that all the road dimensions are correct, and that turns and directions of vehicles are correctly specified. Figure 3 shows a map of the road, with a zoom on some complex parts at intersections. Figure 4 shows the most complex part of this model, the “Rondeau”, where many turns and roads are intersecting and result in a complex highway. To create this type of model, extra caution had to be taken for size and turning angle of the road, so that the moving and flow of vehicles is realistic and smooth.



[Figure: 3]



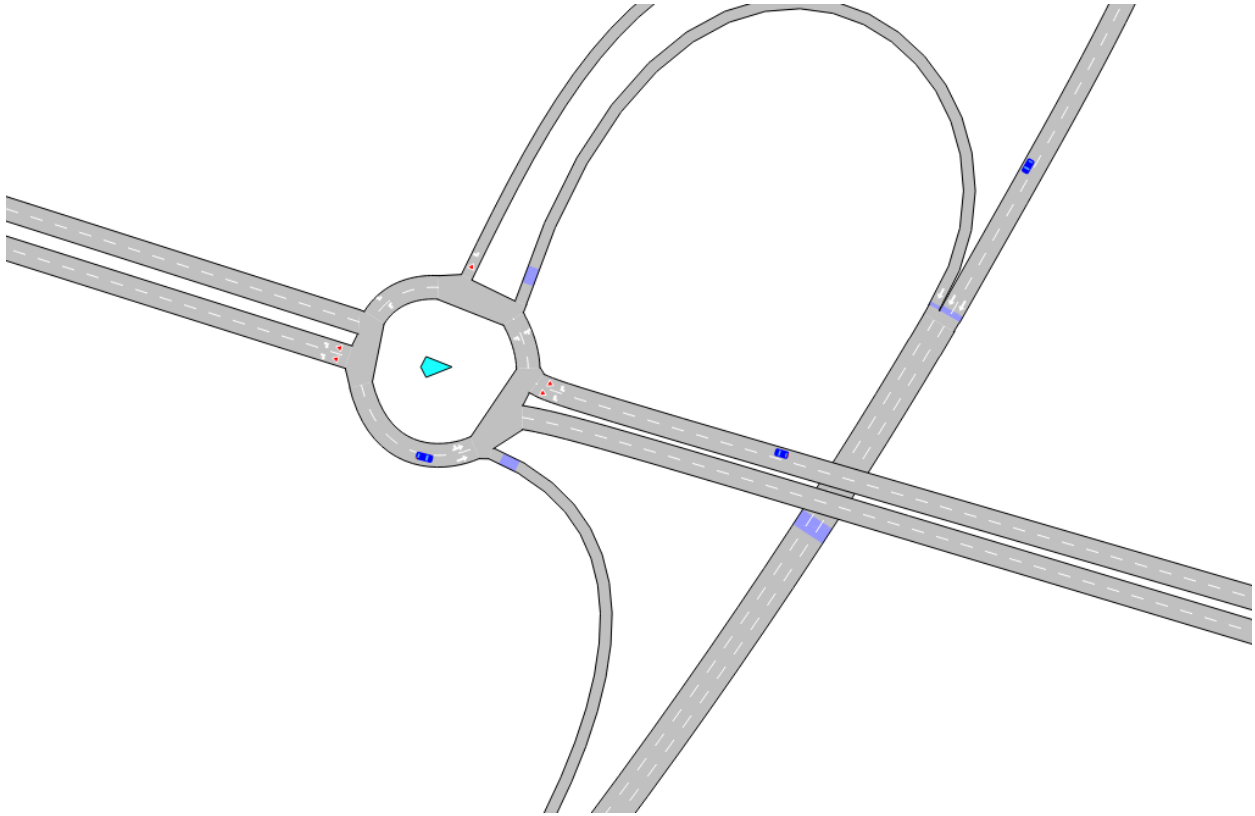
[Figure: 4]

As control tools, in addition to variable speed limits (whose panels are already available in the real highway, although currently not yet used for control purposes), ramp metering lights have been put in the simulator at some on-ramps. These lights currently do not exist on the real road, but they have been put in positions which are meaningful for a possible future implementation, in particular, because there is enough space on the ramp for accumulating a queue of vehicles.

We have also placed virtual sensors, namely, points where data is collected from AIMSUN, e.g., about flow and velocity. Such sensors have been placed in the same positions on the highway where real sensors from the Grenoble Traffic Lab are.

The parameter calibration has been done using data from real sensors, and using the traffic flow method, setting the flow demands on on-ramps to fit the measured ones, and setting other parameters such as the split ratio, the probability of change lane etc. to obtain flows and speeds matching measured data.

Figure 5 gives a screenshot of the visualization tool for the final simulator, where cars are displayed moving. The same figure also gives information about different roads and their direction, the small lines in blue color show the location of virtual sensors (which have been placed exactly in the same place as real sensors of Grenoble Traffic Lab). In this image we can see four different sensors, placed in different roads. Moreover, the red sign shows the give-way sign, i.e., the vehicles from this road need to give priority to the ones already inside the roundabout.

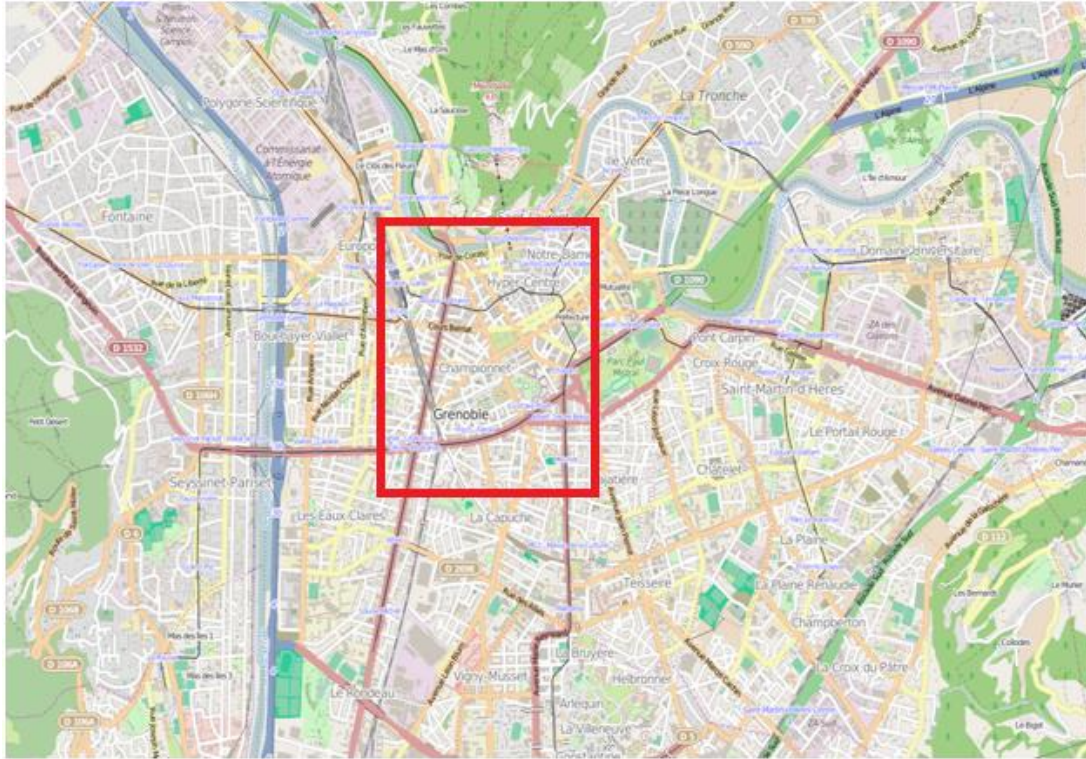


[Figure: 5]

2.3 Simulator of a portion of Grenoble urban area

This is the second part of AIMSUN simulator developed at CNRS, which considers the most congested and crowded part of downtown Grenoble city. This is a crucial part of the town because it both receives traffic to and from downtown (people going to work, shopping). It also includes many small roads and traffic from major roads connecting to highways. This was done in order to emulate big congestions in particular peak hours (i.e. mornings and evenings).

The map for Grenoble city is shown in Figure 6 (based on open street map), where the selected busy portion of town is highlighted. The corresponding AIMSUN map is shown in Figure 7.



[Figure: 6]



[Figure: 7]

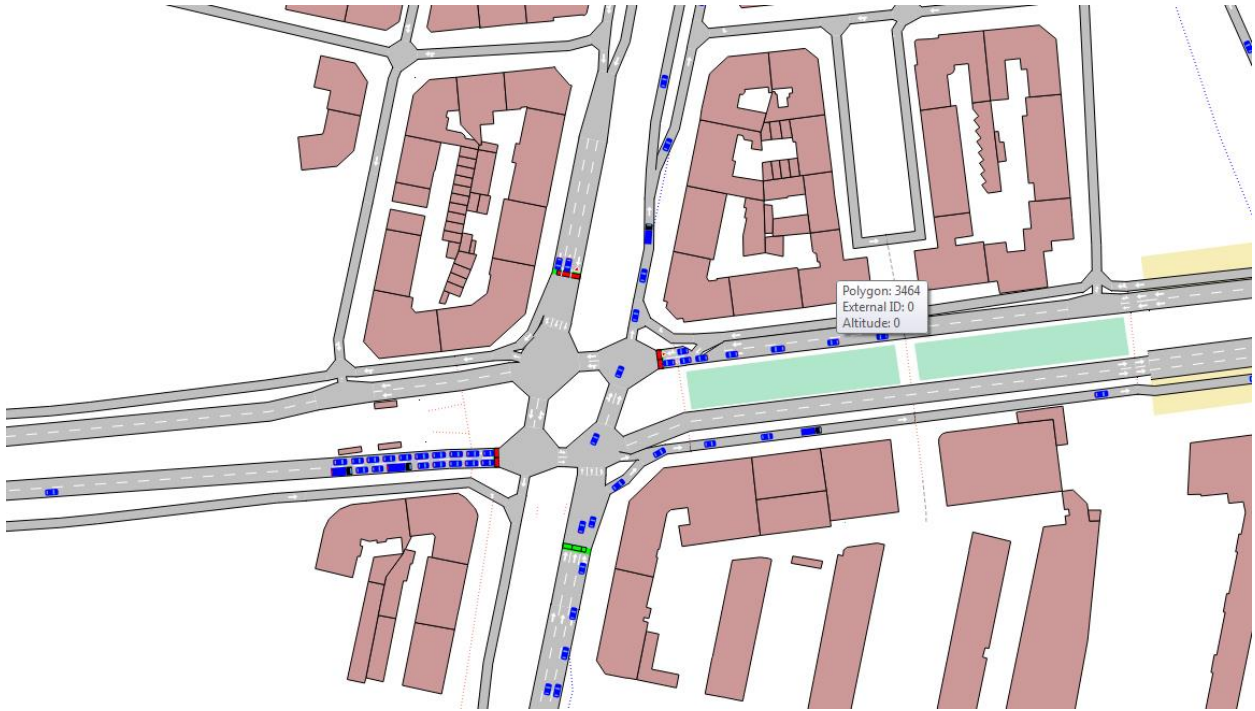
We have put a great amount of efforts in the form of many manual adjustments to produce a good and realistic map using the Open Street Map as a source and AIMSUN's tools. The map was optimized to be as efficient as possible. We have also encountered problems regarding: road turnings, road dimensions, intersection points and many more. Large amount of time was devoted to designing and implementing the roundabouts in the simulator in order to produce a map and realistic traffic that is to be expected by real life drivers regarding the main urban roads of the selected area of interest. Indeed, the latter are composed of several interconnected roads whose vehicles interact with each other as well as with traffic signalization.

Control tools in this urban scenario are traffic lights at intersections; we have manually added traffic lights at all major intersections, in a similar way to what already exists in Grenoble.

Concerning virtual sensors, they can be added wherever needed for the purpose of the simulation: differently from the South Ring, there is no particular reason to fix their location, since there are no real-world sensors whose position needs to be reproduced. As an example, we have started adding three virtual sensors.

Calibration has been done using an origin-destination matrix in such a way to generate realistic traffic patterns. We have used common sense and experience of drivers to define *origin* and *destination* points: points outside town, to represent incoming flow from surrounding areas, in particular of workers reaching their offices; main parking lots; some smaller parking lots in residential areas, etc. Origin-destination flows have been defined in such a way to reproduce a traffic flow which is qualitatively representative of the real one, namely, which shows similar congestion events as in reality.

The images below (Figures 8 to 11) show details of the simulator of the city, with screenshots of the AIMSUN visualization of the traffic flow. As we can see in the images, there are many intersection points, where traffic signals are set up with green and red line on the road. The vehicles are moving in blue color with commercial and public vehicles both taken into account. We have also considered the parking areas, where higher flow of vehicles is present. We have considered: schools, small roads near private residences and the private residences themselves.

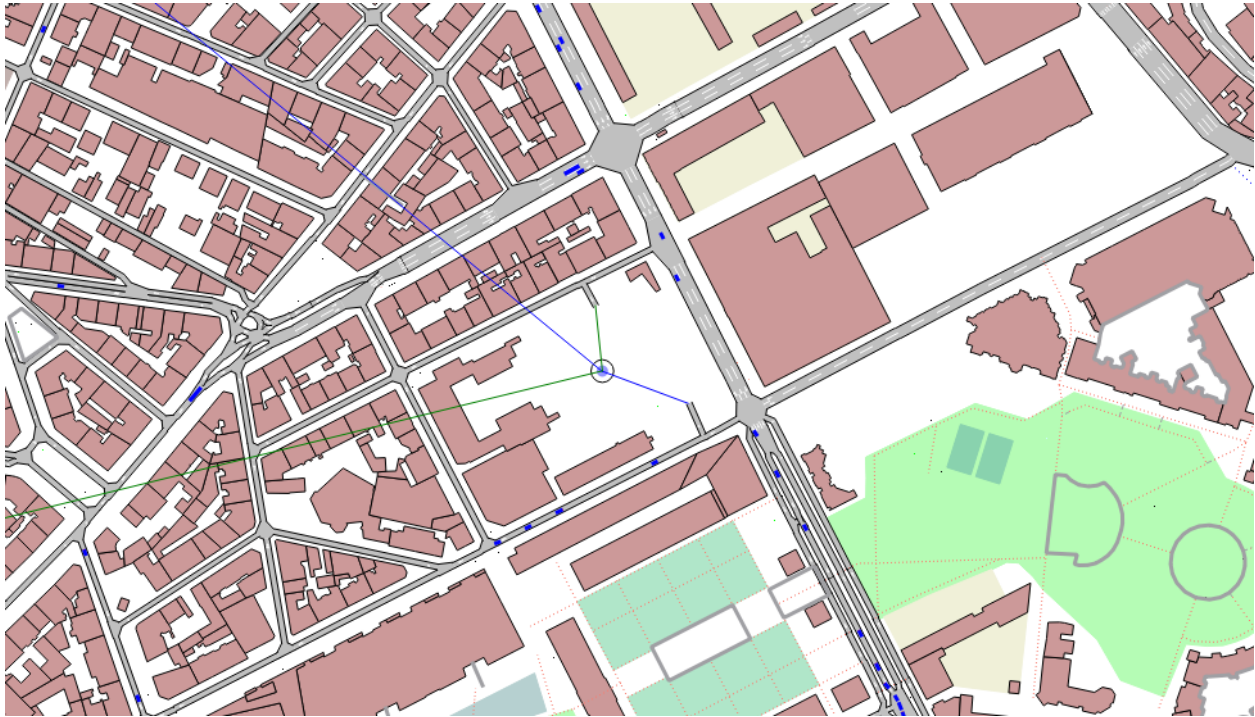


[Figure: 8]



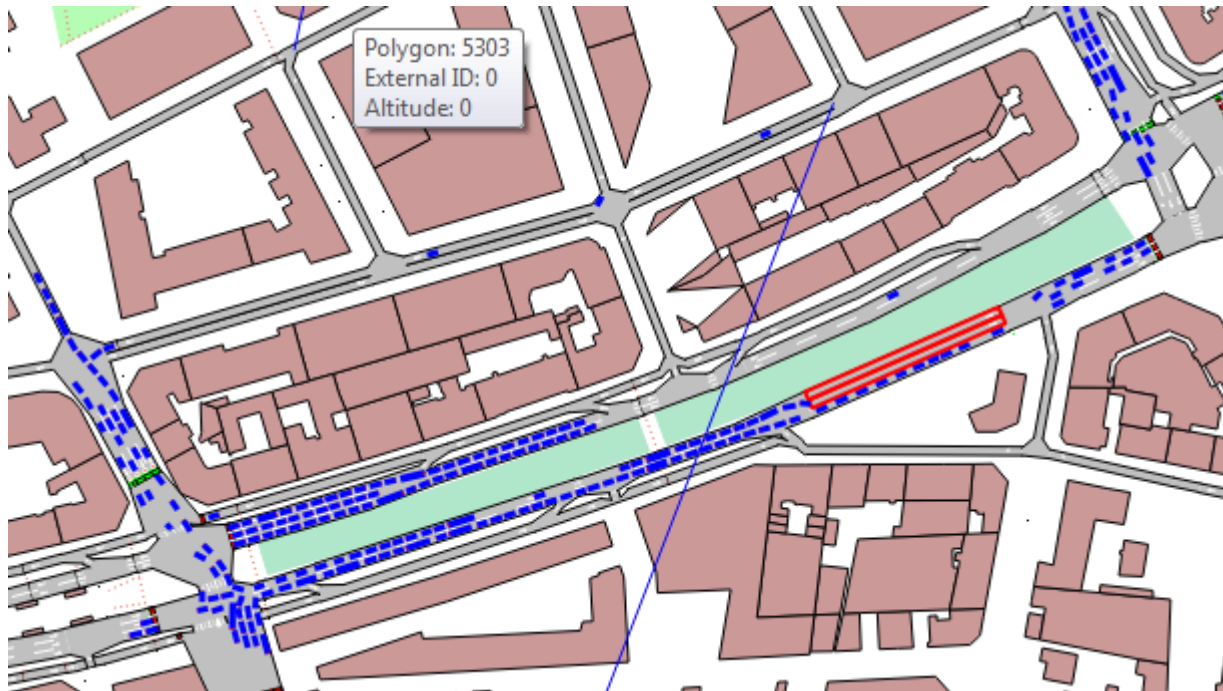
[Figure: 9]

Figure 10 shows a parking area, which has been designed as a “centroid” in AIMSUN, to define it as an origin and a destination of cars, so as to get a representative traffic flow towards and from it. It also shows the small roads which cover the private residences in Grenoble city.



[Figure: 10]

Figure 11 shows an example of congestion, due to both peak-hour traffic and a small accident affecting one lane. Note that the road width is reduced from two to one lane on a portion of a major road; the affected area is shown by a red rectangle in the figure



[Figure: 11]

2.4. Output from AIMSUN Micro-simulator

Data produced by the micro-simulator is in the following forms:

1. It is possible to obtain data concerning each individual vehicle, such as its position, speed, distance covered and path followed. This can be seen as a virtual sensor collecting gps data for each vehicle.
2. It is also possible to have readings similar to those of a sensor placed on the road infrastructure, that is collecting traffic data (i.e., traffic densities and flows) at a fixed position. Moreover, other grouped quantities can be obtained, such as number of vehicles entering or exiting a zone, or number of vehicles following a particular path.
3. Based on the output of the simulator it is possible to calculate other indicators: pollution, consumption of fuel, emission of carbon dioxide, etc.

The output of the micro-simulator can be visualized thanks to the AIMSUN tool, both in the form of a flow of vehicles moving in the city (a simulated video) or in a table form, as it is shown in Figures 12 and 13, or as relational database SQLite. The exported data can be loaded into Matlab by partners using the Matlab's *csvread* functions or it can be easily processed using the SQLite module of Matlab or alternatively using *sqlitebrowser* (<http://sourceforge.net/projects/sqlitebrowser>). Examples of exported data are shown in Figures 14 and 15.

Replication: 12079, Name: Replication

Main Network Summary Output Validation Path Assignment Enroute Paths					
	Waiting to Enter	Inside	Outside	Lost Inside	Lost Outside
All	1	418	331	0	0
Car	0	372	310	0	0
Truck	1	46	21	0	0

OK Cancel

[Figure: 12]

Simulation Vehicle: 10004533 (Temporary) (Layer: Primary)

Static Attributes Dynamic Attributes Path Attributes		
Attribute	Value	Units
Aimsun ID	589	
Vehicle Type	Car	
Arrival Time	08:04:09	
Has Been Enrouted	No	
Tracked	No	
Equipped	No	
Guidance Acceptance	100	%
Cooperation Degree	27.1086	%
Origin Centroid	12037: s3	
Destination Centroid	12028: s1	
Path Type	Route Choice Path	
Path	08:00:00 (1)	hh:mm:ss
Length	4.41145	m
Width	2	m
Maximum Acceleration Desired	2.93451	m/s ²
Deceleration Desired	-3.66131	m/s ²
Maximum Deceleration Desired	-5.81615	m/s ²
Mean Speed Desired	103.275	km/h
Speed Limit Acceptance	1.10701	
Minimum Distance Between Vehicles	0.764974	m
Maximum Give Way Time	10.0301	
Reaction Time	0.8	
Reaction Time at Stop	1.2	
Reaction Time at Traffic Light	1.6	
Vehicle Class	None	
Stay in Fast Lane	No	

[Figure: 13]

1	did	oid	ent	sectionId	xCoord	yCoord	timeSta	speed	travelledDistance	acceleration
2	12079	23	1	12017	713128.2	5006530.59	28811.2	55.87	8.82	0
3	12079	23	2	12017	713140.58	5006531.43	28812	55.87	21.24	0
4	12079	23	3	12017	713152.97	5006532.27	28812.8	55.87	33.66	0
5	12079	23	4	12017	713165.36	5006533.1	28813.6	55.87	46.07	0
6	12079	23	5	12017	713177.75	5006533.94	28814.4	55.87	58.49	0
7	12079	23	6	12017	713190.13	5006534.78	28815.2	55.87	70.9	0
8	12079	23	7	12017	713202.52	5006535.61	28816	55.87	83.32	0
9	12079	23	8	12017	713214.91	5006536.45	28816.8	55.87	95.73	0
10	12079	23	9	12017	713227.29	5006537.29	28817.6	55.87	108.15	0
11	12079	23	10	12017	713239.68	5006538.13	28818.4	55.87	120.56	0
12	12079	23	11	12017	713252.07	5006538.96	28819.2	55.87	132.98	0
13	12079	23	12	12017	713264.45	5006539.83	28820	55.87	145.39	0
14	12079	23	13	12017	713276.8	5006541.11	28820.8	55.87	157.81	0
15	12079	23	14	12017	713289.13	5006542.55	28821.6	55.87	170.22	0
16	12079	23	15	12017	713301.46	5006544	28822.4	55.87	182.64	0
17	12079	23	16	12017	713313.79	5006545.45	28823.2	55.87	195.06	0
18	12079	23	17	12017	713326.12	5006546.9	28824	55.87	207.47	0
19	12079	23	18	12017	713338.48	5006548.01	28824.8	55.83	219.88	-0.01
20	12079	23	19	4808	713350.85	5006548.99	28825.6	55.83	232.29	0
21	12079	23	20	4808	713362.6	5006549.96	28826.4	50.32	244.08	-1.91
22	12079	23	21	4808	713373.14	5006550.83	28827.2	44.8	254.65	-1.91
23	12079	23	22	4808	713382.45	5006551.59	28828	39.29	263.99	-1.91
24	12079	23	23	4808	713390.54	5006552.26	28828.8	33.78	272.11	-1.91
25	12079	23	24	4808	713396.96	5006550.15	28829.6	29.34	279.13	-1.54
26	12079	23	25	4808	713402.67	5006547	28830.4	29.34	285.65	0
27	12079	23	26	5558	713406.55	5006536.05	28832	29.34	298.68	0
28	12079	23	27	5558	713404.98	5006527.84	28832.8	37.64	307.05	2.88
29	12079	23	28	5558	713403.13	5006518.22	28833.6	44.07	316.84	2.23
30	12079	23	29	5558	713400.95	5006507.65	28834.4	48.56	327.63	1.56
31	12079	23	30	5558	713398.63	5006496.45	28835.2	51.48	339.07	1.01

[Figure: 14]

Figure 14 shows an example of data exported from AIMSUN for the individual vehicles locations, i.e., data that can be interpreted as a virtual sensor simulating a gps placed in the car. The table gives information about location of vehicles, speed, travelled distance and acceleration of each vehicle for a particular timestamp and section of the road. Columns “xCoord” and “yCoord” represent the X and Y co-ordinates of each vehicle. These co-ordinates are in standard UTM format. Each vehicle has its own identifier in column “oid”. A road in AIMSUN consists of sections. Each section has an index (column “ent”) related to the vehicle path and an exact identifier (column “sectionid”). “Acceleration” column can be negative and in this case it is deceleration.

1	did	oid	eid	sid	ent	countv	countt	flow	flow_D	speed	speed_D	occupancy	occupancy_D	density	density_D	headway	headway_D
2	12079	12700	Sensor-2	0	1	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
3	12079	12701	Sensor-3	0	1	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
4	12079	12703	Sensor-1	0	1	1	-1	240	-1	55.41582	-1	3.525961	-1	4.273908	-1	-1	-1
5	12079	12700	Sensor-2	1	1	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
6	12079	12701	Sensor-3	1	1	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
7	12079	12703	Sensor-1	1	1	1	-1	240	-1	55.41582	-1	3.525961	-1	4.273908	-1	-1	-1
8	12079	12700	Sensor-2	2	1	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
9	12079	12701	Sensor-3	2	1	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
10	12079	12703	Sensor-1	2	1	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
11	12079	12700	Sensor-2	0	2	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
12	12079	12701	Sensor-3	0	2	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
13	12079	12703	Sensor-1	0	2	3	-1	720	-1	53.8901	-1	10.69514	-1	12.33688	-1	4.414449	-1
14	12079	12700	Sensor-2	1	2	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
15	12079	12701	Sensor-3	1	2	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
16	12079	12703	Sensor-1	1	2	3	-1	720	-1	53.8901	-1	10.69514	-1	12.33688	-1	4.414449	-1
17	12079	12700	Sensor-2	2	2	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
18	12079	12701	Sensor-3	2	2	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
19	12079	12703	Sensor-1	2	2	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
20	12079	12700	Sensor-2	0	3	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
21	12079	12701	Sensor-3	0	3	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
22	12079	12703	Sensor-1	0	3	2	-1	480	-1	54.25145	-1	7.180911	-1	8.736336	-1	2.951555	-1
23	12079	12700	Sensor-2	1	3	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
24	12079	12701	Sensor-3	1	3	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
25	12079	12703	Sensor-1	1	3	2	-1	480	-1	54.25145	-1	7.180911	-1	8.736336	-1	2.951555	-1
26	12079	12700	Sensor-2	2	3	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
27	12079	12701	Sensor-3	2	3	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
28	12079	12703	Sensor-1	2	3	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
29	12079	12700	Sensor-2	0	4	0	-1	0	-1	-1	-1	0	-1	0	-1	-1	-1
30	12079	12701	Sensor-3	0	4	3	-1	720	-1	56.91246	-1	11.08334	-1	12.99711	-1	0.779375	-1
31	12079	12703	Sensor-1	0	4	4	-1	960	-1	52.87468	-1	14.3734	-1	16.89318	-1	3.280399	-1

[Figure: 15]

Figure 15 shows the output data exported from AIMSUN for the virtual sensors placed in the simulator, representing a sensor placed in the road, similar to the real sensors that Grenoble Traffic Lab has on the South Ring. There are many attributes which we are receiving in this type of output, but mainly: vehicle count (column “countveh”), occupancy, density, headway, etc. The suffix “D” for each field shows the Standard deviation for that particular field. This table also gives a list of sensors names (column “eid”) and types of vehicles (column “sid”) used in the simulation. Types can be: all, only cars and only trucks. Column “ent” is for time intervals.

Currently, an API prepared by CNRS, allows to interface AIMSUN with MATLAB: the collected data from the virtual sensors on the Grenoble South Ring simulator are provided to MATLAB, and vice-versa, control laws from MATLAB can command speed limits or traffic lights in the simulator.

An interface with the SPEEDD prototype and AIMSUN is planned as future work, where we will be developing C++ AIMSUN Micro API, which can provide us data directly into the SPEEDD protocol and even perform the control part by passing events into AIMSUN for real-time changes.

3. Conclusion

This document describes the first version the micro-simulator, based on AIMSUN commercial software, and the stumbling blocks that needed to be overcome in order to develop the simulator. This first version includes two significant portions of the town: Grenoble Rocade Sud (South Ring Road) highway and a portion of downtown Grenoble.

A second and last version of the micro-simulator will be Deliverable D8.4, due on month 24th of the project.