LuST: a 24-hour Scenario of Luxembourg City for SUMO Traffic simulations

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1.1 Abstract

Various vehicular communities ranging from telecommunication to infrastructure are working on problems related to traffic congestion, intelligent transportation systems, and mobility patterns using information collected from a variety of sensors. In order to test the solutions, the first step is to use a vehicular traffic simulator and an appropriate scenario. Many mobility simulators are available, but a common problem is finding a realistic traffic scenario. The aim of this work is to provide a scenario able to meet all the common requirements in terms of size, realism and duration, in order to have a common basis for the evaluations. In the interest of building a realistic scenario, we decided to start from a real city with a standard topology common in mid-size European cities, and real information concerning traffic demands and mobility patterns. In this paper we show the process used to build the Luxembourg SUMO Traffic (LuST) Scenario, and present a summary of its characteristics together with an overview of its possible uses.

Keywords: Vehicle-to-X Simulation, Infrastructure-to-X Simulation, Scenario Generation.

1.2 Introduction

This Many vehicular communities are working in a variety of areas that range from crowd-sourcing of information to safety applications. They are also making structural studies concerning infrastructure communications, traffic light systems, and more generally intelligent transportation systems. In order to study mobility patterns, traffic congestion or new communication protocols, we need a vehicular traffic simulator and an appropriate scenario to evaluate new proposals. For the vehicular networking community, the behaviour of the single vehicle is usually important and needs to be modelled. For this reason a microscopic mobility simulator is generally chosen. In our case, we chose the Simulator of Urban MObility (SUMO) [1]. In this context, the common problem that we must face is the lack of properly-working and freely-available scenarios for the community.

In 2014, during the SUMO User Conference, realistic traffic scenarios from the city of Bologna [2] were released to the community. The scenarios, built in the iTETRIS [3] framework, give a very good starting point for the community, but they present some limitations such as the traffic demand, which is only defined over one hour; also, the size of the scenario is relatively small. Alternatively, the SUMO community provides the TAPASCologne[1] scenario package, which includes road networks imported from OpenStreetMaps (OSM) [4] and the traffic demand for the period between 6:00 and 8:00 in the morning. Unfortunately this scenario is

[1] This scenario can be found at http://sumo.dlr.de/wiki/Data/Scenarios/TAPASCologne.

usable only with difficulty, requiring a lot of work to be done to improve the network quality, and to verify how routes are mapped onto both the network and the traffic demand.

In order to focus on car-to-X problems and solutions, the community needs a scenario that fulfils the following requirements: (1) It has to be able to support different kinds of traffic demand such as congested or free-flow patterns. (2) It should support different scenario dimensions. (3) It has to include different road categories (e.g. residential, arterial and highway). (4) It should allow multi-modal evaluations. (5) Is should describe a realistic traffic scenario over one day (i.e. avoid gridlocks and teleportations[2]).

Due to the lack of scenarios that meet all these requirements, the usual approach is to build a simple scenario that fulfils the purpose of the application. This approach results in several problems that are well known to the community, the most prominent being the lack of repeatable experiments allowing the comparison of different solutions or approaches to solving the same problem. Another problem that may be encountered is the specificity of the scenario and the consequent lack of generalization or realism.

We decided to use the road network of a real city as basis for our scenario in order to reproduce real traffic demand and mobility patterns. We chose the City of Luxembourg because its topology is comparable to that of many of European cities and because we have access to its traffic statistics.

In this paper we present the process used to build the Luxembourg SUMO Traffic (LuST) Scenario, a summary of its characteristics and an overview of its possible uses.

1.3 LuST Scenario

Topology. In order to create a realistic scenario we decided to start from a real mid-sized European city. The topology of European cities consists of a central downtown area, surrounded by all its different neighbourhoods, which are linked by arterial roads [5]. Another important characteristic is the presence of a highway in the outskirts that surrounds the city. The size of the city is another very important property: the scenario must be big enough to show the standard congestion pattern visible in modern cities, but it must be small enough to permit simulations in a reasonable amount of time. The City of Luxembourg meets these requirements.

After choosing the city, we used OpenStreetMap (OSM) to extract its road topology. An OSM file contains all the necessary information about the environment and is trustworthy [6]. We used JOSM[3] to extract and manually select and change points of interest and road segments. In this phase we returned information about roads (of any kind), traffic light, locations and names of bus stops, and we also saved information about schools (i.e. location and kind) to be used in the activity generation process.

As the aim of this scenario is to have a working SUMO simulation, all the intersections were checked manually for correctness using an iterative process with JOSM, netconvert[4] and SUMO to ensure that they did not represent an unrealistic bottleneck for the traffic flows.

To provide more flexibility, we decided not to impose any vehicle restrictions on any edge or lane. In order to maintain the traffic patterns close to reality, we modified the number of

[2] In SUMO a teleport occurs when a vehicle is blocked for too long in front of an intersection or collided with another vehicle.

[3] The JOSM Editor is available at https://josm.openstreetmap.de/

[4] See the netconvert wiki page at http://sumo.dlr.de/wiki/NETCONVERT

lanes in some segments of the roads. We tried to standardise the roads in order to obtain a scenario that could easily be modified in the future.

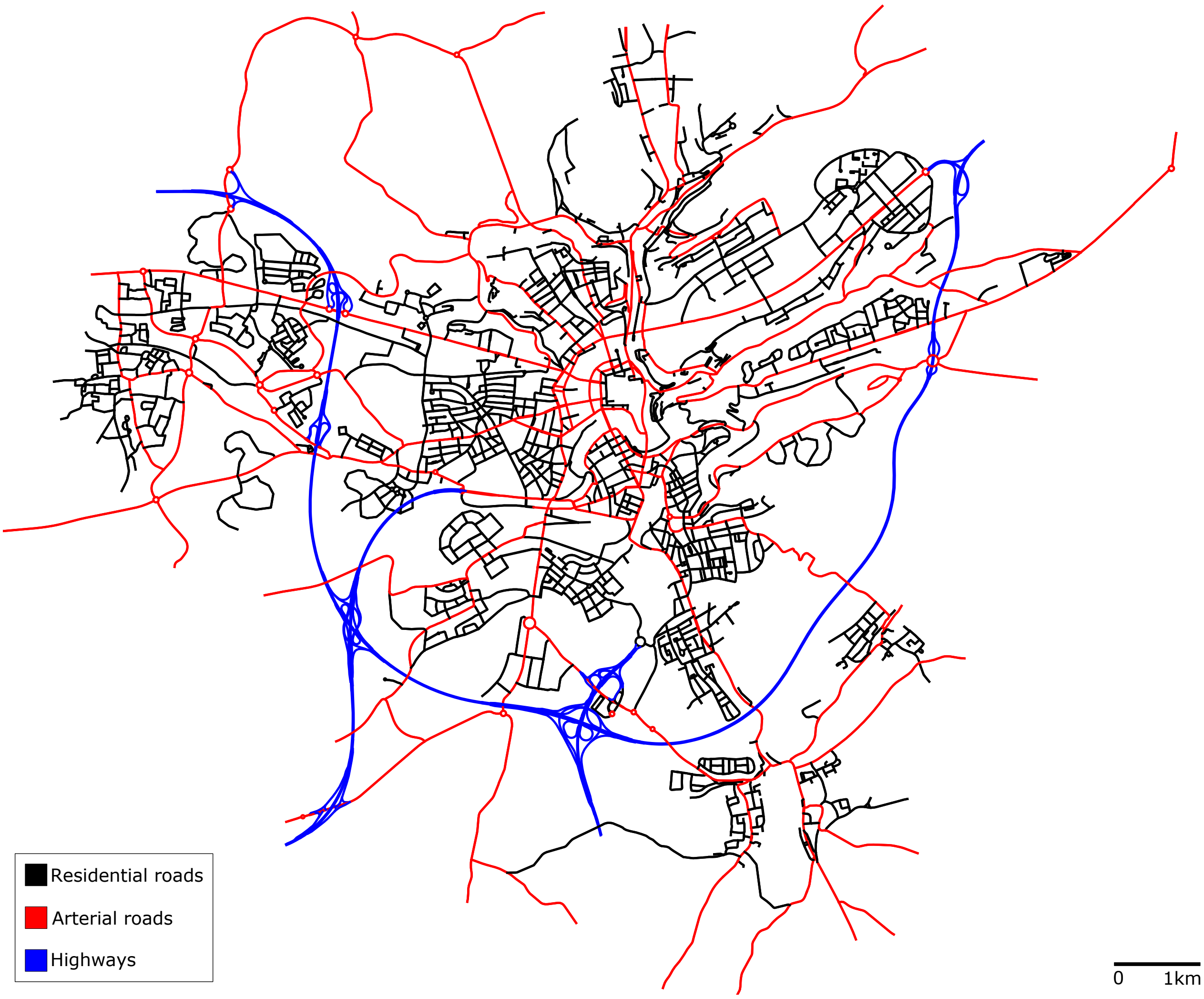

Figure 1-1: LuST Scenario Topology.

Figure 1 shows the topology of the LuST Scenario, with streets coloured by type. The highway is depicted in blue, the main arterial roads in red and the residential roads in black. The static information contained in the **net.xml** file is summarised in Tables 1a and 1b. The scenario covers an area of almost 156 km^2 with a total of 931 km of roads of different types. In the SUMO network file an edge is defined as a segment between two nodes, it may have a shape, and it is divided in one or more lanes.

Demographics. In order to achieve realistic traffic patterns we used the data published by the government, which is available on the Internet site of the Luxembourg National Institute of Statistics and Economic studies (STATEC[5]) (e.g. population, age distribution) to generate the activity demand for the ACTIVITYGEN[6] tool. The activity demand required by the tool must contain information concerning schools, workplaces and residential areas. All of these are retrieved from OSM and STATEC.

[5] The STATEC internet site is https://www.statistiques.public.lu

[6] See the ACTIVITYGEN wiki page at http://sumo.dlr.de/wiki/ACTIVITYGEN

Table 1-2a: LuST Scenario in numbers. Topology information.

Topology	
Area	155.95 km^2
Total nodes	2,376
Total edges	5,969
Total length edges	931.11 km
Total length lanes	1,571.4 km
Edges with 1 lane	3,944
Edges with 2 lanes	1,188
Edges with 3 lanes	764
Edges with 4 lanes	78

Table 1-1b: LuST Scenario in numbers. Intersections information.

Intersections	
Roundabouts	39
Total junctions	4,341
Traffic lights	203
Unregulated	16
Priority	1,914
Internal	1,969
Dead end	239

Mobility. We used a mobility study that describes traffic characteristics over recent years[7]. Based on this report we decided to tune the traffic demand around 140,000 vehicles per day. The public transport database was used to retrieve the information about bus routes[8]. A total of 563 bus stops was added to the scenario. As shown in Table 2, we added 38 bus routes inside the city for a total of 2,336 night and day bus movements per day. The location of the bus stops in the LuST Scenario is not the same as the one in the OSM file, although we tried to keep it as close as possible. For this reason, we had to rebuild the bus routes to match the new bus stop locations. Figure 2 shows an intersection located in the city centre; the yellow squares are the inductive loops positioned 5m [7] from the intersection and the green boxes annotated with an H are the bus stops. We positioned the inductive loops at every intersection with a traffic light, on the highway, and on the on and off ramps (see Table 3). We fixed the location of each inductive loop close to the intersection to allow dynamic adjustments of the traffic light system using the information provided by the detectors.

Table 1-2: Bus information.

Buses	
Number of lines	38
Bus stops	563
Buses per day	2,336

[7] The LuxTram Internet site is https://www.luxtram.lu

[8] The Mobility Internet site is https://www.mobiliteit.lu

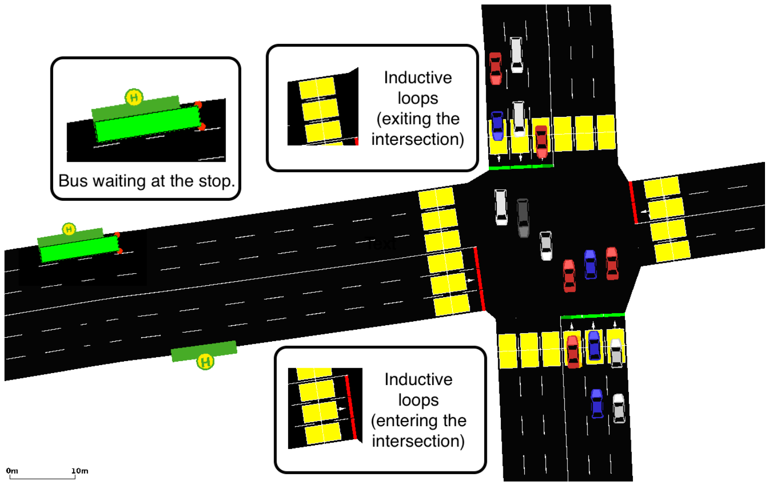

Figure 1-2: Intersection with bus and inductive loops.

Table 1-3: Inducrive loop information.

Inductive Loops	
Total number	3,161
Highways	94
Highway ramps	225
Intersections	2,842

Traffic demand. The ACTIVITYGEN tool utilises the definition of a network and the description of the population. It uses an activity-based traffic model that relies on a multi-modal trip planner including buses, cars, bicycles and pedestrians to derive the daily activities such as work, school, and free time. The output represents the traffic demand for the scenario. We separated the routes provided by the tools between vehicles and buses and optimised them using the SUMO **duarouter** tool. In order to allow the buses to wait at each stop, we added the **stop tag** to the routes proposed by ACTIVITYGEN.

Table 1-4a: LuST Scenario simulation in numbers: SUMO simulation short report.

Simulation Information		
	Total	Percentage
Inserted vehicles	138,361	
Teleports	39	0.0282
Collisions	3	0.0022
Jam	5	0.0036
Yield	10	0.0072
Wrong lane	21	0.0152
Emergency stops	7	0.0051

The short report provided by SUMO at the end of the simulation is shown in Table 4a. In the percentage column we see that all the issues (e.g. teleportation, collisions, emergency stops, etc.) that may be experienced by a vehicle during the simulation are lower than 0.05%, allowing us to assume that the scenario is running smoothly without bottlenecks and gridlocks. The traffic demand over the entire day is depicted in Figure 3. We can clearly see the morning rush hour peak at 08:00. Two smaller peaks are visible around lunchtime and in the evening, this being typical for city traffic scenarios. Figures 5a and 5b show respectively the traffic situation in the city centre during morning and evening rush hours.

Table 1-4b: LuST Scenario simulation in numbers: SUMO trip information report.

	Trip Information	
	Total	Average
Total vehicles	138,259	
Departure delays [s]	9,101,390	65.81
Waiting time [s]	39,744,745	287.47
Travel time [s]	98,070,337	709.32
Travel length [km]	1,016,033.78	7.35
Vehicle travel speed [m/s]		10.36

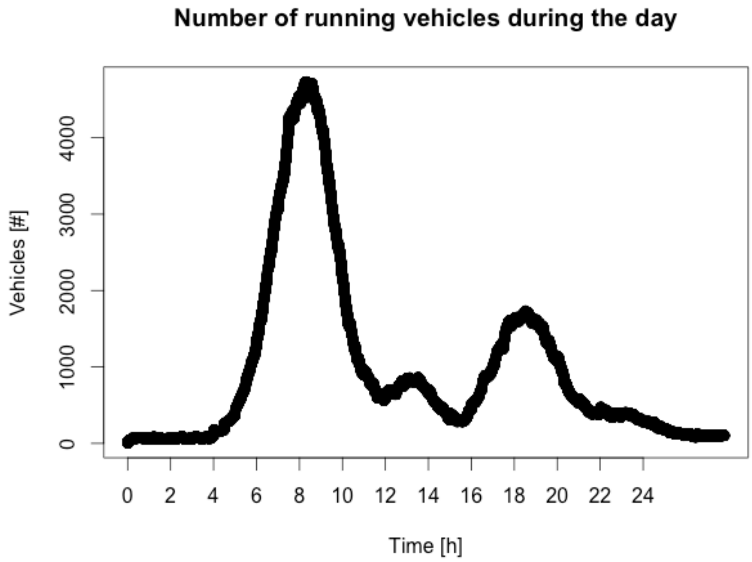

Figure 1-3: Traffic Demand over a day.

In Table 4b we present the data processed from the tripinfo.xml file. Here we see that the average length of a trip is around 7 km and that the average vehicle speed is around 10 m/s. Figure 4 present the distribution of average speed of each trip. In a mid-size city like Luxembourg, the average time required to move from a neighbourhood to the city center is around 10 minutes and this value is respected in the simulation.

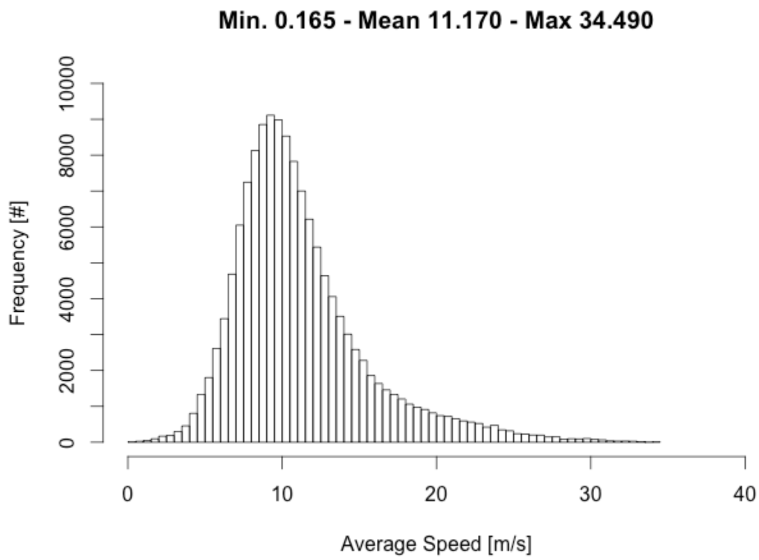

Figure 1-4: Distribution of average speed of the trips.

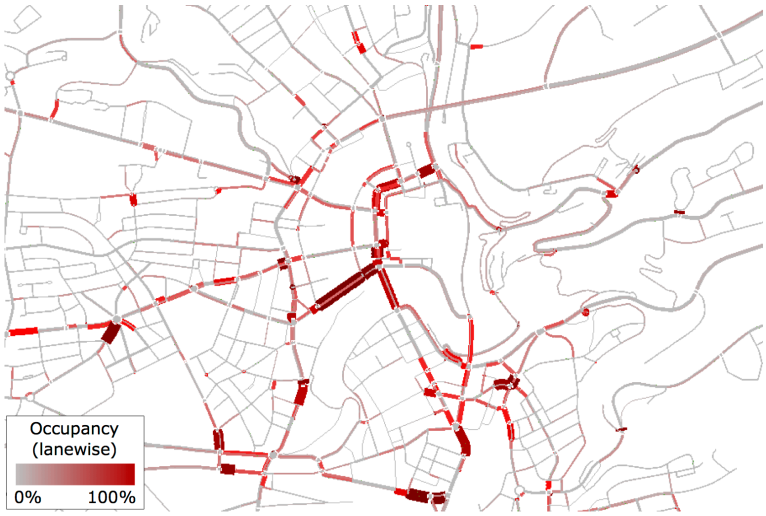

Figure 1-5a: Street occupancy (lanewise) during morning and evening rush hours. Morning rush hour (8:00).

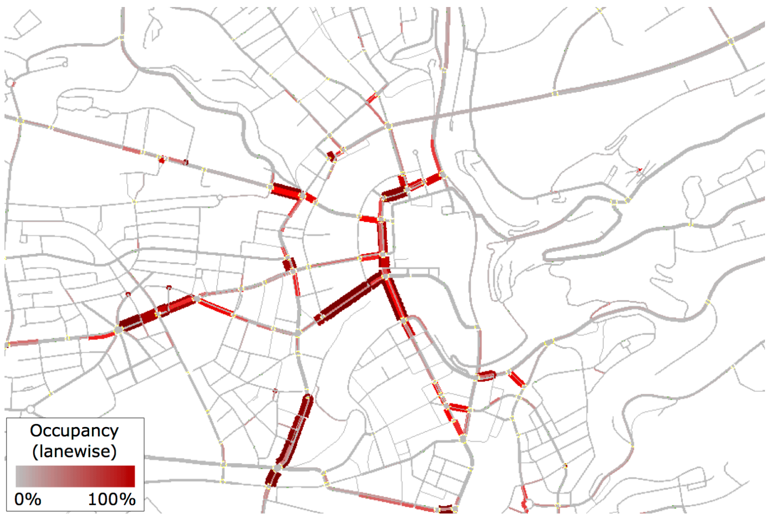

Figure 1-5b: Street occupancy (lanewise) during morning and evening rush hours. Evening rush hour (18:00).

Buildings. In order to use the scenario with other network simulator such as NS3 [8] or OMNet++ [9] it is necessary to have information regarding the shape and position of the buildings. The information is extracted from OpenStreet Map and refined with JOSM to match the modified network topology. Table 5 summarize the polygons imported in the scenario. We decided to have only two different categories of polygons for the moment, the parking lots and everything else (ranged from apartments, houses and construction sites). In Figure 6 is possible to see the location of the buildings (in red) and the parking lots (in grey).

Table 1-5: Polygons information in the LuST Scenario.

Polygons	
Total	14,173
Buildings	13,555
Parking lots	618

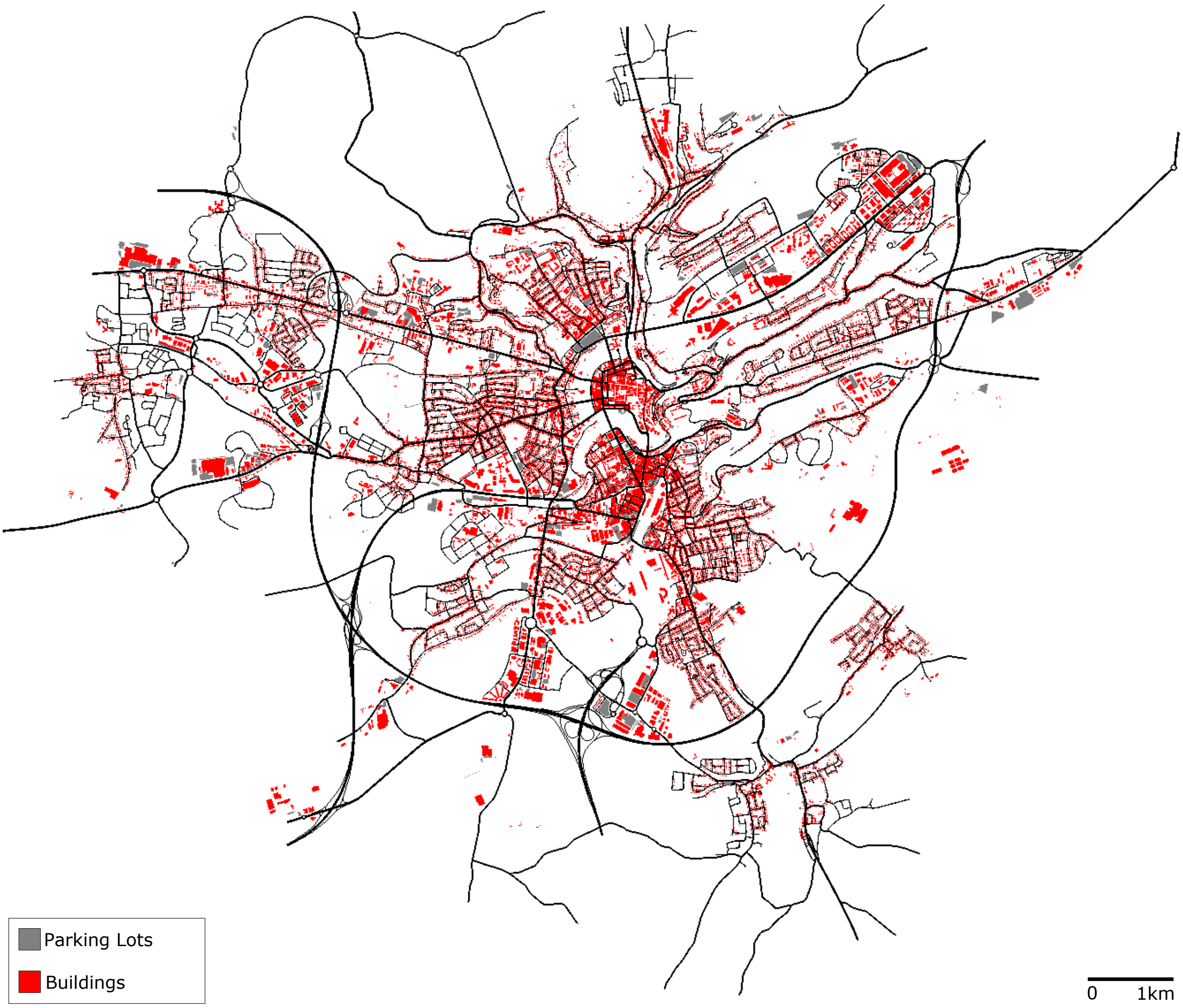

Figure 1-6: Buildings and parking lots information in the LuST Scenario.

1.4 Use Cases

The LuST Scenario is a framework that provides realistic mobility patterns in a mid-size city. The mobility provided by this scenario can be used as an input for other types of simulators such as NS3 or OMNet++ in order to investigate network protocols. When the evaluation of a proposal requires the interaction between a traffic simulator and a connectivity simulator, it is possible to use the LuST Scenario in association with VEINS [10] to obtain a closed- loop feedback between SUMO and OMNet++. Using LuST in combination with those tools allows study of both the performance of VANET protocols and of related applications. Further, it allows evaluation of different multi-modal strategies for commuters. Using the SUMO toolset it is possible to simulate smaller traffic scenarios that only use a subset of the available road network, allowing testing of protocols and applications on different scales. Among the features provided by SUMO there is the possibility of providing an on-board routing system for the vehicles. In our case, we decided to provide to the 70% of the vehicles this routing mechanism, since the commuters are used to checking traffic information and are likely to modify their route when there is a serious congestion ahead. Using this on-board system, it is possible to change the percentage of cars that react to surrounding congestion, obtaining scenarios with different levels of congestion to test different routing strategies. In our urban area there are 203 intersections managed by the traffic light system. These intersections can be used to test optimisation algorithms for a main arterial road (e.g. green waves) or emergency protocols to allow firefighters, ambulances or the police to be prioritised.

1.5 Conclusion and Future Work

In this paper we have introduced a traffic scenario built for the research community, the Luxembourg SUMO Traffic (LuST) Scenario. This scenario meets all the common requirements needed to have a common basis for the evaluation of various protocols and applications. To build this scenario we started from a real mid-size city and with a typical European road topology and its mobility patterns. The LuST scenario covers an area of 156 km2 and 932 km of roads. There are 38 different bus routes with 563 bus stops. All intersections with traffic lights and all highway ramps are equipped with inductive loops. We used ACTIVITYGEN to generate the traffic demand using real information provided by various data sources. We have discussed several use cases for the LuST Scenario. Among them are the evaluation and testing of network protocols, and applications for intelligent transport systems.

Future work consists mainly of the maintenance of the scenario with new versions of SUMO and the implementation of additional tools. As new features are provided by the SUMO simulator, the scenario can be enriched with other transportation modes (e.g. pedestrian, bicycle). At the moment the traffic light system uses a static scheduler; among the additional functionality we want to provide, is a dynamic version of the traffic light system.

The scenario is freely available under the MIT licence to the whole community. The scenario is hosted on GitHub (https://github.com/lcodeca/LuSTScenario). Your contribution is highly appreciated!

1.6 Acknowledgements

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