Simulation and Visualization platform for Automated Vehicles and Mobility Services (SIMnVIS)

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The project is a collaboration of*:*

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1. Introduction

The development of automated vehicles and new mobility services lead us to a situation that we need to start thinking new models and platform to evaluate the system effects since the traditional syntax, terms and context will not apply anymore. To support its development, new and updated requirements of tools and methodologies are needed. However, it is very cumbersome, time consuming and costly to apply new vehicle concept on the road in reality. It is necessary to build an open, modular simulation and visualization platform, where the impacts of automated vehicles and integrated mobility services can be demonstrated, investigated and visualized. This platform can connect modeling environment, test technologies, identify efficient business model and evaluate impacts related to business models, increase resource efficiency on land use and construction of infrastructures.

In order to make the platform possible, we need to have common view, from both the technical aspects to the measurements (KPIs) and to the mock-up visualization for showing the outputs/results. The state of art analysis shows how the current tools are used, which modelling frameworks are available and how mature they are. The use cases set the application scenarios based on stakeholder's requirements and the mock-up visualization is built up through the vision.

2. State of the art analysis

The state of the art analysis[1] provides an overview of possible modeling frameworks for the development of a simulation platform. This platform should be a tool for the simulation-based analysis of self-driving vehicles and mobility services. Therefore, depending on the final objective of the analysis, we will require different kinds of approach. On the one hand, traffic simulation with a high level of detail allows the evaluation of the driving behavior and the interaction between vehicles on the road. In this way, the simulation will provide information about road capacity, speed, etc. On the other hand, from the transport planning perspective, we are interested in the competition between different mobility services and the demand behavior with regard to the supplied transport system. This will provide conclusions about the design of transport services, modal split, new mobility concepts, business models, etc.

With these goals in mind, we summarize some of the current traffic and transport simulators or simulation platforms that provide modelling frameworks on we can develop the future platform. These pre-existing tools can be improved in different directions to meet the requirements. For traffic simulation, three tools for the microscopic level of analysis are included: SUMO, AIMSUN and VISSIM. These simulators describe the dynamics of individual vehicles in a disaggregated way. The motion of each vehicle is determined by car-following models and lane-changing models. They describe the driver actions (safe distances, acceleration, deceleration and lane changes) in front of the traffic environment. VISUM is presented as a macroscopic simulator for

[1] More detail information can be found in a separate report.

transport planning. In this case, the modeling approach assumes that traffic flows are characterized in an aggregated way by the time-space relationship between macroscopic variables: density, volume and speed. Finally, MEZZO is a simulator at mesoscopic level of analysis. It is an intermediate solution based on simplifications of traffic flow dynamics of individual vehicles.

On the other hand, microscopic agent-based modelling for transport planning is introduced. Unlike the previous microscopic models, the term microscopic here refers to individual demand behavior of each person or agent. However, the level of detail in the traffic flow dynamics is less precise. MATSIM is a multi-agent transport simulator. Additionally, BEAM and AMODEUS are described. They are other tools developed on the MATSIM modeling framework. Alternatively, three modelling frameworks are presented for the development of agent-based models that can be applied to transport analysis: GAMA, POLARIS and ANYLOGIC.

The analysis of the tools has been done according to requirements previously included in other traffic simulation taxonomies. The aspects considered are:

- Software **category**. The distinction is between ***open source*** and ***commercial software***. The former group allows us the free use of the software and access to the source code. Therefore, other programmers can study, modify and improve the initial code for specific purposes and add new modules. Commercial software has a charge for use and the modification of the original code is not possible or has strong limitations.
- Software **portability**. In what operating systems the software can work. The main relevant operating systems are Windows, Linux and MacOS.
- Model **category**. There are three different levels of analysis in the simulation field: ***microscopic***, ***mesoscopic*** and ***macroscopic***.
- Model **edition** and **user interface**. Easy or complex interaction with the software. How can users build the simulation? By means of text files, XML files or graphical user interface. An intuitive graphical environment makes the tool user-friendly.
- **Infrastructure**. The road network on the simulation is composed by roads and intersections.
- **Entities**. ***Type*** of vehicles: car, motorbike, public transport, bikes, priority vehicles such as ambulances or police cars, etc. ***Characteristics*** of vehicles: dimension, speed limits, weight, height, width, etc. Other entities included are ***pedestrians***.
- **Demand** Model. OD matrices or Activity-based model.
- **GIS**. The capability to import maps from geographic information systems to encode road network.
- **Outputs**. Data, statistics and files obtained at the end of the simulation. ***Environmental impact***, that is, the availability of the software to calculate fuel consumption, emissions and noise pollution.

– **Visualization**. In this item, we discuss how the software shows the results of the simulation. Two-dimensional (***2D***) or three-dimensional (***3D***) visualization and the level of realism.

Software Category	Model Category: Micro – *TFD*	Micro – *ABM*	Meso	Macro
Open source	SUMO	MATSim (BEAM; AMoDeus) GAMA POLARIS	Mezzo (BusMezzo)	---
Commercial	AIMSUN VISSIM	AnyLogic	---	VISUM

Figure 1: Simulation tools that in software and model categories and run in micro, meso and macro levels

3. Stakeholder analysis

Stakeholders that are commonly listed include Trafikverket, Transportstyrelsen, cities, automakers, mobility service suppliers, OEM, academia, freight dispatchers, and infrastructure providers as is shown in Figure 2.

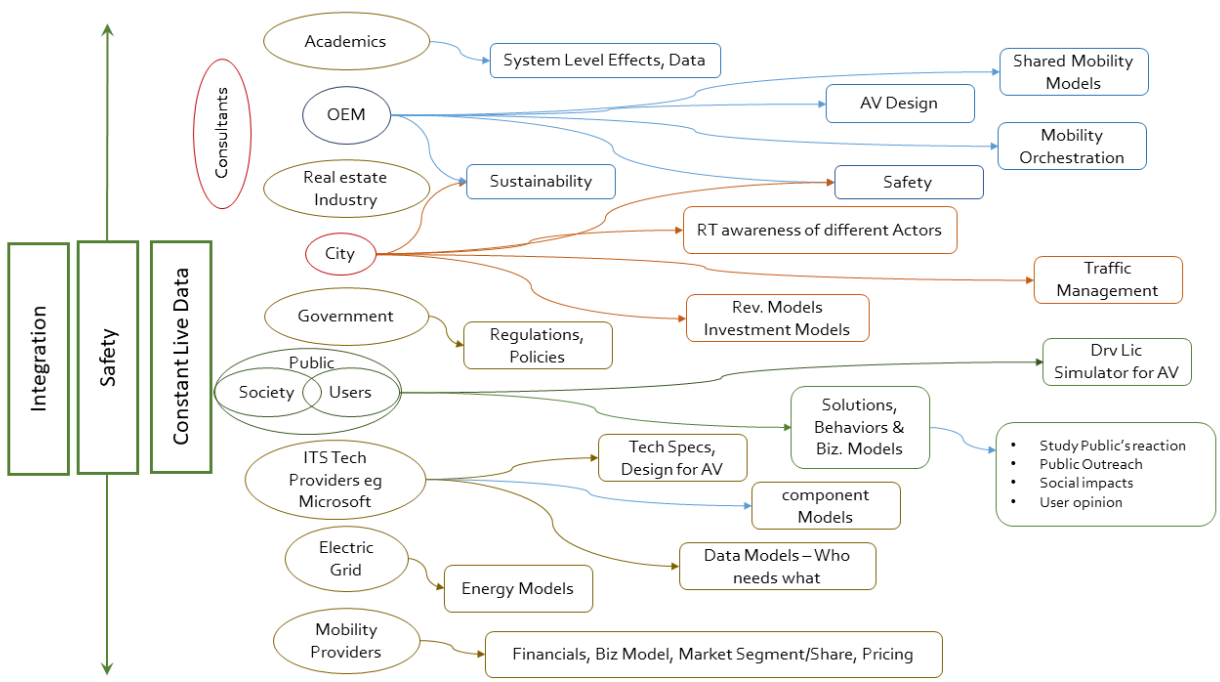

Figure 2: Stakeholders that can benefit from using SIMnVIS

The use-cases vary due to the dynamic of stakeholders’ requirements. In general, regulation change, road infrastructure, vehicle design, business models related to automated vehicle and mobility services draw the common interests. In order to support the future types of vehicles and mobility services, there is a need to have a certain type of platform, where stakeholders from different areas can meet up, test new demo vehicles and services and optimize them prior to having them in reality. SIMnVIS plays also as such a platform, along the workshop and meetings in SIMnVIS, two use-cases have been identified as list in the tables below.

Table 1: Three use-cases that identified through SIMnVIS meet-ups

USE CASE 1
1. Description of the use case: What is the optimal deployment (business model) of a shared vehicle service in terms of vehicle type (level of automation, drive line, vehicle size, driving environments) and service offer (waiting times, price, quality), and what are the traffic, economic and environmental effects of such a service.
2. Limitations found in the current simulation-visualization tools that are used to solve the proposed use-case? • The descriptions/syntax of services, vehicle types and vehicle behavior does not exist in current simulation and visualization tools • The description/syntax of infrastructure (both road, parking, drop-off and pick-up, charging) is insufficient/inappropriate to simulate the use of new vehicle types • The description/syntax of behavioral choices, both on the level of choosing access to mobility (car ownership, buying subscription, etc.) as well as on a trip/level are insufficient to describe market shares of different services and vehicle types.
3. What are the model requirements of the SIMnVIS platform for the use-case? Considering the scope of the use case, assessing the optimal service deployment based on individual choices and societal outcomes, it is perceived that an activity-based agent-based simulation would be most appropriate since such a framework will be able to: - Address all the relevant behavioural responses ranging from location choices, activity patterns to dynamic route choice changes - Address key characteristics of new vehicles types and their behavior in a flexible manner and in mixed conditions (varying levels of market shares) - Explicitly model the business model (dispatch model) of a shared vehicle service - Address key characteristics of infrastructure changing and V2X communications in a flexible manner - Simulate the flow of vehicles/traffic through the road network For example, entities, model approach (like, activity-based model, trip-based model, agent-based model, etc.) level (micro, meso, macro), perspectives (demand, supply) The SIMnVIS platform would be required to describe: - Characteristics of new vehicle types - Characteristics of a dispatch model of shared vehicles to users

- Characteristics of infrastructure components
- Choice behavior of consumers

4. How should we evaluate the use case?

Data requirements

- Infrastructure: digital description of roads, parking, etc.
- Population and employment data
- Land use data
- Vehicle characteristics and behavior
- Social

Model syntax/processes

- Business model: a model component that includes the algorithms for sending out a vehicle with certain characteristics and price to a specific customer call for a trip
- Travel demand model: a model component that determines choices of individual on a variety of levels: access to mobility (ownership vs service), activity pattern, destinations, mode/service choice, departure times, route choice
- Infrastructure: connectivity algorithms and use cases, traffic/vehicle flow algorithms

Input parameters

- Policy parameters
- Business model and service design parameters
- Behavioral parameters

KPIs

- Market share
- Usage and occupancy levels of vehicles
- Revenues
- Operating costs
- Congestion / travel times
- Occupancy parking
- Energy use
- Emissions

- Distributional / equity effects
5. How should we disseminate the results? A combination of 2D, 3D and aggregated descriptive KPIs in tables and graphs would be appropriate to disseminate results from the simulation.

USE CASE 2
1. Description of the use case. Study the impacts of cooperative intelligent transport systems (C-ITS) technologies from a function implementation perspective. How would a GLOSA (Green Light Optimized Speed Advisory) or TTG (Time to green) function affect the traffic flow? How would it affect un-signalized side-street traffic? How would it affect vehicles without the function? Results from such simulation would pose requirements on the function to have the desired effects. In VICTA Lab such simulation would also provide a way to validate that the implementation complies to those requirements – i.e. simulating with the actual vehicle functionality in the loop.
2. Limitations found in the current simulation-visualization tools that are used to solve the proposed use-case? We need variability in: Environment models (big city, small city, high-way etc.) Penetration levels Type of traffic signal system (fixed time, adaptive) Traffic density Driver behavioral models
3. What are the model requirements of the SIMnVIS platform for the use-case? - Environment models with detailed road network and infrastructure (micro and meso simulation). - Realistic simulation of infrastructure such as traffic signal timing etc. - Agent-based driver behaviour models for equipped and unequipped vehicles (GLOSA/TTG). - Agent-based simulations of various road participants (pedestrian, car, bus, bicycle etc.).
4. How should we evaluate the use case? KPI:s: - Traffic flow - Travel time - Traffic light stop time - Fuel consumption - Penetration rate
5. How should we disseminate the results?

Results will typically be KPI:s rather than visualization.

4. Projects that can link to SIMnVIS

The overall objective of identifying existing projects is to further understand today's traffic models to enable analysis of future transport systems of automated vehicles and mobility as a service. The project listed in the table below summarizes the project aim and the level that that the project focus on. The simulator used and the possible link to SIMnVIS helps to form a whole picture for SIMnVIS to evaluate the system effects.

Table 3: Projects that can link to SIMnVIS on different levels

Project 1	
Project name	**iQMobility Automated Bus Services**
Project focus/aim	To develop a prototype of a transport system for inner city traffic with automated buses. Within the scope of the project, the advancement in key technology areas will enable to demonstrate the following scenarios.
Which simulator (if any) is used?	BusMezzo
Which level is focused (Macro, Meso, Micro, Nano)?	Meso
Data?	-
The possible link to SIMnVIS (e.g.: in which aspects, how)	1. Automated depot handling 2. Autonomous driving in urban environments, with enhanced road user interaction; 3. On-line coordination of multiple busses in urban environments; 4. Coordinated autonomous driving of two vehicles, in urban environments.
Project 2	
Project name	**WSP New Mobility 2019**
Project focus/aim	To develop a planning tool to support the generation of macro scenarios for traffic models
Which simulator (if any) is used?	System Dynamics software + in-house developed python scripts
Which level is focused (Macro, Meso, Micro, Nano)?	Macro
Data?	-
The possible link to SIMnVIS (e.g.: in which aspects, how)	Concerning same type of issues (autonomous vehicles, shared mobility services). But modeling aggregated/total volumes over time, not traffic.
Project 3	
Project name	**Norra Djurgårdsstaden**

Project focus/aim	Applied project to check the traffic situation in an development area with 30 000 new workplaces and 10 000 new inhabitants. Existing harbors will remain in operation which is the main traffic challenge.
Which simulator (if any) is used?	Transmodeler
Which level is focused (Macro, Meso, Micro, Nano)?	Hybrid micro/meso
Data?	Demand data: Ferries, heavy transport, work, other. Network data: road, rail, signals, transit, bike.
The possible link to SIMnVIS (e.g.: in which aspects, how)	Provision of applied data and networks.
Project 4	
Project name	**Inner city model of Stockholm**
Project focus/aim	Simulation of Stockholm inner city
Which simulator (if any) is used?	Transmodeler
Which level is focused (Macro, Meso, Micro, Nano)?	Micro
Data?	Network: Car, bus, signals. Demand: cars, busses.
The possible link to SIMnVIS (e.g.: in which aspects, how)	A relatively large applied micro model that can be used.
Project 5	
Project name	**Kodning av regioncentrummodellen**
Project focus/aim	Development of a network model for the regional centre of Stockholm
Which simulator (if any) is used?	Transmodeler
Which level is focused (Macro, Meso, Micro, Nano)?	Meso
Data?	Network: car. Demand: Car (by 15-minute interwall), heavy
The possible link to SIMnVIS (e.g.: in which aspects, how)	Data that can be used in applications.
Project 6	
Project name	**CoEXist**
Project focus/aim	Development of AV-ready traffic and transport models and applying them on real use cases to assess the automation readiness of road infrastructure
Which simulator (if any) is used?	Vissim and Visum
Which level is focused (Macro, Meso, Micro, Nano)?	Micro and Macro
Data?	Field test of automated vehicles in Helmond Videobased measurements from a shared space in Gothenburg
The possible link to SIMnVIS (e.g.: in which aspects, how)	Development and application of simulation models for assessment of traffic performance of the introduction of automated vehicles

	Ongoing micro simulations of a shared space in Gothenburg and macro model evaluations of Gothenburg region using Visum.
Project 7	
Project name	**SMART**
Project focus/aim	Development of microscopic and mesosopic traffic simulation models to enable investigations of traffic performance effects of the introduction of autoamted vehicles and fleets of automated vehicles for first/last-mile service in a public transport system
Which simulator (if any) is used?	Sumo / Vissim / BusMezzo
Which level is focused (Macro, Meso, Micro, Nano)?	Micro and Meso
Data?	
The possible link to SIMnVIS (e.g.: in which aspects, how)	Development and application of simulation models for assessment of automated vehicles

5. Mock-up visualization

To develop a virtual transportation system simulation platform, in which city planners, architects, builders, manufacturers, researchers and other interested parties will be able to simulate and visualize different conditions of transportation scenarios. Such as travel patterns, emissions, road constructions, new mobility services, new types vehicles etc. The visualization platform is intended to give the opportunity to test different approaches and to make informed decisions before the plans are finalized and implementation started. The possibility of simulating in advance will not only be of help in the planning process but also improve cost and time efficiency, and aid in designing the best quality conditions in the interested areas of the stakeholders.
The mock-up visualization can be seen in the following link:
https://www.dropbox.com/s/ipseq8z2qol2s6z/Sequence%2001.mp4?dl=0

6. Conclusions & future research

The pre-study is to gather stakeholders and map their requirements on a platform for simulation and visualization of automated vehicles and mobility as a service.

- The goals that have been fulfilled through this pre-study project is:
- Identified and compared the existing simulation tools in a state-of-the-art analysis.
- Formulated requirements on the open simulation and visualization platform through stakeholder analysis.
- Described the vision and eventually visualized this in a mock-up visualization.
- Refined ideas and create further project proposals in dialogue.

There are four main results gotten from the pre-study project.
First, the result of stakeholder analysis (requirements, KPI:s), model architectures and model techniques within a system-of-system perspective.

Second, state-of-the-art analysis that inspected the modelling frameworks that are available and and their characteristics.
Third, visualization requirements and a mock-up visualization showing the vision.
Fourth, further research project application to define criteria for the creation of a "digital twin" solution for automated vehicles and mobility as a service.
The project was conducted mainly in two phases to fulfill the goals.

- In Phase 1, the state-of-the-art analysis was conducted focused on representative simulation tools and models. One workshop and one meeting have been held to identify stakeholders, KPI:s corresponding to stakeholder requirements.
- In Phase 2, one meeting and one workshop have been held to set up the mock-up visualization. The potential of mapping current simulation related projects on to SIMnVIS. Phase 2 also identified the scenarios, use-cases and needs on system effects for a further project application.

For the future work, we need to build the model plat form. Test the model platform in defined use cases, and validate the model by integrating data in data library. The system level effect will be evaluated and the visualization will be set through different ways according to the needs. Results dissemination, project management, platform maintenance and update will also be a focus that will be covered in the continuous future work.