LEVITATE: Automated Urban Transport Simulation

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The main objective of Work Package 5 (WP5) of **LEVITATE** is to identify how the introduction of **Connected and Automated Systems (CATS)** in several urban transport operations will affect different **impact areas**, with a focus on the transition towards higher levels of automation. This is a process that includes the following main steps:

- Identification of **impacts** relevant to connected and automated urban transport
- Identification of urban transport related **interventions**, through a stakeholder reference group workshop and an extensive literature review
- Identification of impact **assessment methods** for the different impacts and interventions
- Short, medium and long-term **impact assessment**
- Synthesis of **results** and implications for **policy**

In order to provide a structure to assist in understanding how CATS impacts will manifest in the short, medium and long-term, a preliminary taxonomy of the potential impacts of CATS was developed by Elvik et al. (2019). This process involved identifying an extensive range of potential impacts which may occur from the future expansion of CATS. A range of impacts were classified into three distinct categories:

I. **Direct impacts** are changes that are noticed by each road user on each trip. These impacts are relatively short-term in nature and can be measured directly after the introduction of intervention or technology.
II. **Systemic impacts** are system-wide impacts within the transport system. These are measured indirectly from direct impacts and are considered medium-term.
III. **Wider impacts** are changes occurring outside the transport system, such as changes in land use and employment. These are inferred impacts measured at a larger scale and are result of direct and system wide impacts. They are considered to be long-term impacts.

A targeted literature review was conducted in order to provide an overview of the societal level impacts of high automation in urban transport (Roussou et al., 2019). The large scale introduction of CATS in urban environments will affect fundamentally **urban transport and space** (Fraedrich et al., 2019). The benefits from fully automated public transport could include **reduced crash rate, increased punctuality, shorter headways and greater availability** (Pakusch & Bossauer, 2017). Under these circumstances, a greater proportion of people are expected to be using public transport. Nevertheless, the role of CATS for public transport can be **controversial**. On one hand, by providing first and last mile services, CATS can boost the use of other transport systems by providing **efficient door to door transport** along with the time and the chance for passengers to relax, work or read while travelling. Therefore, transport **modal split** could be affected, and public transport suppliers would face **challenges** as serious reconsideration would be required for existing **business plans**. These changes in modal split could lead to **congestion** unless changes in road network also take place (Boesch & Ciari, 2015). A study by Owczarzak and Żak (2015) compared several public transport solutions in relation to CATS and regular urban transport and concluded that the combination of CATS with the urban bus system is expected to **increase travel comfort** by reducing crowdedness and enhancing privacy, reduced travel costs and increased availability, timeliness and reliability of transportation service. The authors stated that the operation of CATS in public transport systems could be beneficial towards their efficiency and effectiveness of the latter.

Automation can also facilitate a transition to **Mobility as a Service (MaaS)** that could limit the negative effects of road transport (European Commission, 2017), as long as it promotes car sharing, ride sharing or sourcing and not private mobility solutions. According to Firnkorn and Müller, (2015), automation could attract **more people to car sharing** for the first or last mile of their trip instead of walking, cycling or using a private car. Autonomous taxis or car sharing could be considered as part of the public transport as with suitable business models they can promote sustainability, reducing the number of private cars and accordingly, the congestion. Fewer vehicles that operate more efficiently would reduce car traffic and advance public transport (Pakusch & Bossauer, 2017).

Simulation

The types of impacts that are presented in Deliverable 3.1: A taxonomy of potential impacts of connected and automated vehicles at different levels of implementation (Elvik et al., 2019) will be estimated and forecasted using appropriate assessment methods, such as **traffic microsimulation, system dynamics and Delphi panel** method. For example, traffic microsimulation can directly provide short-term impacts. Therefore, it will be used to forecast **short-term impacts** to be able to develop relationships that can infer dose (in terms of introduction of sub-use case) and response (selected impact). Traffic microsimulation also provides further input to assess **medium-term impacts** by processing those results appropriately to infer such impacts. System level analysis (such as by tools found within system dynamics) can provide measure of **long-term impacts**. For the sake of simplicity and applicability of assessment methods, it is assumed that for the appropriate level of automation, **adequate infrastructure exists**. It is also assumed that the pure **technological obstacles** for the sub-use cases in consideration are **solved**.All these results relating to the relationships between sub-use cases, impacts and any intermediate parameters will be provided to WP8 of LEVITATE, which concerns the development of the LEVITATE **Policy Support Tool (PST)**. The results will be integrated within the PST modules and functionalities so that impact assessment can be carried out by the users.

Traffic simulation within WP5

Traffic microsimulation is one of the main assessment methods used in LEVITATE. The purpose of traffic simulation is: (i) to **identify** the impacts of the adoption of CATS on traffic, including travel time, traffic volume, and traffic emissions to the environment under several traffic simulation scenarios and (ii) to **evaluate** the influence of difference traffic volume levels the presence of automation features both on a microscopic and a macroscopic level. Traffic microsimulation provides information related to **single vehicles**, whereas more macroscopic model refers to entire flow streams. There are also certain hybrid models, such as the model of AIMSUN, which allow for all levels of analysis, namely macroscopic, mesoscopic and microscopic analysis. The simulation inputs include data from various sources such as the road geometry and design, traffic volume, modal split, O-D matrices etc. This analysis will examine **impacts** mainly on traffic, environment and energy efficiency and will provide insights into the impacts of microscopic flow characteristics of CCAVs. The tools used for this analysis mainly include microscopic modelling tools for autonomous transport.

Description of point to point AUSS

A **stakeholder reference group workshop** was conducted to gather views on future of CATS and possible use cases of urban transport, termed sub-use cases, from city administrators and industry. A list of sub-use cases of possible interest for urban transport from the perspective of CATS has been developed. Within LEVITATE, this list has been prioritized and refined within subsequent tasks in the project to inform the interventions and scenarios related to urban transport. In turn, these will be included in the LEVITATE Policy Support Tool (PST).

The automated urban transport related **sub-use cases** that were formulated after the stakeholders workshop and the literature review are the following:

I. Point-to-point automated urban shuttle service (AUSS)
II. Anywhere-to-anywhere AUSS
III. Last-mile AUSS
IV. E-hailing.

The point to point AUSS simulation has now been completed. The study network that have been used for the traffic microsimulation in AIMSUN software is the city of Athens. The network is presented in Figure 1 and consists of **1137 nodes and 2580 sections**.

Figure 1: The city of Athens network in AIMSUN software

The **Athens transport network** includes 170 public transport lines and 1030 public transport stations. More specifically, there are 95 bus lines, 14 trolley lines, 4 metro lines, 2 tram lines, 5 suburban train lines and 50 intercity bus lines which are presented in Figure 2 and were included in the simulation model.

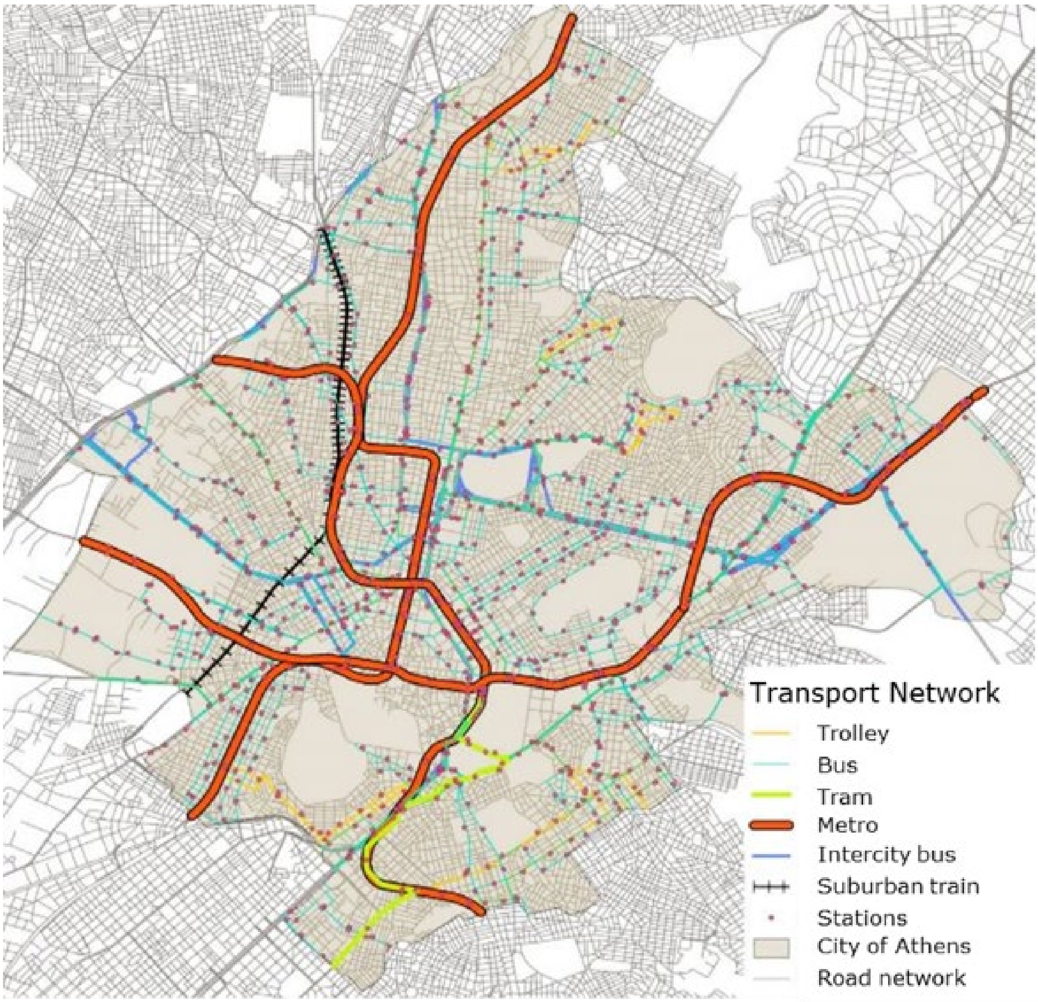

Figure 2: The Athens transport network

Scenarios
In order to define unknown parameters some assumptions have been made. Two general **assumptions** were that all autonomous vehicles are **electric** and that they used two main driving **profiles**:

- **Cautious**: long clearance in car-following, long anticipation distance for lane selection, long clearance in gap acceptance in lane changing, limited overtaking, long gaps.

- **Aggressive**: short clearance in car-following, short anticipation distance for lane selection, short clearance in gap acceptance in lane changing, limited overtaking, no cooperation, small gaps.

Another assumption of the present study is that the shuttle bus was modeled as a cautious AV, because this driving profile was considered more appropriate for a public transport service. Moreover, the shuttle bus service tested operating on a **dedicated lane** and assumed that one of the existing lanes has been converted to the shuttle service dedicated lane or one of the already dedicated bus lanes. In addition, the automated shuttle buses are considered to have a total capacity of 10 passengers. Their dimensions are a length of

5m and a width of 2.5m. The maximum operating speed of the buses is 40.0km/h, while the mean speed 25.0km/h. The frequency of the service is 15 minutes.

For the present sub-use case, **4 shuttle bus lines** were implemented in the city of Athens in order to complement the existing public transport as shown in Figure 3.

I. Line 1 connects the metro station "Viktoria" (A) with the metro station "Panormou" (B)
II. Line 2 connects the National Garden (A) and Greek Parliament with the National Archeological Museum (B)
III. Line 3 connects Omonoia Square (A) with Acropolis - Parthenon (B) and
IV. Line 4 connects metro station "Rouf" (A) with metro station "Neos Kosmos" (B).

Figure 3: The automated shuttle service bus lines

The shuttle service simulation sets included peak and off peak hour traffic conditions and the use of a dedicated lane during peak hour conditions, as shown in Table 1.

Table 1: Simulation sets

Number of Simulation sets	**Sub-use case specific scenarios**		
	Scenario Parameters		
	Traffic Demand	Route	Service Frequency
1st set	Peak hour	-	15min
2nd set	Peak hour	dedicated lane	15min
3rd set	Off Peak period	-	15min

The impact assessment of the shuttle bus service is analyzed for **each different simulation** set for different autonomous vehicles penetration rates in the prevailing traffic. These market penetration rate scenarios are presented in Figure 4.

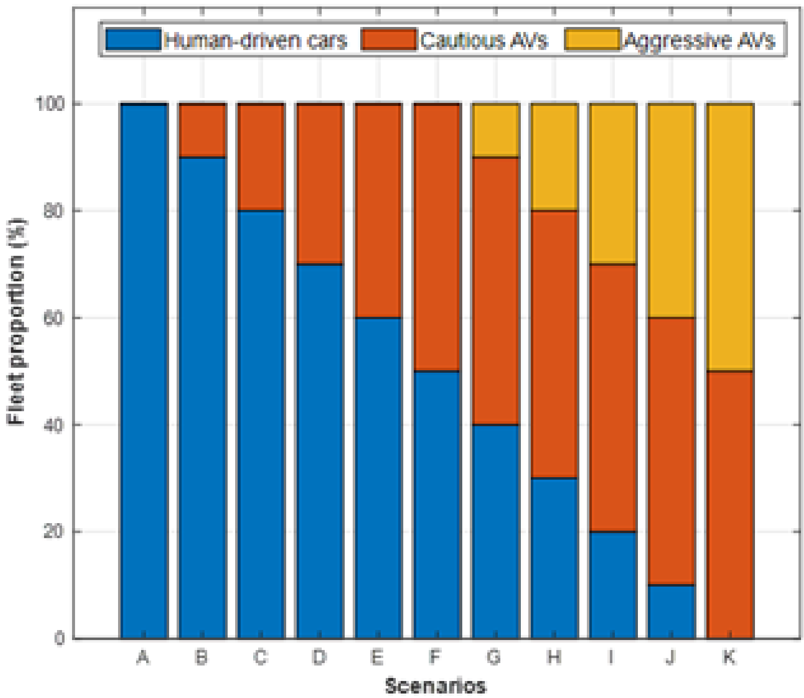

Figure 4: AVs market penetration rate scenarios

Results

When the shuttle bus drives on a dedicated lane, the delay time and total distance travelled remain the **same** during peak hour for all mobility scenarios. Due to the high traffic volumes during peak hour, the existence of a dedicated lane does **not significantly influence** the outlying traffic conditions. As it can be observed, automation **decreases** delay time for both peak and off peak hour scenarios. Hence, total distance travelled displays **significantly** higher values when the number of autonomous vehicles is increased.

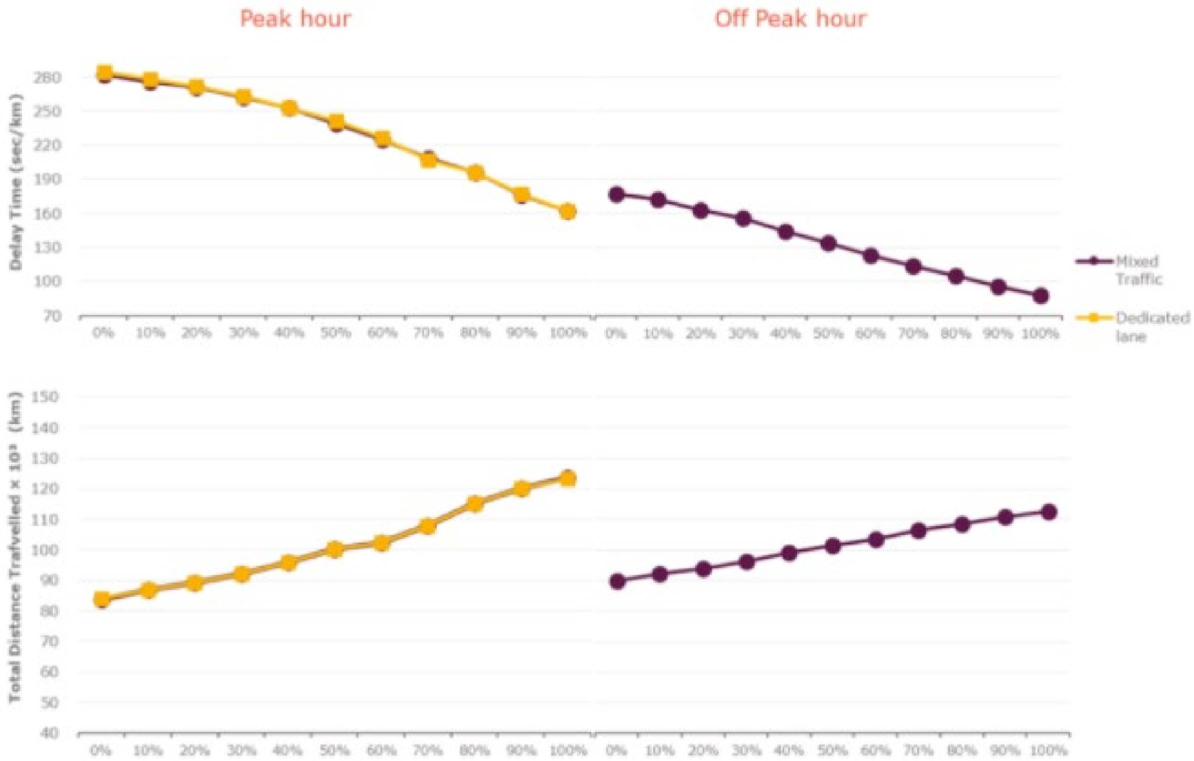

Figure 5: Impacts on delay time and total distance travelled

Regarding emissions, automation **decreases** the CO2, NOx and PM emissions during both peak and off peak hour conditions, as shown on Figure 6.

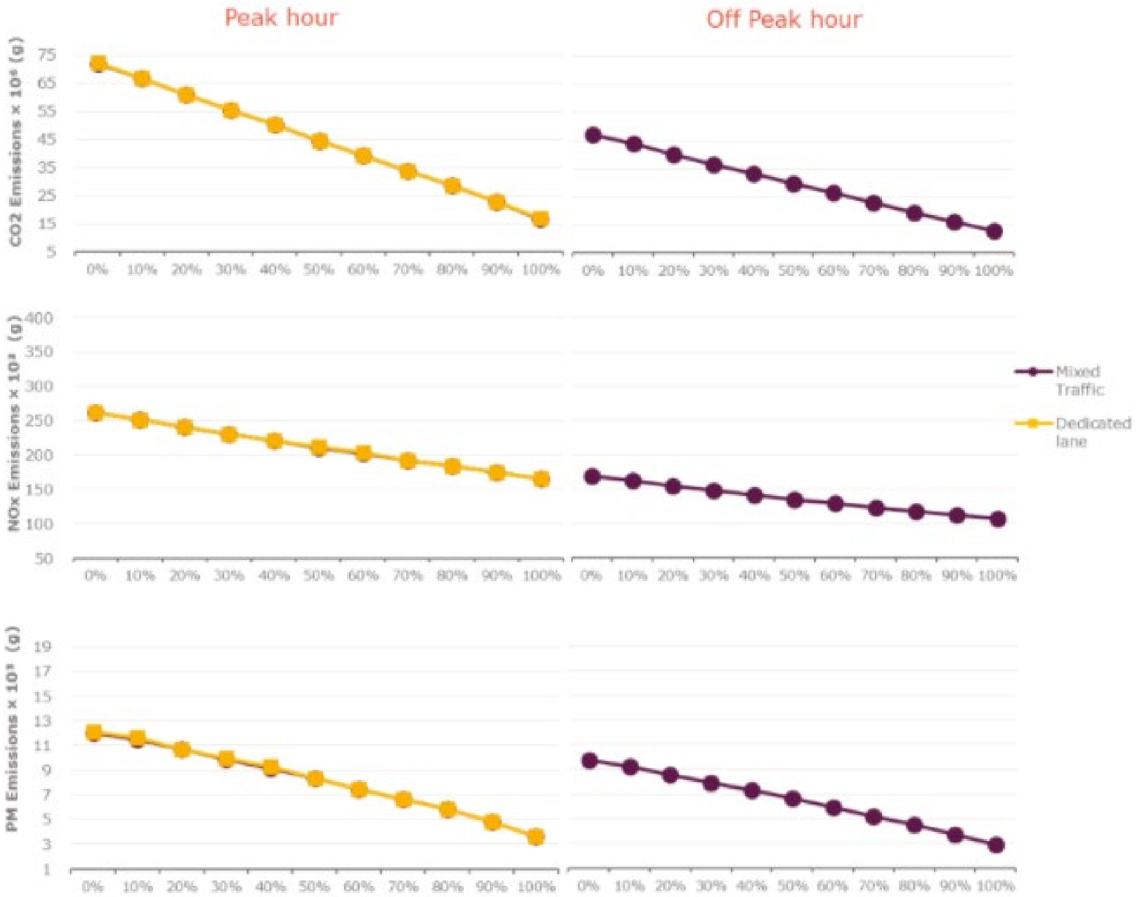

Figure 6: Impacts on CO2, NOx and PM emissions

Lastly, the introduction of automation seems to increase the number of conflicts during peak hour condition with and without a dedicated lane and during off peak hour, as well.

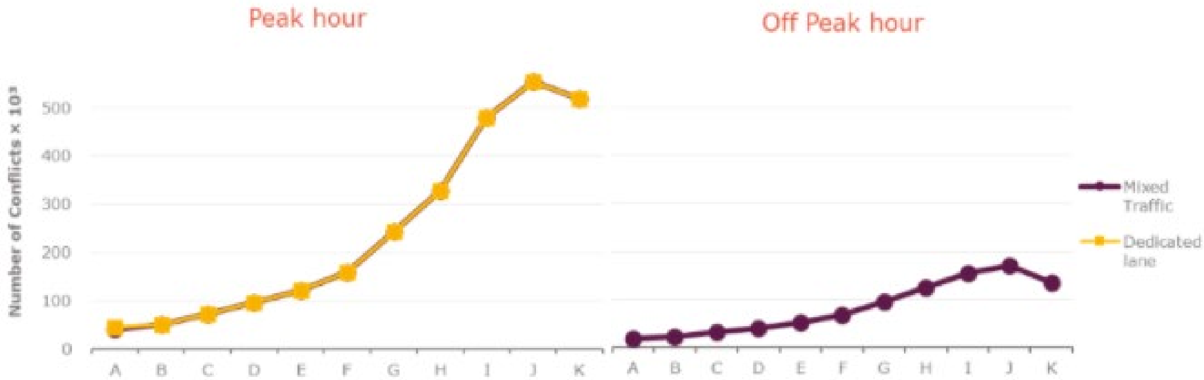

Figure 7: Impact on number of conflicts

As per the aforementioned, once all sub-use cases are assessed, a **synthesis** of results will be established, to provide a **comprehensive overview** of the impacts, cost and benefits of connected and automated driving for urban transport in the relevant dedicated scenarios. The results will be used to produce guidelines and recommendations that will be provided to WP8 and inform the **PST development**.

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