Project Report

Automated Vehicles Traffic Control Tower (AVTCT)

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In collaboration with:

ITRL — INTEGRATED TRANSPORT RESEARCH LAB
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1. Background & Purpose

The fast developments of automated vehicles (AV) on the technological front are promising to deliver many advantages with regards to transport efficiency, fuel economy, and traffic capacity. However, these advantages might be mitigated by challenges especially when it comes to safety. Therefore, remote assistance of automated vehicles may be needed as driving conditions are not always predictable with many situations that may need supervision. Therefore, the importance of a traffic control tower rises to aid the development of automated vehicles and provide safety in unpredictable conditions. Such a control tower will be used for control and operation on vehicle, fleet and traffic levels, which all will be affected by the introduction an automated and driverless vehicles.

AVTCT is a multiple stakeholder research project led by integrated transport research lab (ITRL) at KTH, with project partners are mobility service lab (MSL) KTH, Carmenta, and AstraZero. The reference group of this project includes: Volvo, Scania, Ericsson, and Traffikvert. The goal of the project is to understand the role of a traffic control tower (TCT) for automated road vehicles (AVs). In order to understand the role of the traffic control tower the project aimed at performing a pre-study and build a prototype of control tower in order to understand the functionalities and roles of the control tower as well as the possibilities of design and layouts.

First, the pre-study aspect of the traffic control tower project consists of two main activities. The first activity included multiple workshops that were organized by KTH ITRL. In these workshops, the project partners as well as reference group actors have participated in to increase the knowledge on the control tower role in the different use cases that they traffic control tower may play an important role in. Second, the project aimed also at building an integrated prototype to demonstrate the potential design and use of a traffic control tower in teleoperation.

The report addresses the results of the project on different fronts of the traffic control tower with regards to state-of-the-art, workshops, research questions, prototype development and integration, conclusions future research and the participating partners.

2. State-of-the-art analysis

The state-of-the-art (SOA) analysis is conducted on three folds. First, the current state of automated driving system (ADS) control is viewed and found that the focus of automated driving systems (ADS) is on the vehicle itself, and solely assure safety (Kang et al., 2018). Solutions for control failures are either return to human driving or stop the vehicle. AVs make decisions based on the perception of the environment and predefined situations on conditional scenarios (Pendleton et al., 2017). The driving scenarios are highly dynamic and not always predictable, when the complicated traffic rules and real situations dynamically interact, it is far more than enough to follow a predefined control, let alone making decisions on contradicting information. Using a human driver on-board or an emergency stop as fallback is inefficient, costly and could be unsafe. Furthermore, it is not applicable for the commercial mobility services with fleets of shared taxis that are expected and part of the widespread vision (Fagnant et al., 2015; Ohnemus & Perl, 2016).

Second, the current state of traffic control in other transportation, mainly aviation and railroad is studied to find potential solutions for on-road automated vehicle traffic control. The aviation industry has fully embraced automation in flight control and navigation systems since the mid-1970's (EE Times, 2016). Control towers have been mainly used in coordinating among airports and aircrafts, controlling flying courses, directing taking off and landing to further improve safety and efficiency. Compared to on-road automated driving, the aircraft autopilot - systems are mature and have become almost a routine in the aviation domain for many years. Despite that, the control tower is still central in safety and efficiency operation, and is not replaceable (Manske & Schier, 2015; Gawade & Zhang, 2016). Through this fold, the question that arises is that: given the current development status of automated vehicles, can a remote traffic control tower (TCT) improve the safety, service and operation of automated road vehicles?

Third, the potential of setting up remote control tower for automated traffic control is examined. In practice and early trials there are several vehicle developers that are exploring the opportunities with remote control towers for automated road vehicles. Nissan, Phantom Auto, Starsky Robotics, Waymo's cars by Google, Uber and Toyota have announced planning to have human remotely in a type of call center to help the automated driving vehicles (Consumer Electronics Show 2017, Waymo, 2017, Wired 2017). However, these pioneering works only link with their own product development and promotion. The research on what means are necessary for automated vehicle traffic control tower (AVTCT) to centrally support operations, management and control of automated vehicles, especially with regard to fleets of automated vehicles, is still scarce. There is no existing modules of showing how AVTCT should be set up.

3. Research questions:

Based on these three folds, the following three questions are mainly examined:

Q1. What can be learnt about AVTCT from the current ADS and the use of traffic control tower in the aviation and railway domains?

Q2. What are the required functionalities and roles of AVTCT?

Q3. What opportunities and challenges can AVTCT provide to increase safety and efficiency of AV fleet management and commercial services?

It is necessary to understand the potential functions and benefits of AVTCTs and investigate how they can be integrated with the technical aspects, human factors, situation awareness, and policies on national, regional, manufacturer and fleet levels.

4. Results and objectives fulfillment

The AVTCT project planned the following deliverables:

- **D1-1** A state-of-the-art analysis on automated vehicle management centres, including inventory of existing modules and system components
- **D1-2** Identification of use cases, operator needs, and technical ergonomically design requirements.
- **D2-1** A prototype demonstrator of a traffic management center, visualizing one or more of the identified use cases. Goal: 2 demo events in 2018.
- **D2-2** Data integration and system configuration of the AD Aware CTC Platform
- **D3-1** Report on analysis of gaps, challenges and research questions.
- **D3-2** Project proposal and applications for one (or several) larger projects, including (1-2) Phd positions and involving stakeholders from industry and academia.

The project has achieved the majority of its deliverables with the exception of creating PhD position. A PhD position will most likely be formed in external projects related to the second phase of the project, but internally we will focus on testbed development and integration with partners. The results covered conducting the state of the art analysis D1-1 D3-1, identification of use cases D1-2, answering its questions through the pre-study part. Moreover, the project partners managed to build an innovative platform manifested in four major demonstrations in 2018. Furthermore, the potential continuation of the project also expresses the success in creating future projects, AVTCT2 meeting D3-2.

4.1 Literature results (D1-1, D3-1)

The literature study finds that AVTCTs have the potentials to control vehicles when the ADS control fails. AVTCT can control and manage automated vehicles in mixed traffic situation. Decision-making can be more proactive, reactive and responsive because information is processed more concentrated. Cooperation among stakeholders and support both from technical side and policy side can be conducted through AVTCT. AVTCT does not only serve as a safety control center but also a platform for handling requirements from various actors and make the whole transport system more efficient and intelligent. Having AVTCT facilitating the ADS and integrating other aspects in the transport system can bring great potential to improve uptime and service accessibility, enhance fleet management, promote shared mobility services and optimize fleet utilization on a system level.

Figure 1 specifically illustrates how AVTCT interacts with automated vehicles.

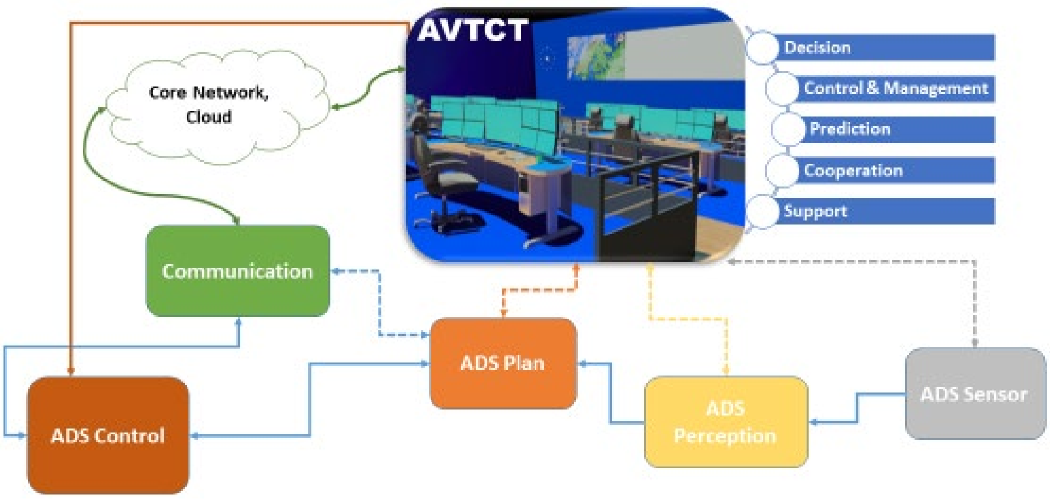

Figure 1: Potential roles of AVTCT in controlling automated vehicles

Although potentials of AVTCT are found in automated driving system, there are still many challenges in configuring the conceptual framework to set up AVTCT. As is illustrated in Figure 2, to set up an AVTCT demonstrator, many aspects need to be taken into consideration. This mainly leads to design challenges and operation challenges. First, technologies supporting automated vehicles control like image sensing, information filtering, sensor fusion, object detection and human machine interaction needs time to develop to achieve the level of reliability needed to ensure safety. Second, regulations, infrastructures, public acceptance cannot keep up on the same pace as technology breakthrough for AV control. Nevertheless, it is unfeasible and too costly to have a human in each AV ready to take control, especially in fleet management, commercial services and shared mobility services.

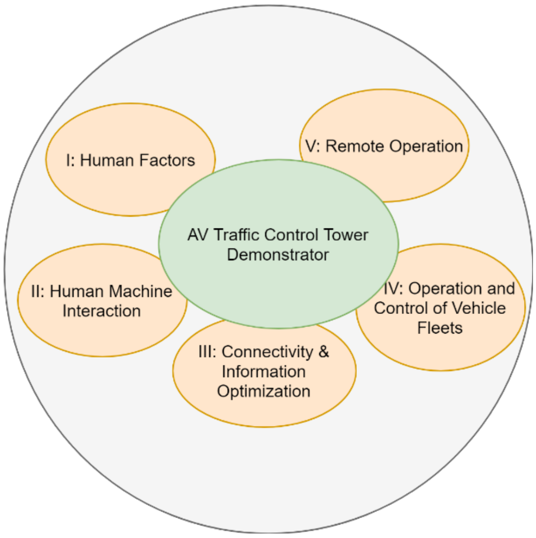

Figure 2: AV Fleet Management and Remote control service with various components through AVTCT

4.2 Workshops: (D1-2)

Three workshops has been conducted with project partners as well as reference group including representatives from Volvo, Scania, Ericsson, Trafikverket. The workshops discussions regarded to the importance and role of the control tower have been conducted. Important findings from the workshops was connected to three main use cases as well as operator control tower factors with high impact to the operation of a control tower. In the following, three use cases are constructed in group work:

<u>A. Platoon on a highway: assuming we have a driver</u>
In this case, three modes of operation have been discussed in terms of driver of first truck control, Auto control by OEM, or remote control from CT. The role of the control tower is discussed in terms of Traffic situation awareness like sudden bad weather, vehicle mgmt in the platoon, Fueling status, technical failure (Sensor failure, a flat tire lost communication) as well as maintaining security of fleet from hacking attempts. an important aspect is the load importance may drive into the role of a ct.

<u>B. AV truck trying to offload in a terminal/transport hub</u>
In this case, within a transport terminal, the vehicles are on autonomous mode in a tight system, the control tower takes over in multiple situations to measure failure, enhance Security situational awareness, finding no space to unload, assist the need to find a parking lot, facing other operators or vehicles/humans.

<u>C.A shared AV carrying people inner city (Bus like)</u>
The control tower role in this case revolves around safety aspects as the transport case is with passengers not goods. For example if an SAV crashes into another vehicle, the tower takes control and needs to act when it comes to technical design failure (lidar limitations), traffic lights failure, Sudden bad weather. Another role for the tower is connected to damage assessment procedure, as well as handling Incident control on fleet level

In a second workshop factors of high importance to development of control tower have been discussed with industry experts and sorted in terms of certainty and impact. These elements are of high importance to planning scenarios concerning control tower. In the following a list of the factors discussed:

A. High uncertainty

- Contexts and conditions for CT
- Level of automatic control
- Level of authority for control tower
- Efficiency requirements
- Standardization of sensor suite
- The level of autonomy
- Vehicle design
    - Service / contract
- Efficiency requirements
- Level of human interaction towards vehicle
- Distribution of control tower
    - Size, Business vs op
- Dealing with Infrastructure mixed traffic

B. Medium uncertainty

- Performance Vs requirements on data and data rates
- Who pays for what? Who wants all these services?
- Security vehicle and tower
- The level of situation awareness
- Level of immersion and comprehension
- Reliability of connection to the vehicle
- Laws allowing remote control of multiple vehicles
- Reliability of connection to the vehicle
- Quantify value for control tower

C. Low uncertainty

- Technical failure /flat tire /sensor failure
- Cost/efficiencies in compared with drivers
- Communication to the passengers
- Breakeven / what fleet
- Digital limitations
- Passenger trust / personal perception AV
- Size and speed of the vehicle

4.3 Prototype & demonstration (D2-1, D2-2)

A demonstration of prototype was built up in the Integrated Transportation Research Lab in KTH refer to figure 3 and 4. Both a real traffic management control room and a scaled down autonomous vehicle kit to manage. The Carmenta TrafficWatch information was also integrated to provide a central user interface (UI) with real-time traffic information. For each operator, UI elements such as touch tablets, steering wheels and augmented reality devices are required to support individual operator tasks and various types of information flows. A cellular-vehicle-to-X (CV2X) architecture was selected for communication. This prototype allows the exploration of relevant use cases, deployed on a smaller physical scale It can also be interfaced with low-latency 5G interfaces, which can further support the definition of the use cases explored in workshops with experts:

1) a platoon on a highway with a driver
2) AV trucks delivering goods in a terminal/transport hub
3) a shared AV transporting people in the inner city

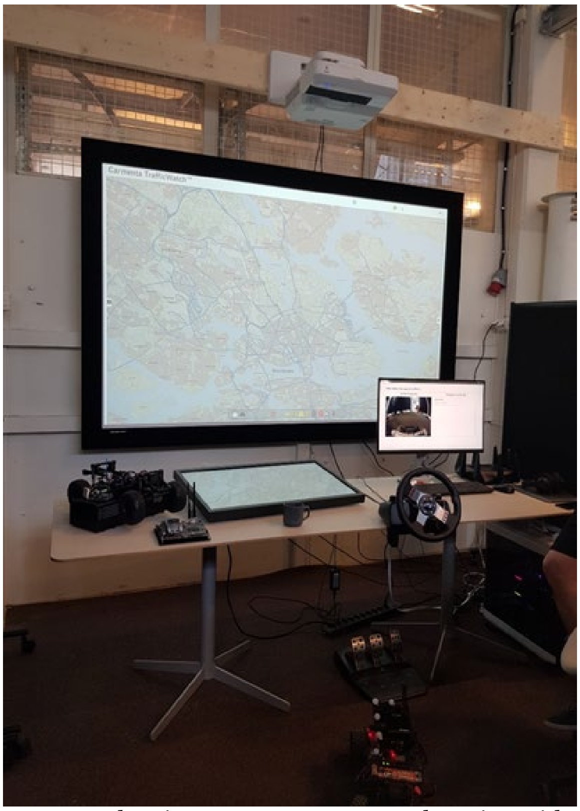

Figure 3: Demonstration of prototype showing SML Remote Control Station with the CTC Operator UI on a big screen at KTH ITRL

In the following the development of the autonomous vehicles as well as the technical integration of the traffic control tower platform subcomponents will be discussed

SVEA Smart Mobility Lab's Automated Vehicles

In the Smart Mobility Lab's (SML) we developed the Small Vehicles for Autonomy (SVEA) platform and built up a Cellular-Vehicle-2-Everything (CV2X) communications platform that can be used on commercial or industrial cellular networks. The SVEA platform is developed to match the information signals and demand the similar data bandwidth as full-scale cars with a powerful on-board computer, the Nvidia TX2, and a rich sensor suite. Due to the SVEA platform's small size, we will be able to scale up and use the SVEA cars to experiment with different aspects of AVTCT in setups that are difficult to achieve with full-scale vehicles.

The SVEA vehicles are connected to each other, the infrastructure, and the control tower via a custom built CV2X communication web app that is intended to simulate similar performance and capabilities that full-scale, industrial CV2X infrastructures might observe. Using a highly adaptive communications algorithm, we can deploy this communication web app in situations that demand large amounts of data, or even help mitigate low latency connections by adjusting our data compression.

Pushed by the Interlink partnership between SML and Veridict the SVEA cars and the other SML vehicles are connected to the Veridict platform to create the capability to inject our real vehicles into macro, real-time vehicle datasets and simulated datasets. The SVEA cars can report their position and route and have these data points visualize among other connected vehicles on the Veridict map.

Figure 4 self driving vehicle used in the AVTCT demonstrator

Integration with Traffic Watch

The AVTCT1 project is following closely on the work done in a previous “AD Aware Traffic Control project” (see Ref). The system solution developed in that project has been extended by adding a communication channel to the Smart Mobility Lab’s (SML) backend system and further to the Small Vehicles for Autonomy (SVEA) platform (see figure 5).

New software components have been implemented so that when an SVEA vehicle is tracked and controlled by the SML Remote Control Station system, the positions of the vehicles together with their planned routes are sent the Central Traffic Cloud (CTC) for monitoring and anomaly detection.

The CTC solution is based on Carmenta TrafficWatch™, an adaptable and scalable SW platform for effective decision-making in traffic control centres. Implemented and deployed as a set of services using the latest container technology it is easy to integrate in any cloud platform. Interfaces to external data providers are handled by functions in the Carmenta TrafficWatch platform and can be aggregated for use within the CTC.

When a potentially hazardous situation is detected by CTC where the SVEA is unable to resolve the situation using its automated functionality, messages are sent from the CTC back to the SML Remote Control System to aid a possible take-over for remote control of the vehicle. The messaging structure and content are based on the DATEX2 standard.

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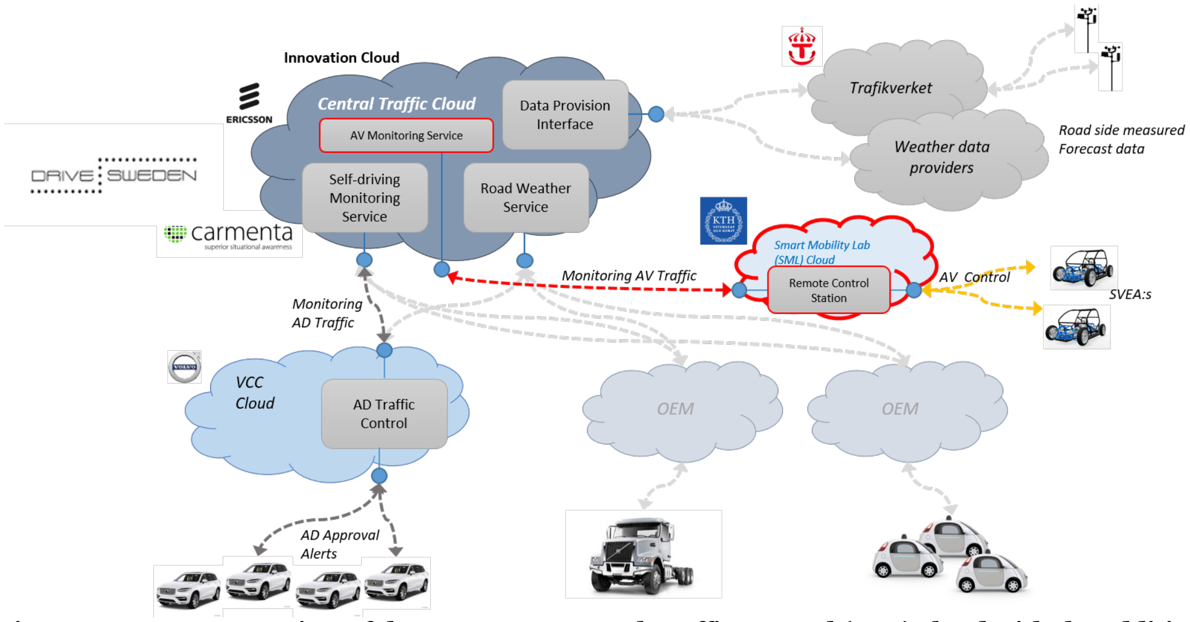

Figure 5. A system overview of the AD Aware Central Traffic Control (CTC) cloud with the additions made in the AVTCT1 project for integration with the SML test bed (in red). The design of the Drive Sweden innovation cloud allows for adding a number of OEM-clouds and external data sources

Visual simulation & connectivity:

An important component for supporting the safety requirements of automated vehicles that are connected to a control tower is represented by a set of novel interfaces providing real-time information on both the status of the vehicles and their decision making (e.g. short and long term mobility planning). Low-latency streaming of the video feed from the onboard cameras is a core component of such interfaces. However, based on our results from the pre-study it is clear that additional functionalities are needed. In particular, by adopting fast performing AI algorithms, we have been exploring solutions providing a layer of information augmentation. Most of the work in the pre-study has been performed via advanced simulations and a novel demo system has been developed.

Figure 6 AVTCT demonstrator: Hyper-realstic simulator

Since visual realism is an important prerequisite for users to provide reliable feedback, the simulator has been built on top of GTA V, a hyper-realistic video game. Several software modules have been developed to control all aspects relating to simulate remotely monitoring and take-over of an automated bus, providing connectivity in an urban environment. These include the possibility of controlling a) weather and time of the day, b) traffic conditions and pedestrian behavior, c) the latency in the information systems (e.g. simulating 4G or 5G settings), d) the driving behavior via steering wheel or high level controls, e) input sensors and output actuators via eye-tracking, audio and directional sound modalities.

In parallel to the development of the simulator, additional work has been performed on defining and exploring AI methods to supporting augmentation of the actual video streaming feed in real-time. In specific, a new family of detectors for object recognition and segmentation has been developed by Ericsson and tested on video feeds from vehicles in different traffic and weather conditions.

Demonstrator Scenario

The scenario defined and used for the demonstration was carefully chosen to test and showcase the different functions in the developed system. The pictures in the figure below shows both the physical setup inside the SML premises and how the demo route is mapped to actual road network.

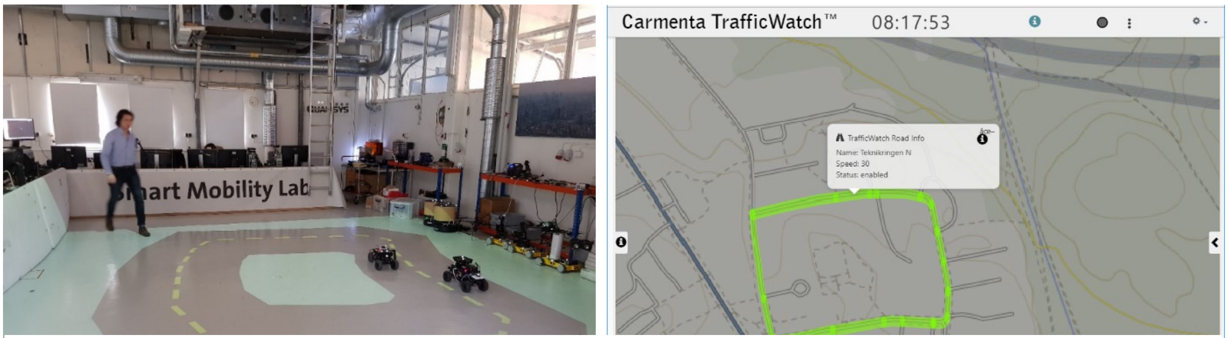

Figure 7 The left picture shows the model test area setup on SML premises. The picture to the right shows a screen dump from the CTC Operator UI showing the test area mapped to the actual road network. The green rectangle represents the fixed route used in the demo.

1. SVEA1 and SVEA2 are driving in normal speed and both vehicles are tracked and visible in Carmenta TrafficWatch OperatorUI.

Below is a summary of the steps in the scenario used for the demonstration. As the route to be driven by the SVEA:s is a closed loop, the scenario is built around the laps taken by the vehicles.

Lap 1:

1. SVEA1 and SVEA2 are driving in normal speed and both cars are tracked and visible in Carmenta TrafficWatch Operator UI.

Lap 2:

1. SVEA1 is driving its lap with SVEA2 behind it (and out of sight).
2. SVEA2 stops suddenly, due to an accident.
3. SVEA2 then will block the road for SVEA1 in the next lap.
4. The SVEA2 stop is detected by Carmenta TrafficWatch (it has stopped at a predefined location)
5. SVEA1 is continuously tracked by Carmenta TrafficWatch and its position is visible in the Operator UI.
6. A phone call/information comes to the operator in the SML Remote Control Station that an accident has happened with an immediate risk for collision.
7. Control room starts a Birds Eye view on SVEA1.
8. Carmenta uses its traffic situation simulator (the TrafficWatch Injector Tool) to create a DATEX2 “Situation” and send it to Carmenta TrafficWatch.
9. The “Situation” is registered by the Carmenta TrafficWatch as an ongoing accident and its possible effect on all monitored road segments is analyzed.
10. An “Incident” is detected and signaled because the “Situation” is located <u>on</u> a monitored segment. The Incident is shown in the Operator UI as a pink line and the Control Room Operator is alerted through a notice message in the UI.

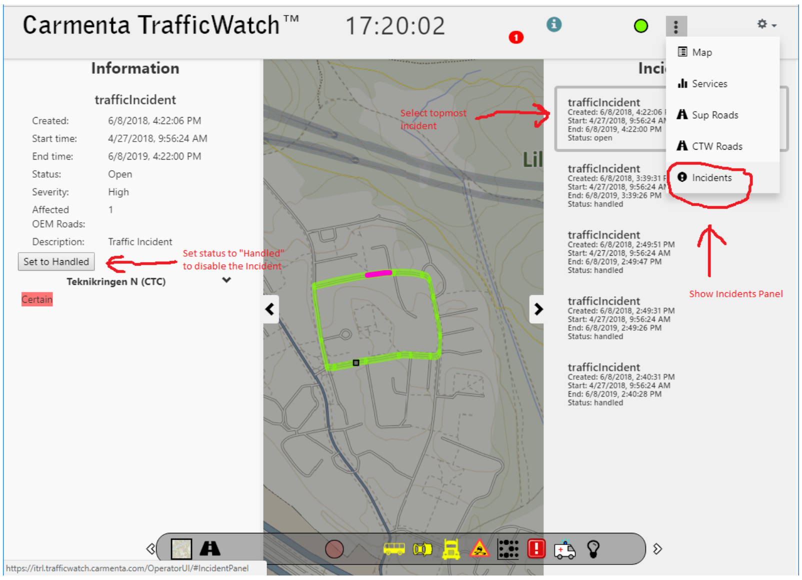

Figure 1. Screen dump showing the Operator UI where an Incident has been detected and shown as a pink line overlaying the green demo route.

11. A warning message is automatically sent as an “AD Advice” to the SML Remote Control Station using the message exchange mechanism developed in the project. The “AD Advice” message holds the following information:
    - Situation Type such as Accident, Obstacle, Road Work etc.
    - Probability (of Occurrence) with the values; Risk Of, Probable or Certain
    - Severity in five steps from Lowest to Highest
    - Start-time and end-time
12. The Remote Control system receives the message and when a specified distance from the Incident is reached the SVEA1 turns its self-driving mode off.
13. When SVEA1 reaches the Incident it automatically stops and pings to the room the need for Remote Control
14. The Remote Control system switches to remote control of SVEA1
15. SVEA1 is the remotely controlled to overtake SVEA2 in a safe way.
16. After the overtaking maneuver is done, SVEA1 is set to self-driving mode and continues its route.
17. After resolving the “accident” Car 2 is set back on track in self-driving mode.
18. The “Situation” is resolved and Carmenta TrafficWatch sets the “Incident” to “Handled”, either by manual intervention by the Operator or automatically due to status changes.
19. The Situation is finally removed from the scenario in using the Carmenta TrafficWatch Injector Tool.

Lap 3 and more:

20. SVEA1 and SVEA2 are driving normally and both cars are still tracked by Carmenta TrafficWatch and visible in the Operator UI.

Developments at AstaZero

In the next phase of the project the intention is to integrate the testbed with AstaZero and perform selected tests there for verification and validation in a full scale testbed. AstaZero is a leading testbed for verification of future automated and connected transports. It was opened in 2014 and had back then a focus of verification of active safety functionality. This has been a solid base when developing the testbed toward the verifications needs of future mobility.

At the opening of the test facility AstaZero in 2014 a traffic control system was introduced. This was primarily to surveille all the vehicles that operated on the different tracks and to ensure safety. The only control parameters was position and speed and the commands was given to the vehicle drivers via radio.

Today, the basic traffic control system is still present and is about to be upgraded to better fit the future of automated and connected vehicles. For example the communication between the traffic control and the vehicle can no longer go over radio between the control and the driver as the vehicle might not have one. The traffic control must also have the ability to place geofences over certain areas or around certain vehicles. The control must also have the ability to discharge the vehicle in case of abnormal behavior.

To meet tomorrow's increased demand for verification and also the increased complexity when automated and connected vehicles are introduced a traffic control like test system is under development. The test system will guide and lead the objects while testing complex scenarios including several vehicles and objects. In parallel a research platform of the system is maintained for development of functionality such as safe-way-out paths, interface to simulation platforms and the inclusion of virtual test objects. The research platform could also support testing needs regarding the communication infrastructures (ex 5G).

Looking a bit more ahead a traffic management system with integrated and situation based emergency stop functionality including safe-way-out for highly complex traffic scenarios is the target. To support development the system will allow for translation between simulation and physical environment and even use a mix of the two. This will allow to bring the verification process our from the test facility and enter real-life environment.

4.4 Industrial design (D1-2)

Throughout a summer internship, an industrial designer established a concept for traffic control room with inspiration from railway industry. In the following, the design description of the control room starts from one operator's desk and upscale the idea to a control room for multiple operators. For more details, please refer to industrial design report.

The operator's desk

Figure: Global design of the desk;

The final form of the desk and its shape has been worked to avoid losing to much space. We can see that the screens have been integrated to the desk with the good angle and curve.

In front of the operator seat, there is an empty space which will contain the wheel. We can clearly see that the working place is not disturb by this space. The operator has a mouse, a keyboard and a graphic tablet to interact with the computer. A place is saved for the central unite. Indeed, we will need a powerful computer to make everything work.

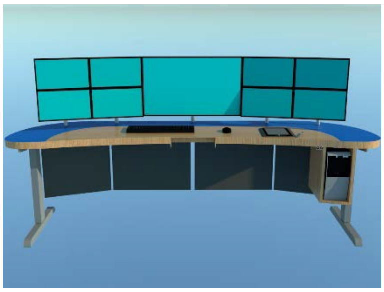

Figure Front view of the desk. We can see the space saved for the wheel and have the point of view of the operator. We can see that the wide of the screens is not disturbing at all;

Figure 30: Desk from the back view. We can see the way the screens where fixed. Those are of course easy to modify of high, inclination and deep. Therefor if the operator wants it, he will be able to adapt it as he want to.

Figure 31: In high position, the desk can go up to 1m10, so he can stand up without any problem. This can be changed just by pressing the buttons next to the central unite (See Figure 28 to have a better point of view);

A Global control room

Nowadays it is important to make sure that everyone can come to work in this place. Therefor it is important that every worker have a working place from a least 11m². We will make sure that everyone have this place without taking the circulations in consideration. To be sure that everyone can go in the room, the main way are 1m40 wide and the small one are 1m20. It is needed that there is a least 90cm for a wheelchair to cross and 1m40 so that two people can walk side by side. The room has "floors" to make sure that the operators on the back can also see the giant screen. We made ramp for the people in wheelchair.

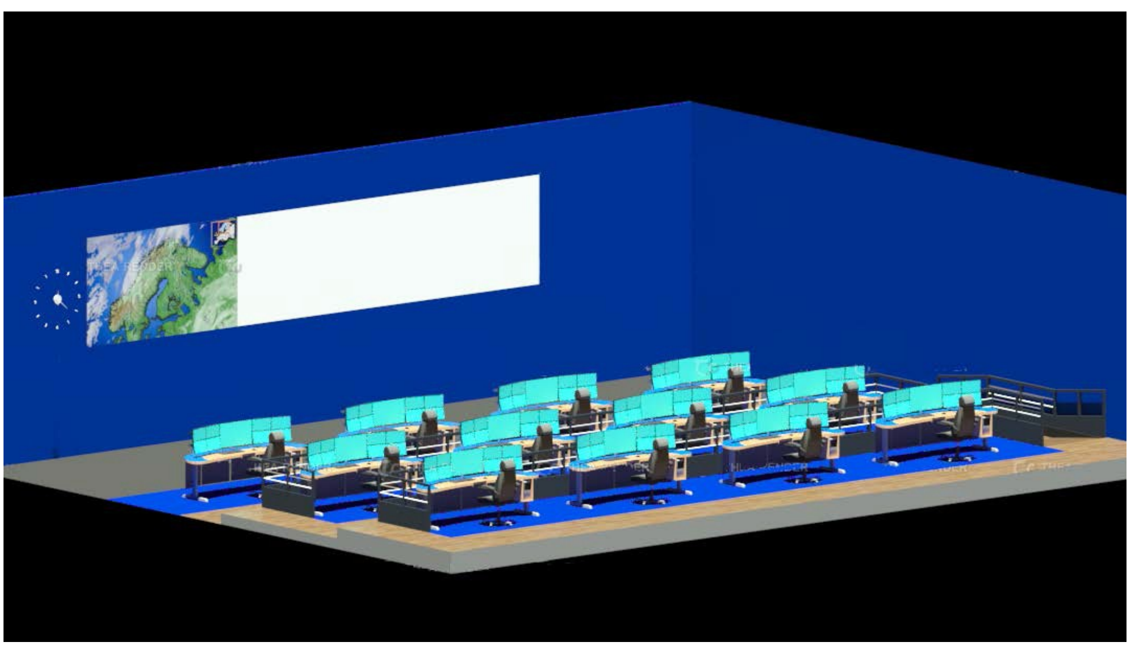

Figure 32: Control tower for automated vehicles; (*Own credit*)

This is how the room could look like. There are twelve desks in this room. A number of the desks can change depending on the area the operators are working on. Each operator looks at the giant screen and can have many other information on the screens next to it.

The design of the room is quiet simple and based on what is done for the train. The desk are facing the giant screen and aligned. It could have been possible to set them like in a amphitheatre but this kind of installation is not relevant in our case because we don't have that much operators.

Figure 33: The control room for a human point of view;

5. Dissemination and publications

As a part of research dissemination, the research outputs have been disseminated in various events, including at/via

- A- A demonstration of the control tower, on CIT'18 Symposium: the future of integrated transport at ITRL, June 11, 2018
- B- A demonstration of the control tower on test sites Stockholm June 12, 2018
- C- Participation in Smartare Industri 2018, November 29, 2018
- D- Participating in launching 5Gs with Ericsson, Telia, & KTH at ITRL, 5 Dec 2018
- E- Video of the prototype through KTH main webpage and Facebook page.

The results of the control tower project will be disseminated in Two papers which are under development, entitled respectively:

1. Automated vehicle traffic control tower - the bridge to next level automation?
2. Conceptual model and demonstration of automated traffic control tower

These papers will be submitted to scientific journals like IEEE Control System Magazine and the results will be presented at conferences like Position 2030 and IEEE Automated Vehicles Symposium.

6. Conclusions & future research

The automated vehicle traffic control tower (AVTCT) centralizes the decision and can act as an economic and safe backup of automated systems. It can also improve efficiency by improving fleet management and traffic flow. In AVTCT, one person can manage multiple automated vehicles, take actions upon request, and take over the control after system failures. One role of AVTCT is assuring the traffic safety and increase traffic efficiency. Another role could be coordinating among the fleets, infrastructures, service providers and traditional road users. AVTCT can act as a decision maker and can also be a decision support system for automated vehicles in dynamic driving scenarios. Control tower has been widely applied in aviation, marine and railway. However, the context is different for automated on-road driving and automated driving in the air, on railway and in the water. The AVs need road network and get more complicated interactions with surroundings infrastructure. The scale that AVs cover in transport is also broader and more complex than those aforementioned transportation modes. It is therefore novel to introduce the method of AVTCT for operate and control AVs. Furthermore, it is necessary to test possible functionalities and benefits of AVTCT, as well as reveal challenges and find answers for open questions in applying AVTCT.

For the future work, we need to find possible answers for those open questions discovered in the SOA by gathering perspectives from industries, business, authorities and users. The possible economic impacts need to be investigated to see how AVTCT can help to optimize the vehicle utilization and to reduce energy use. The conceptual model needs to be set up in real scenario in order to apply the architecture framework and possible business models that come along the adoption of AVTCT. System effects that will be brought by AVTCT are also a focus for future work.

7. The participating partners and contact persons

- Jonas Mårtensson - Project Ieader Associate Prof, KTH ITRL
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- Kristian Jaldemark Head of Development, command & Ctrl Carmenta
- Monica Ringvik Chief Technology Officer - AstraZero

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