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Operation Control Center for automated Vehicles – Conceptual Design

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Purpose*: Although automated vehicles are actively being tested in public areas, they are still limited to the operational design domain and require human assistance. The goal of this paper is to develop a concept for a module-based operation control center (OCC) that enables effective and safe deployment of different types of automated vehicles.*

Methodology*: In order to determine the modules of an OCC, the findings from the requirements engineering from the research project "AS-UrbanÖPNV" were combined with a market analysis. For a better understanding of the interaction of the OCC functions, a cross impact analysis was conducted.*

Findings: *Different use cases were collected and the functional requirements for an OCC were derived. Based on this, a modular architecture of an OCC was created. Finally, future research needs with respect to data analysis were discussed.*

Originality*: The existing OCCs are mostly specialized on the particular vehicle type or transport purpose and hardly take into account the environmental data. A scalable and adaptable OCC architecture can offer synergy effects and many advantages.*

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1 Introduction

Automated vehicles are expected to improve the traffic system in terms of higher efficiency, safety, pollution reduction, service quality and travel experience (Agora, 2020). Automated driving can be applied at different automation levels as well as for different use cases or business models. In addition to private use, collaborative mobility services in particular are becoming a much-promised business model. The greatest contribution to sustainability, better mobility and efficiency can be made by automated vehicles in a shared deployment scenario where they are integrated into public transport services (UITP, 2022). While the automation of individually used vehicles is taking place gradually, the use of automated vehicles for various service offerings in the public transport sector makes sense from automation level 4 (fully automated) (Agora Verkehrswende, 2017).

Although some vehicle manufacturers are already testing their full automated vehicles (level 4) in public area they are still very limited to the operation design domain (ODD) and dependent on human assistance in many traffic situations. In most deployments the presence of a safety person on board to intervene in an emergency or to assist beyond the ODD is required. According to forecasts the fully autonomous driving will not be achieves at least before 2030 (Lalli, 2019). The main problem areas are the human interaction and the efficiency of the journey or transport (Feiler, et al., 2020). If an automated vehicle can no longer proceed on a planned trip, it must be capable of performing a safe stop, also called a “minimal risk condition” or fallback (Waymo, 2021). The unintended standstills and waiting time reduce the efficiency and the acceptance by passengers or other traffic participants (Feiler, et al., 2020). However, in order to be able to use automated vehicles in regular operation today, industry and research are largely in consensus that a human operator should monitor the automated vehicle fleet and support it if needed remotely from an operation control center (OCC) (Leonetti, et al., 2020). Depending on the local legal regulation the remote monitoring and control from the OCC is also prescribed (to a certain extent) for deployment of automated vehicles without a safety person on board. In Germany the so-called technical supervision should monitor and intervene in emergency (emergency stop or restart function) but is not allowed, for example, to drive the vehicle remotely in public space (Bundesministerium für Digitales und Verkehr, 2022).

The goal of the traffic turnaround is to reduce the volume of traffic. Shared and combined (hybrid) transports are becoming increasingly important in this context. To enable a regular operation an OCC is needed. The existing OCCs are mostly specialized on the particular vehicle type or vehicle provider and hardly take into account data from the environment or other sources besides the vehicle sensors. The purpose of this publication is to analyze the current market situation concerning automated driving in road transportation in terms of application fields and technology offer. Based on this, the requirements for an operation control center for different kinds of on-road vehicles und use-cases are collected. Afterwards, the requirements are structured and grouped into modules of an OCC. The modular design of the OCC offers the flexibility and addresses demands of different deployment use cases for automated vehicles in public transport as well as for freight transport (Khan , et al., 2020).

2 State of the art

The SAE J3016 standard defines the level of automation of road vehicles as follows: Level 0 is non-automated driving, where all tasks are performed by the driver. Level 1 is assisted driving. Level 2 is partially automated driving. Here, the accelerator and brake as well as the steering are operated by the system over a certain period of time or in a certain situation. However, the driver must monitor the system at all times and be ready to take over all functions. In Level 3, called highly automated driving, the driver does not have to constantly monitor the system any more, but must be ready to take over the control at any time when the system requests it. Level 4 is fully automated driving. Here, steering as well as accelerator and brake are completely taken over by the system. The driver does not have to monitor the system, but must be prepared to take over all functions. If the driver does not take over the system after being asked to do so, the vehicle has to be able to perform a minimal risk condition, for example to drive to the roadside. Under certain conditions, specified in the operational design domain (ODD) it is possible to operate without a safety person on board. Level 5, autonomous driving, is defined by the system taking over all functions of the vehicle all the time, everywhere and in all conditions. In this case no safety person is needed (Shuttleoworth, 2019).

There are two design approaches for automated vehicles: the modular based and the end-to-end based. The modular design consists of separate software modules for localization, perception, mission planning, motion planning and control. The end-to-end design is based on artificial intelligence and machine learning methods to process the sensor data in order to plan and control the vehicle (Liangkai , et al., 2020). Both approaches have not yet achieved the mature technology level. The main challenges are the road detection, lane detection, vehicle detection, pedestrian detection, drowsiness detection, collision avoidance, and traffic sign detection (Khan , et al., 2020). Furthermore, technical failures or problems with human interaction are possible. Some of the challenges are briefly listed (Liangkai , et al., 2020):

- Artificial Intelligence for AVs and in particular standardization of safety issue, infeasibility of complete testing
- Multisensors Data Synchronization
- Failure Detection and Diagnostics
- Dealing with bad weather conditions and emergency maneuvers
- Interaction with smart infrastructure
- Dealing with human drivers

The fully automated vehicles (level 4) are very limited to their ODD which is specified by the manufacturer. The ODD defines for example the roadway types, infrastructure (intersections, traffic lights, roadside-units), speed range, time of the day or weather conditions under which the vehicle can safely operate. Thus, the state of the art of automated vehicles according to SAE J3016 is between "partially automated" and "fully automated" (Kostorz, et al., 2019).

To increase the safety and provide the vehicle with traffic or environmental information the v2x-technology is used. The included types of connectivity are: V2I – Vehicle-to-Infrastructure, V2V – Vehicle-to-Vehicle, V2N -Vehicle-to-Network and V2P – Vehicle-to-Pedestrian (Coppola & Morisio , 2016). The v2x-communication standard provides two types of messages. Common Awareness Messages (CAM) which are sent out periodically Decentralized Environmental Notification Messages (DENM) which are intended for alerts of hazards and other non-periodical information (Al-Dweik, et al., 2017). With the v2x-comminication (via road side units) the roadmap updating, road events detection, and making up blind spots of AVs is possible (Al-Dweik, et al., 2017). The on-board sensor set should be supplemented by the provides digital map and validated by the vehicle sensors (ERTRAC, 2022).

Furthermore, the use of remote human operators can compensate for the shortcomings and increase the safety and service level of AVs (Zhang, 2020; Kettwich & Dreßler, 2020). The leading manufacturers of automated vehicles are developing the first OCC applications to speed up the transition to regular operation. These applications enable functions such as fleet management, sensor data monitoring, passenger communication and rarely teleoperation (Zhang, 2020). In teleoperation, longitudinal and lateral acceleration can be accessed via the vehicle's so-called drive-by-wire interface, providing real-time control remotely (Phantom Auto, n.d.). The teleoperation service is mostly provided for individual cars as well as indoor and outdoor transport services, but rarely for public transport. The companies like Phantom Auto, Ottopia, Fernride (Fernride, n.d.), Einride developed first software solutions for teleoperation of cars (Ottopia Technolgies, n.d.), trucks and tractors (Phantom Auto, n.d.; Fernride, n.d.; Ottopia Technologies, n.d.; Ottopia Technolgies, n.d.). These OCC applications are quite limited to the particular vehicle type or operational scenario and consider comparatively little environmental data (v2x- or infrastructure data) or logistic data (Schaeffler Paravan Technologie GmbH & Co.KG, 2021).

Recently, the amount research in terms of required functions and implementation of OCCs for automated vehicles has increased. The permissible latency times for data transfer and teleoperation functions and the design of the optimal user interface are often addressed in the literature. However, there is comparatively little research on an OCC architecture and its components derived from the requirements of various use cases and vehicle types.

3 Methodology

In the research project “AS-UrbanÖPNV” a prototype OCC application for automated shuttle buses was developed. The requirements engineering for the control center focused on the use cases for an automated shuttle bus in public transport. Workshops and interviews were conducted with the local public transport company as a potential operator in order to define the functional requirements and its implementation design. The collected data is included in the further OCC module design.

The goal of this publication is the development a flexible and adaptive OCC architecture so that different types of vehicles can be handled. Modularization is one of the essential steps in product engineering. It contributes to more comprehensibility and combinability or recombination of the system. Modular design enables faster and easier adaptations and thus more effective development of the system (Schmidauer, 2002). In order to design the modules of an OCC for the supervision of different automated vehicles the market analysis was conducted. For this purpose, the use cases for the automated shuttle buses were expanded to include other vehicle types and services, such as freight or hybrid transport. The subject of the market analyses were on-road vehicles with automation level 4 (or 5 in the future) for passenger or freight transport and their application scenarios. Since, according to the SAE definition, up to level 3 the presence of a person in vehicle is required anyway. Furthermore, only the shared mobility use cases for public road transport were considered. The analyses exclude the vehicles for individual use and internal transport and handling of goods in logistics facilities such as city hubs and industrial plants.

The market analysis builds the basis for deriving of the main functions and requirements for the OCC and consists of use case analysis and best-practice analysis. After the requirements were collected, they were evaluated with regard to the mutual influence in order to build the functional modules. For this purpose, the cross-impact analysis according to Reibniz (Reibniz, 1992) was chosen.

3.1 Market analysis

The European Road Transport Research Advisory Council (ERTRAC) developed a roadmap for Connected, Cooperative and Automated Mobility in Europe, which defines the stepwise development of automated driving and the Vision 2050 as well as Agenda 2030. According to Agenda 2030 separate domains will emerge and offer a wide variety of use cases such as (ERTRAC, 2022):

- Highway Automation and Assisted Corridors - will enable hub2hub truck operation and cooperative assistance with strong infra support
- Confined Autonomy - will show more and more mastering complexity, main use cases are parking, separate lanes, hub-internal mobility, highway construction sites with strong infra support
- Urban Autonomy - will master complexity with growing speeds and so enable wider ODDs in unrestricted mixed traffic
- Rural Assistance with first Autonomy approaches - enable automated shuttles in sparsely populated areas on specific tracks and first automated municipal and delivery services

Especially for the urban domain vehicles such as valet parking, shuttles in restricted areas without a safety driver for last mile passenger transport or goods transport, bus transport on pre-defined routes (instead if conventional bus routes) as well as taxi-like transport on pre-defined routes are expected till 2030 (ERTRAC, 2022). The level of automation expected in predefined areas of operation by 2030 is level 4, therefore the operations control center is considered an important enabler in all use cases (Mitteregger, et al., 2022).

Since OCC already exists in different technical systems, the main functions of a conventional control center in public transport can be transferred to automated transport, but need to be supplemented with more specified requirements. In order to supplement the functions of an OCC two approaches were combined. First, the literature review and a use case analysis were conducted. Secondly, the OCC offerings of the leading manufacturers of automated vehicles and specialized providers of remote control (teleoperation) applications for road vehicles were researched.

3.2 Definition and analysis of use cases

The literature review identified 19 relevant use cases for automated vehicles for passenger and freight transportation. Of these, 12 use cases relate to passenger transport, 4 use cases to freight transport, 2 use cases to hybrid transport and 1 use case to parking services. Table 1 shows an excerpt of the use case analysis. For each use case, the following considerations (5 categories) were made: (1) purpose of the transport (goods, passenger transport, hybrid, other), (2) operational design domain, (3) target group (users), (4) provider and level of integration in public transport, (5) vehicle requirements and enablers. This enabled a more detailed consideration of each use case in order to subsequently determine the specific requirements for the OCC.

Table 1: Use cases for automated vehicles (excerpt)

Use case	**Description**
First/last mile feeder to public transport station	Feeder service, fixed route, operational times in parallel to high-capacity public transport, on-demand or fixed stops (e.g. during rush hour) and shared use.
Local bus service	Replacement of local public transport in small cities, on-demand shared fleet-based service, dynamic routing, 24h operation
Special service (campus, business, park, hospital)	Feeder to public transport stations and additional service on private grounds, shared use, scheduled service during morning and afternoon peak – otherwise on-demand. Possibility of hybrid vehicle use carrying correspondence and small parcels.
Bus Rapid Transport (BRT)	High frequency fixed route, fixed stops, separated lane, shared use.

Use case	Description
Robo-taxis	Point-to-point on demand premium service; for private use and sequential sharing
Car-sharing	On-demand sequentially shared private service, reserved for a period of time, dynamic routing, extended operational times.
Intercity travel	Long distance fixed route connection between urban areas on highways
Fleet Depot	Automated and optimized fleet management in the (bus) depot (parking and charging management).
Modular Platform/System	Separation of drive module and transport capsule enables a new type of modularity and thus also a new intramodality
Mobile parcel station transport	Transport of a smaller parcel station as a mobile pick-up station with cargo bikes or automated vehicles
Shuttle trips for goods transport	Shuttle between two closely located sites, e. g., to transport goods between production facilities and/or warehouses. The locations can be connected by private or public roads transports between depots and warehouses
Delivery robots	On-demand delivery tasks for smaller goods (e.g. food delivery, small parcels, tools)

For example, the following characteristics according to the 5 categories were elaborated for the use case “First/last mile feeder to public transport station”:

- Purpose of the transport: passenger transport
- ODD: urban: mixed traffic, presence of vulnerable road user, large variety and complexity of infrastructure, lower speed, day or evening time

- Target group (users): users in areas not covered by public transport core network
- Provider and level of integration in public transport: public transport company; fully integrated in public transport offer, e.g. the operating times are displayed in the passenger information system
- Vehicle requirements and enablers: shuttle buses with a ramp, space for pram/luggage/wheelchair; v2x-communication, high speed mobile network, operation control center.

3.3 Best-Practice-Analysis

As part of the best practice analysis, the typical tasks of a control center in public transport were first researched. Berger et. al. offers a structured compilation of the essential functions of a conventional control center in public transport. These include for example (Berger, et al., 2015) :

- Operations execution: Traffic and operational planning, monitoring of regular operations, vehicle dispatching in case of planned deviations from regular operation, fault management, emergency management, disaster management
- Service tasks: dynamic passenger information, passenger communication, customer service
- Vehicle / depot management: performance and quality controlling

The minimum safety requirements for the vehicle and the control center are also specified in the ordinance on autonomous driving from the German Federal Ministry of Digital Affairs and Transport. Among other things, the regulation prescribes that the control center must be able to stop (switch off) and start the vehicle remotely in an emergency (Bundesministerium für Digitales und Verkehr, 2022).

In order to gather further input for deriving the functional requirements of an OCC, the OCC applications of the leading manufacturers of automated vehicles and specialized providers of remote control (teleoperation) applications for road vehicles were researched. As table 2 shows, some of the applications include the conventional tasks of a control center and supplement them with tele-assist and/or teleoperation functions. In most cases, teleoperation is offered as a separate service by specialized companies. Teleoperation is also more likely to be used at close range, for example on a company site. Some companies offer also a platform-as-a-service to integrate customers own fleet of vehicles into their teleoperation system.

Table 2: Functions of an operation control center of selected provider of automated vehicles and remote control systems

Companies	Fleet Monitoring	Fault / Emergency Management	Dispatching / On-demand	Tele-Assist	Teleoperation	Remote Cockpit	Passenger communication	Communication authorities	Infrastructure monitoring/ control
Waymo (Google)	+	+	+	+	+	n.s.	+	+	-
Ford/Argo	+	+	+	+	-	-	+	+	-
Cruise	+	+	+	+	-	n.s	+	+	-
EasyMile	+	+	+	+	i.p.	-	+	+	-
Navya	+	+	+	+	n.s.	n.s.	+	n.s	n.s
Phantom Auto	+	n.s.	n.s.	+	+	+	n.s.	n.s.	-
Fernride	+	+	n.s.	+	+	+	-	n.s.	-
Einride	+	+	n.s	+	+	-	-	n.s.	n.s.

Legend: + - included; - - not included; n.s. – not specified; i.p. – development inprogress

Sources: (General Motors, 2018), (Jin, 2021), (Easy Mile, 2020), (Einride, n.d.), (Fernride, n.d.), (Ford, 2021), (Navya, n.d.), (Navya, n.d.), (Phantom Auto, n.d.), (THE VERGE, n.d.), (Cluff, 2021), (Argo ai, 2021), (Waymo, 2021)

However, tele-assist, when the operator assists in validating the traffic situation and decision making, is considered an essential function and is being developed by many providers. The existing OCCs have only few interfaces to the infrastructure objects in order to be able to monitor or control them.

3.4 Functional requirements for an OCC

In the first step, all essential functional requirements for a control center were collected. The requirements derived from the best-practice analysis and from the findings of the "AS-UrbanÖPNV" project were additionally supplemented with the specific requirements resulting from the use case analysis. To enable the integration of different mobility service providers, the additional information and interfaces related to logistics services were included into the requirements catalog. The requirements listed below have been identified:

Requirements for public transport

1. Monitoring of the traffic situation with the help of a digital map
2. Monitoring of vehicle sensor data (position, speed, technical status, etc.)
3. Monitoring and visualization of schedule delays
4. Monitoring of the connectivity quality (latency)
5. Classification and visualization of requests
6. Prioritization of requests
7. Vehicle dispatch and dynamic rescheduling (plannable deviations such events)
8. On-demand planning (resource overview and AI-assisted planning)
9. Fault management (technical faults, etc.)
10. Emergency management (alert concept and measures; communication with authorities and passengers)
11. Remote control or Tele-Assist e.g. by confirmation of the journey after evaluation of complex traffic situations, when intervention of an OCC was requested or maneuver-based by providing a new path for the vehicle
12. Teleoperation (with joystick or cockpit), when requested or as a regular service (e.g. parking)
13. Infrastructure monitoring (visualization and status updates traffic lights, construction sites)
14. v2x-communication monitoring (road side units, sensors, warning massages)
15. Infrastructure control (intersections, traffic lights, bollard)
16. Passenger safety (answering of the emergency calls and alerting of the authorities)

17. Passenger communication (answering requests form passengers)
18. System Diagnosis and predictive assistance / maintenance
19. Analyzing the environmental data
20. Monitoring vehicle capacity (passenger)
21. Charging and Batterie Management
22. Providing operative information and visualization of the fleet on the map
23. Demand-driven dispatching and route planning
24. Cybersecurity

Requirements for goods transport

1. Customer communication (answering requests from logistic service customer)
2. Monitoring of delivery schedules and deviations
3. Monitoring vehicle capacity (freight)
4. Providing logistics information: e.g. transport and delivery costs; delivery times; inventory; delivery quality (interface to the ERP system of the logistics service providers, if applicable)
5. Vehicle module management, if hybrid transport (automated or remote-controlled module switch, maintenance, resource overview)
6. Site and infrastructure monitoring for delivery (parking space, etc.)
7. Cold-chain monitoring

4 Building of the OCC modules

After the various functional requirements have been compiled, they are evaluated in terms of their relevance for the operations control center system. The cross-impact analysis was used for this purpose. A matrix with 31 columns and rows consisting of the requirements listed in chapter 3.4 was created. The impact of one requirement on the others was evaluated on a scale of 0 to 2, where 0 - low impact, 1 - medium impact and 2 - high impact. The row totals describe the active impact on the system and the column totals describe the passive impact. By adding the column or row totals and dividing by the number of elements, the limit score for active impact is obtained. The elements that are higher than this score have a predominantly active impact and can be described as system drivers. Our analysis resulted in 15 requirements that lie in the active area. These 15 elements build the core module of the OCC. These elements are common to mostly all application scenarios and vehicle types. Figure 1 shows the common module consisting of these 15 elements and the additional modules.

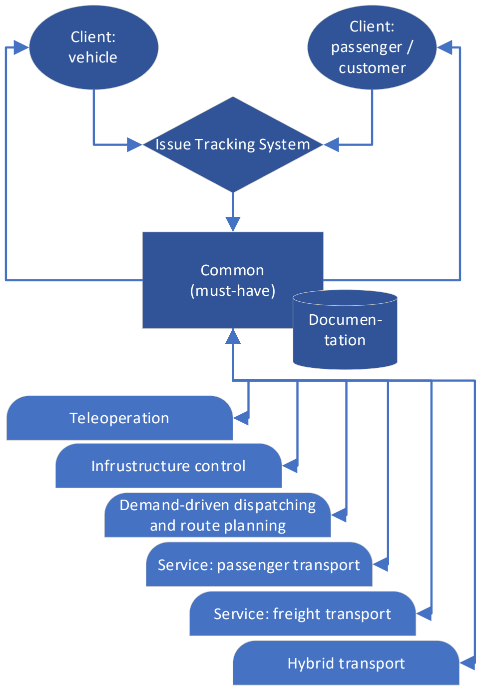

Figure 1: Conceptual modular design of an operations control center (OCC)

4.1 Standard modules

Standard modules include the functions that are essential for the OCC and for ensuring the safety of passengers, cargo and other traffic participants, as well as for the availability of the vehicle. These are also independent of the respective means of travel. Figure 1 shows a possible architecture of an OCC with a common module and further use case dependent add-on modules. These can then be added individually or in combination, for example, depending on the transport task.

The standard workflow of an OCC is to accept and process incoming requests. The requests can either come from the vehicle itself, or from a person via an interface in the vehicle or via a mobile app. For example, the vehicle may send a request at previously defined sections of the route (such as a complicated intersection or traffic circle) where additional validation of the traffic situation is required, or due to a technical error. But also a passenger may want to report an emergency or ask a question. Before the OCC can handle the request, the requests should be classified and prioritized by an intelligent algorithm, so that the most effective processing can be performed. In the prioritization, the emergency request is of course at the top of the list. For the other requests, in addition to the error message or request class itself, other environmental influences such as the current traffic situation, where the vehicle has stopped, infrastructural information, etc. should be considered.

When the requests are sorted by priority and appear in the event list, they can be processed partially automatically, e.g. by predefined automatic response messages or by outsourced intelligent assistance systems. Another part of the requests must be accepted and handled by the human operator. For this purpose, the operator can use the functions defined in the common module (see Figure 2) plus the add-on modules, depending on the specialization of the control center, to handle the issues.

The common module should enable various monitoring tasks. The vehicle fleet should be displayed on a digital real-time map. The map overview should also provide further information on current traffic reports, traffic and infrastructure information. Information on vehicle status and condition must be available on demand.

In case of deviations and error messages, appropriate measures shall be initiated. For example, a vehicle dispatching and rescheduling algorithm can solve the problems of availability of the vehicle automatically. Or the human operator uses the sensor data to assess the situation and initiate appropriate measures. For emergency situations, interfaces to the security authorities should be as automated as possible in order to initiate effective rescue measures. In order to ensure availability, safety and a high level of service, the future control centers for automated vehicles should use the possibilities of digitization and include a continuous system diagnostic. The sensor data and the environmental data can be used for predictive maintenance but also for better prioritization of the incoming requests. Controlling latency is also essential. Especially for tasks such as tele-assist and teleoperation, the operator should always be able to make sure that the delays in the video streams are within the permissible range. Tele-assist (remote control) function is a graphical user interface to interact with the vehicle and passengers. The current vehicle-related information (sensor data) should be visible on this surface and the planned control commands, such as “stop”, “start”, “open doors” or “close doors”, etc. should be implemented.

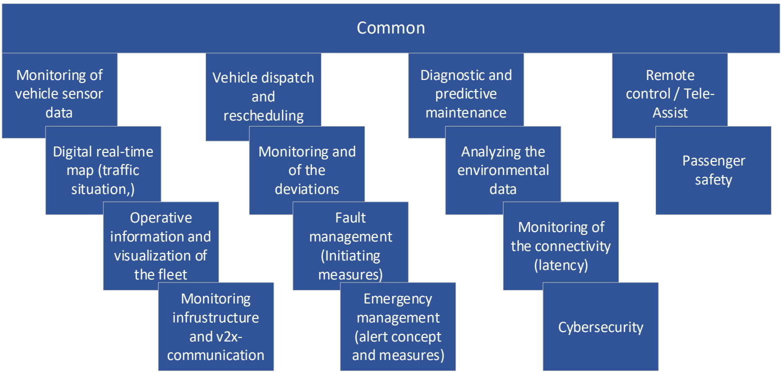

Figure 2: Components of the common module

4.2 Additional modules

The additional modules can be implemented depending on the use case. The teleoperation module is mostly useful if the vehicles are to be remotely controlled in a non-public area. This is often the case on a factory site or in a depot. Since remote control is not allowed in the public sector, at least in Europe. The installation of a remote cockpit is also suitable for teleoperation, although there are solutions with a joystick on the market.

The control of the infrastructure can make sense under certain circumstances, but requires a special permit and will therefore be difficult to implement in the majority of cases. For example, public transport companies could control the priority switching of traffic signals according to demand.

Demand-driven dispatching and route planning software can also be implemented if an on-demand service is offered. Furthermore, service modules for passenger or freight transport can be added. The passenger service module enables the operator to answer passenger requests similar to a call center. For this, the operator can rely on the public transport network information such as departure times and transfer possibilities. The freight service module enables answering of the customer requests and provides logistical information such as current vehicle capacity, delivery times and delay, delivery quality, transport and delivery costs, etc. It enables seamless monitoring of the cold chain and the infrastructure required for delivery (e.g. handling points and equipment).

5 Conclusion and further research

Since vehicle automation is an evolutionary process, it can be expected that the ODD will continue to expand in the coming years. However, as long as the technology has not yet reached the necessary maturity or automation level 5, the control center will play an essential role in the transition to regular operation and serve as a fallback. This will result in new functions for the OCC, which have only been the subject of research for a last few years. While some OCC applications already exist on the market, they are often use case specific and specialized either in fleet management and monitoring or in teleoperation. Teleoperation, however, is more commonly offered for goods transportation.

In order to meet the complexity of the requirements, the different task areas of the OCC must be more strongly networked with each other and with the environment in the sense of a digital ecosystem. Therefore, public transport companies or larger logistics companies are more likely to operate an OCC for the public domain in the future. In order to determine the essential and optional modules of the OCC, the findings from the research project “AS-UrbanÖPNV” were used on the one hand and a market analysis was carried out on the other hand. For a better understanding of the interaction of the identified functional requirements, a cross impact analysis was applied and the common (must-have) module as well as add-on modules were elaborated. The chosen methodical approach has resulted in a concept (rough system architecture) for an OCC. To create the technical and software modules, the functional requirements must be transferred into physical system components, i.e. hardware and software components, including the necessary interfaces. After this, the technical system modularization can take place by evaluating the mutual influences, e.g. with the help of a design structure matrix, and combining them with a clustering or partitioning algorithm to form technically coherent modules.

Nevertheless, by compiling the use cases for both passenger transport and freight transport, it was possible to take a comprehensive look at the functional requirements and compare them with each other. In the future, synergy effects could be achieved by combining freight transport and passenger transport, at least in densely populated urban areas, since the analysis showed that the functions of an OCC differ only slightly depending on the use case.

The common module must essentially perform the monitoring tasks, dispatching, fault management, emergency management, as well as tele-assist (remote control). The required interfaces to the environment and the bus must be ensured. In the case of tele-assist and tele-operation, interfaces in the vehicle must be exposed for communication with the OCC, which represents a possible point of attack for cybercrime. Therefore, the cybersecurity is one of the most important issues for further research. Also, the issues such as request prioritization and systems health monitoring need to be explored in relation to the very complex ecosystem consisting of a mixed traffic, the v2x infrastructure and other environmental influences.

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