

Who Will Drive Automated Vehicles? - Usability Context Analysis and Design Guidelines for Future Control Centers for Automated Vehicle Traffic

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ABSTRACT

In order to create framework conditions for the introduction of highly or fully automated vehicles in Germany, the Federal Ministry of Transport and Digital Infrastructure has drafted a bill to amend the Road Traffic Act and the Compulsory Insurance Act. A key aspect of the bill on automated driving is the introduction of Technical Supervision. This serves as a fallback level and must be able to intervene from the Control Center if necessary. Since future Control Centers for automated vehicles will differ significantly from existing Control Centers in other contexts, an appropriate distribution of tasks between the Technical Supervision and the automated vehicle on the one hand, and between the personnel within the Control Center on the other hand, must first be found. Therefore, this paper describes the requirements for framework conditions, work contents and processes, the necessary tools and the qualification of the employees of future Control Centers, which were identified on the basis of an analysis of the context of use. Since an analysis of existing systems and the participation of actual Technical Supervisors is not possible due to not yet existing Control Centers for highly or fully automated vehicles, the analysis is based on a systematic literature review and an expert workshop.

Keywords: Control Center, Technical Supervisor, Dispatcher, Teleoperator, Automated Vehicle Fleet

INTRODUCTION

In contrast to conventional motor vehicles and vehicles with automated driving systems up to SAE level 3, motor vehicles with SAE levels 4 and 5 (highly and fully automated) will no longer require a driver (SAE, 2020). As a result, they have great potential to have a positive impact on society. On the one hand, they can contribute to the mobilization of people who are unable to drive themselves (Schoitsch, 2016). On the other hand, when implemented as a shared mobility concept, they offer an alternative to private vehicles and can thus relieve the burden on the transport infrastructure, alleviate the problem of parking space and lead to a general reduction in resource consumption associated with vehicle production

and use (Yu et al., 2017). Moreover, since human error is the leading cause of accidents, automated vehicles will continue to improve road safety (Bocca and Baek, 2019).

As current European legislation requires the vehicle to be controllable by a person driving the vehicle (European Parliament, 2018), the implementation of highly or fully automated driving functions is not yet possible. However, in order to create a national framework for the introduction of highly or fully automated vehicles, the German Federal Ministry of Transport and Digital Infrastructure has drafted a bill to amend the Road Traffic Act and the Compulsory Insurance Act until the regulation is revised at European level (Deutscher Bundestag, 2021).

Due to new risks that arise with the introduction of highly or fully automated vehicles through, for example, technical failure, hacking or limited situational understanding of the automated driving function (Litman, 2021), a central aspect of the bill on automated driving is the introduction of Technical Supervision. This serves as a fallback level and must be able to intervene, if necessary, when the automated vehicle reaches its limit while operating on public roads (Deutscher Bundestag, 2021), and thus provides the opportunity to create a framework in which automated driving can succeed without a human driver, based on the technology currently available. The draft bill stipulates that the Technical Supervisor must be a natural person who can disable and enable driving maneuvers in specific situations. However, the monitoring and intervention can be carried out by the Technical Supervisor from an external Control Center (Deutscher Bundestag, 2021). The requirements for future Control Centers for automated vehicles will differ from today's Control Centers because, unlike in other contexts such as air and rail transport, trained and responsible personnel will not necessarily remain on board of the vehicle. Thus, a definition and suitable distribution of tasks between the Technical Supervisor and the automated vehicle on the one hand, and between the employees within the Control Center on the other, must first be found. Therefore, this paper describes the requirements for framework conditions, work contents and processes, the necessary tools and the qualification of the employees of future Control Centers, which were identified on the basis of an analysis of context of use.

METHODOLOGY

According to the human-centered design process model of DIN EN ISO 9241-210 (Deutsches Institut für Normung e. V., 2020), the context of use was first defined in order to derive the requirements of use. Since an analysis of existing systems and the participation of actual users was not possible due to not yet existing Control Centers for highly or fully automated vehicles, the analysis of context of use was initially based on a systematic literature review. This included publications on Control Center concepts for automated vehicles as well as publications on Control Centers for other modes of transport such as bus, rail and air. The focus was on task analysis and human-machine interaction design. In order to complement the results of the literature review,

an expert workshop was conducted with developers of highly automated vehicles on the one hand and developers of the Control Center Human-Machine Interface (HMI) on the other hand.

Due to their central role, the tasks of Technical Supervision were first defined separately according to regular and fault/exceptional operation. After defining the tasks, appropriate workflows of the Technical Supervisor were developed. Based on this, a role definition and distribution within the Control Center, separated according to task areas, was developed and corresponding requirements for the working personnel, for the location of the Control Center and size of the vehicle fleet, as well as for the working equipment were identified. The results are presented in the following.

TASKS OF TECHNICAL SUPERVISORS

The tasks of the Technical Supervisor can be divided into seven categories: Monitoring, Release and Deactivation, Indirect Control, Direct Control, Coordination, Communication and Other Tasks, which are described in more detail below.

Monitoring

Monitoring tasks form the basis for all other tasks and include receiving and observing data sent by the vehicle (Bogdoll et al., 2022). This does not involve permanent monitoring of each vehicle, but rather monitoring of the fleet to the extent that a fault message or request from a vehicle is perceived. Accordingly, the task of Technical Supervision is to perceive the message and obtain information in order to build up appropriate situational awareness to decide on further action (Deutscher Bundestag, 2021; Graf and Hussmann, 2020).

Release and Deactivation

The lowest level of vehicle control is the task of Release and Deactivation. In situations that the vehicle cannot handle on its own, e.g., because it would have to violate traffic rules to drive around an obstacle, the Technical Supervisor has the task of checking, considering, selecting and releasing the driving maneuvers proposed by the vehicle (Deutscher Bundestag, 2021). The approved maneuver is then executed by the vehicle itself. If the vehicle's proposed maneuvers cannot be enabled, the vehicle must be placed in the minimum risk state by deactivating the automated driving function or an alternative maneuver must be initiated by the Technical Supervisor as described in the following.

Indirect Control

The next level of vehicle control is the Indirect Control task category. This is necessary, for example, when none of the maneuvers proposed by the vehicle are considered suitable. In this case, the Technical Supervisor does not have direct control over the vehicle's actuators, but specifies driving maneuvers that the vehicle then performs independently (Biletska et al., 2021; Deutscher Bundestag, 2021; Kettwich and Dreßler, 2020; SAE, 2020).

There are several ways to provide the vehicle with such a maneuver. Kay (1995) proposes the STRIPE method using waypoints as higher level targets. In this approach, the vehicle transmits video footage to the Control Center and the Technical Supervisor uses the mouse to set waypoints within the camera image, which the vehicle then drives to in sequence. Gnatzig et al. (2012) describe indirect control through the specification of trajectories that the vehicle follows in turn, which can be done either by entering parameters or by drawing the trajectory on an interactive map (Biletska et al., 2021). Schitz et al. (2020) consider indirect vehicle control by specifying suitable corridors. Here, the Technical Supervisor defines an area within which the vehicle is allowed to move independently. The exact route within this corridor is then calculated by the automated vehicle system itself. In the method presented by Kim und Ryu (2013), the Technical Supervisor controls a virtual twin of the vehicle in a three-dimensional virtual world using a steering wheel and pedals. Waypoints are set on the traversed route of the virtual vehicle. The automated vehicle system eventually generates the route from these waypoints and drives it autonomously. In turn, Feiler et al. (2020) propose to apply the conduct-by-wire concept which was originally developed as a driver assistance system (Kauer et al., 2010) to the context of indirect vehicle control. This involves indirect vehicle control through a sequence of individual driving maneuvers such as lane changing, turning or following the current lane (Kauer et al., 2010).

Direct Control

The highest level of vehicle control is the Direct Control task category. Often, the Technical Supervisor has complete control over the vehicle's actuators and thus not only plans the maneuvers, but also executes them with the help of appropriate input means (Biletska et al., 2021; Kettwich and Dreßler, 2020). In contrast to Indirect Control, there is no digital twin, which is controlled first and whose route is then followed by the vehicle itself, but the Technical Supervisor controls the vehicle directly.

Coordination

The Coordination task includes organizing, planning and coordinating the operation of the vehicles in a fleet. Among other things, the role of the Technical Supervisor is to put the vehicles of a fleet into service or out of service (Biletska et al., 2021; SAE, 2020), restructure the deployment schedule in the event of vehicle breakdowns (Feiler et al., 2020) and inform vehicles of potential route closures (Feiler et al., 2020; Kang et al., 2018; Kettwich and Dreßler, 2020).

Communication

Since the driver is no longer the point of contact in highly or fully automated vehicles, Communication is another category of tasks for Technical Supervisors. In this context, they form the communication interface for all actors in the vehicle interior and environment.

Communication with passengers may consist of responding to passenger requests as well as proactively contacting passengers to inform them of incidents (Kettwich and Dreßler, 2020; Mirnig et al., 2020). It may also be necessary to ask people in the vehicle for help, for example to provide first aid or to remove an object from the door frame to allow the door to close (Kettwich et al., 2021).

Outside the vehicle, communication with other road users, passers-by or authorities, like police, fire brigade or ambulance service, may be necessary (Deutscher Bundestag, 2021; Zhang, 2020). If the vehicle is involved in an accident, the Technical Supervisor must alert and send emergency personnel to the location (Biletska et al., 2021; Deutscher Bundestag, 2021; Feiler et al., 2020). In addition this task includes passing on information about other accidents, road closures or other relevant traffic events to or receiving information from the emergency services (Kettwich and Dreßler, 2020).

If a problem cannot be solved externally from the Control Center, it is also the responsibility of the Technical Supervisor to send field staff to the vehicle to repair or rectify a fault and to support them during their work by providing information and data (Georg and Diermeyer, 2019; Kettwich et al., 2021; Kettwich and Dreßler, 2020).

Other Tasks

Other Tasks of the Technical Supervisor include the documentation and analysis of incidents during operation (Graf and Hussmann, 2020; Kettwich et al., 2021). According to the draft bill, the Technical Supervisor is required to initiate road safety measures after the vehicle has been brought to a minimum risk state (Deutscher Bundestag, 2021) such as activating the hazard warning lights.

ROLES AND WORKFLOW

There are several approaches in the literature for clustering and allocating tasks to different roles within Technical Supervision. These are listed in Table 1. In the following, these are related to the categories of tasks described above. On this basis, a new distribution of roles is proposed.

The draft bill (Deutscher Bundestag, 2021) only groups the tasks according to whether they involve driving or not. The SAE (2020), in contrast, defines four tasks. Remote Assistance includes Monitoring, Release and Deactivation and Indirect Control. Remote Driving equals Direct Control. Dispatching includes the Coordination task area and Fleet Operation includes the Communication and Other Tasks areas. Bogdoll et al. (2022) also group the task areas into four categories. Remote Monitoring includes Monitoring only. Remote Assistance includes Release and Deactivation as well as Indirect Control. Remote Driving, as in SAE (2020), equals Direct Control. All Other Tasks are grouped under the term Remote Management. Kettwich und Dreßler (2020) create five task categories. They also distinguish between Monitoring and Remote Control, which, however, in contrast to Bogdoll et al. (2022) and SAE (2020), includes both Release and Deactivation as well

as Indirect and Direct Control. They divide the non-vehicle control tasks into Dispatching, Communication and Management. Feiler et al. (2020) group the identified tasks into three categories: Emergency Service, Fleet Service, and Teleoperation Service. Emergency Service tasks include Communication and Other Tasks. Fleet Service includes Monitoring and Coordination and Teleoperation Service includes Release and Deactivation, Indirect and Direct Control.

Table 1. Clustering of task categories.

	Monitoring	Release and Deactivation	Indirect Control	Direct Control	Coordination	Communication	Other Tasks
draft bill Deutscher Bundestag, 2021	tasks involving vehicle driving				tasks not involving vehicle driving		
SAE, 2020	Remote Assistance			Remote Driving	Dispatching	Fleet Operation	
Bogdoll et al., 2022	Remote Monitoring	Remote Assistance		Remote Driving	Remote Management		
Kettwich and Dreßler, 2020	Monitoring	Remote Control			Dispatching	Communication	Management
Feiler et al., 2020	Fleet Service	Teleoperation Service			Fleet Service	Emergency Service	

One result of the expert workshop conducted was the division of Technical Supervision into the roles of Dispatcher and Teleoperator: The role of the Dispatcher includes Monitoring, Coordination, Communication and Other Tasks, while the Teleoperator is responsible for Release and Deactivation, Indirect and Direct Control and must also be able to communicate with actors inside and outside the vehicle.

The work process would therefore consist of Dispatchers first generally monitoring and coordinating the vehicle fleet. If then a situation arises in which a vehicle is reaching its limits, the Dispatcher will forward this request to the Teleoperator and, if necessary, inform passengers, passers-by, authorities or even other vehicles in the fleet. The Teleoperator receives the request and obtains the necessary information to decide whether to release a vehicle's proposed maneuver or to take direct or indirect control of the vehicle. If required, the Teleoperator also communicates with actors inside and outside the vehicle. If the fault is rectified or cannot be rectified, the Teleoperator sends the task back to the Dispatcher. In the latter case, the Dispatcher takes care of the passengers and replaces the vehicle. Depending on the frequency

of incidents, it may be useful to also give the Dispatcher the option of releasing suggested driving maneuvers, so that the handover to the Teleoperator only occurs when indirect or direct control is required.

This division of roles is based on the assumption that, in the future, Dispatchers will be assigned to a company owning or offering an automated vehicle fleet and will thus only be responsible for one specific fleet of vehicles. On the contrary, the Teleoperator could in future act more as a service provider who can be booked on demand and thus be responsible for several fleets at a time.

QUALIFICATION REQUIREMENTS

A further reason for the division into the roles described above is the necessary qualification of the personnel for the tasks described. An analysis of related occupational groups in air and rail transport shows that the predominantly cognitive work of these occupational groups requires rapid detection, recognition and identification of errors as well as communication skills (DFS Deutsche Flugsicherung, 2011; Dix et al., 2021; Hampshire et al., 2020; Wang and Fang, 2014). In particular, Dispatcher tasks require good process coordination skills. Teleoperator tasks further require the ability to cope with sudden high levels of stress after potentially long periods of low workload. Teleoperators must be able to make decisions based solely on vehicle data, maps and camera recording. Due to local distance, the ability to quickly gain situational awareness is critical (Feiler et al., 2020). Moreover, perceiving and responding to the dynamic environment could be further complicated by possible connectivity issues.

REQUIREMENTS FOR FLEET SIZE AND CONTROL CENTER LOCATION

Both the Dispatcher and Teleoperator workstations should consist of a sufficient number of workstations for the number of employees needed to monitor the vehicle fleet, as is common in existing Control Centers (Georg and Diermeyer, 2019). The number of Dispatchers or Teleoperators required for a fleet of vehicles can be estimated using the queueing model (Goodall, 2020). Here, the minimum number of employees is calculated according to the fact that the probability of not having a free employee available for a support request is lower than the probability of a driver in a conventional vehicle becoming medically incapacitated. Waymo reports that there is one intervention every 17847 km (Herger, 2019). Thus, with a turnaround time of one to ten minutes per request, Goodall (2020) suggests that 3,9 million Uber drivers could be replaced by fewer than 400 Control Center employees. Ottopia Technologies (2021) takes a more pragmatic approach with the golden ratio of Technical Supervisor to vehicle, assuming that one employee can be responsible for ten vehicles. Einride (2020) also assumes ten vehicles per employee. Overall, to avoid the employees to be underchallenged (Kettwich et al., 2021) or overchallenged, the number of vehicles assigned to an employee must be thoroughly calculated.

While it makes sense to locate the Dispatchers' workstations close to the fleet, the location of the Teleoperators' workstations is not that important as long as a stable connection to the vehicles is guaranteed.

WORK EQUIPMENT REQUIREMENTS

According to the results of the expert workshop, it also seems to be appropriate to separate the roles of Dispatcher and Teleoperator in terms of workstation equipment.

In addition to a sufficiently large monitor, keyboard and mouse, Dispatchers need good communication systems in order to perform their tasks. When designing the HMI, it is also important to ensure that the monitoring task is supported in the best possible way. For example, fault messages should be categorized according to their urgency, visually marked and in the case of high urgency, acoustically supported (Kettwich et al., 2021). Furthermore, the documentation task should be supported by a largely automated documentation of the notifications and their processing by the personnel (Kettwich et al., 2021).

The Teleoperator's workstation must be equipped with suitable input devices for controlling the vehicle, such as a steering wheel and pedals or a joystick (Feiler et al., 2020). In addition, the number and position of monitors should be designed to provide an overview of the vehicle environment as comprehensive as possible and to allow camera perspectives to be combined (Georg and Diermeyer, 2019). To improve situational awareness, it is also helpful to include additional information beyond the traffic rules. For example, traffic infrastructure information such as street names and house numbers could be displayed (Kettwich et al., 2021).

Since previous research on HMI design for Control Centers of highly or fully automated vehicles has focused on individual task areas and not distinguished between the roles of Dispatcher and Teleoperator, it is still relatively unexplored how to manage the transfer of a vehicle request from the Dispatcher to the Teleoperator, as well as the feedback of a completed or unsolvable request from the Teleoperator to the Dispatcher. Especially considering that the Teleoperator is likely to be a service provider rather than part of the company owning or offering the vehicle fleet, it is necessary to consider when a handover should take place, what information needs to be transferred and in what format.

CONCLUSION

This paper describes the tasks, roles and processes of future Technical Supervisors of highly and fully automated vehicles, as identified by a literature review and an expert workshop, and derives requirements for the location of the Control Center and the size of the vehicle fleet, the qualifications of the staff and the necessary work equipment. Technical Supervision is divided into the role of the Dispatcher, who monitors and organizes the vehicle fleet and communicates with actors inside and outside the vehicle, and the role of the Teleoperator, who has to take over the control of the vehicle in

an indirect or a direct manner. How these two roles can work together in the best possible way will be investigated in further studies during the ongoing research.

ACKNOWLEDGMENT

This research was funded by research project “Campus Free City – real lab for the research of a networked fleet of modular robot vehicles”, carried out at the request of the Federal Ministry for Digital and Transport (BMDV), under research project No. 45KI15I091. The authors are solely responsible for the content.

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