How Will Automated Trucks Change the Processes and Roles in Hub-to-Hub Transport?

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Abstract. Hub-to-hub transport will be one of the first use cases for automated driving in the transportation industry. As current in-hub processes are based on a driver being present, it is important to investigate how automated trucks are to be integrated in future in-hub processes when they arrive driverless. Following on from previous research, the in-hub tasks that will still have to be carried out manually in and around the truck were identified. By conducting individual workshops with seven experts of the logistics industry, four different processes were developed for the integration of automated trucks in future in-hub processes. The results show that hub personnel will still be needed for all of the processes. The processes developed differ in that they either include a trailer exchange or truck and trailer are not separated. The respective future roles and responsibilities are described for each process, and the necessary prerequisites and possible problems are discussed.

Keywords: Automated Trucks · Hub-to-hub Transport · Process Development · Task Distribution · Future Roles

1 Theoretical Background

Automated driving in the transportation industry offers the potential to successfully overcome current challenges, such as increasing driver shortages [1]. In SAE level 4, the automated driving system can completely take over the driving task within the defined operational design domain (ODD) [2, 3]. If system limits are exceeded, the system is able to reach a risk-minimized state and therefore does not have to be monitored. This even eliminates the need for a driver inside the vehicle. Hub-to-hub freight transport is cited as one of the first use cases for automated trucks and it is expected to occur by 2030 [4, 5]. Hub-to-hub transport refers to the transportation of goods between two or more logistics centers that are built close to and are connected by the highway. Therefore, the most part of the transport occurs on standardized and normed highways. In the case of automated hub-to-hub transport, the ODD of the automated system covers the route between two logistics centers via highways. The transportation industry is particularly interested in the

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automation of hub-to-hub transport in order to overcome driver shortages, but also for its expected benefits on an economical, environmental and social level [6]. For example, the total cost of ownership for trucks is expected to decrease in the long term, due to increased fuel efficiency and reduced labor costs [6, 7] out weighing the increased costs for sensors and automation. Furthermore, automated trucks are expected to improve traffic flow and reduce congestion, leading to better panning of transport times [6]. To benefit from these advantages, the technical development of automated driving functions is currently being pushed forward [8]. Although the technical implementation of these automated driving functions forms the basis for automated transport, a successful automation of hub-to-hub transport requires more than developing automated driving functions for the ODD. A successful introduction of automated driving in this domain depends on synchronized measures in automated driving technology, infrastructure, logistic processes and human resources. Above all, it is important to investigate how future incoming and outgoing goods processes of the hubs will have to be designed for trucks arriving driverless at the hubs. Currently, the incoming and outgoing goods processes at hubs are designed for the presence of truck drivers. For example, the driver is included in registration at the hub, handling of freight documents, or loading and unloading of the truck [1, 9–11].

This paper addresses the fact that, in the future, these incoming and outgoing goods processes will have to be redefined when automated trucks arrive without a driver at the hubs. As an introduction to this topic, the results of two previous studies are presented in the following sections. Firstly, the design of current hub processes that include the help of a truck driver is addressed in more detail [11]. Secondly, the development of the German logistics environment up until the arrival of automated trucks on the road by 2030 is presented [12].

1.1 Current Tasks and Processes

As mentioned above, current incoming and outgoing goods processes are designed based on a driver being present. Escherle et al. [11] conducted a task- and process analysis of four different logistic hubs in Germany and identified an overlying process that could be observed in each of the hubs. The authors identified four consecutive phases: registration, unloading goods, loading goods, and exiting the hub (Fig. 1). The driver is responsible for driving the truck on the hub premises between these phases. Depending on the transported goods and the organization in the hub, there can be several unloading and loading stations [9, 11].

For registration the tasks to be done vary depending on the hubs' state of digitalization [11]. Where the state of digitalization is low, more manual tasks have to be performed by the driver: The driver has to park, get out of the truck, walk to a registration office, register and hand over documents to a person working in the office. The office worker interacts with a system and informs the driver about the unloading and loading points he or she has to drive to.

The results of the task and process analysis also show that drivers often have to cope with difficult traffic situations while driving on the hub premises. These are the result of multiple different traffic participants, missing lane markings or unclear traffic regulations.

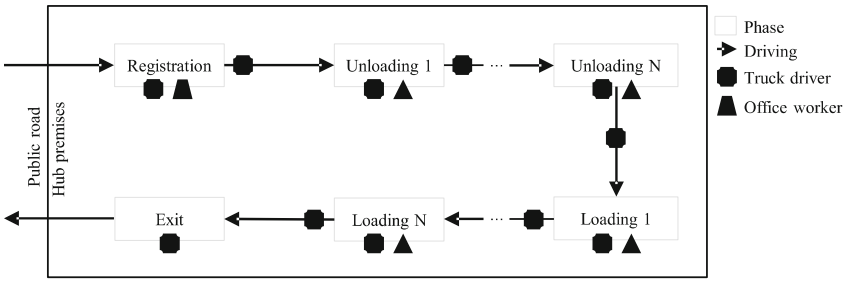

Fig. 1. Phases of incoming and outgoing goods processes of hubs in Germany based on the findings of Escherle et al. [11]. The symbols refer to the roles involved in each phase.

In the unloading phase, the driver brings the truck into the correct position. The tasks in this phase depend on the body that is used with the truck. If swap bodies are used, the truck driver opens the locks for detaching the body from the truck. Once the body is disconnected from the truck freight documents are exchanged between the driver and a hub worker and the driver can drive on to the loading point. The subsequent unloading process of the swap body is carried out by hub personnel [9, 11]. If fixed bodies are being used with the truck, truck and driver stay for the whole unloading process. In this case, the driver has to open the trailer and remove the load securing. Then the driver waits while the hub personnel unload the required part of the goods, e.g. using forklifts. The driver is then responsible for securing the remaining goods and closing the trailer. At the end of the unloading phase, freight documents are again exchanged between hub personnel and the driver. Unloading can take place at several unloading points until the trailer is empty.

After the unloading phase, the driver drives the truck to its loading position. The loading phase includes similar tasks to the unloading phase: either the driver has to attach a preloaded swap body to the truck, or the driver has to open the trailer and secure the load, while hub personnel are then responsible for loading the trailer, e.g. with forklifts, and then the driver closes the trailer again. In either case, the freight documents have to be exchanged between the driver and the hub personnel to complete the loading phase. Then the driver drives the truck off the hub premises. These tasks of the current process and the responsible roles are summarized in Table 1.

For automated trucks arriving driverless in the future, several challenges arise from the design of the current processes [11]. These include spontaneous changes in the unloading or loading position that are currently communicated to the driver in an ad hoc manner. Especially where fixed truck bodies are used, processes tend to be less standardized and the driver is spontaneously involved at a deeper level in the process and asked to help with other tasks. Furthermore, deficiencies in the hub infrastructure such as missing lane marks or the many traffic participants could be problematic for driverless trucks in the future. Digitalization plays an important role in the integration of automated trucks into the hub processes [11]. Especially in the registration phase and for document exchange at the loading and unloading points digital solutions might offer great potential to substitute tasks currently assigned to the driver. However, it remains open to question as to whether these digital solutions as well as the outcomes from other

trends in logistics will be available by 2030 when the first automated trucks are expected in hub-to-hub transport.

Table 1. Tasks and responsibilities in the phases of the current in-hub processes [11].

Phase	Task	Responsible
Registration	Parking	Truck driver
	Exchange of documents	Truck driver + office worker
	System registration	Office worker
	Information on (un)loading points	Office worker to truck driver
Driving	Steering truck	Truck driver
	Navigation on hub	Truck driver
Unloading	Park truck in correct position	Truck driver
	Open trailer / detach swap body	Truck driver
	Unloading	Hub personnel
	Load securing	Truck driver + hub personnel
	Close trailer	Truck driver
	Document exchange	Truck driver + hub personnel
Loading	Park truck in correct position	Truck driver
	Open trailer / attach swap body	Truck driver
	Loading	Hub personnel
	Load securing	Truck driver + hub personnel
	Close trailer	Truck driver
	Document exchange	Truck driver + hub personnel

1.2 Future Logistics Environment of Automated Trucks

To identify which of these current tasks will remain in place for the future in-hub processes involving automated trucks, an understanding of the logistics environment by 2030 in Germany is crucial. Current trends in logistics include globalization [13–16], digitalization [17–19], environmental as well as social sustainability requirements [16, 20], and combined transport [21–23]. Further, the adaption of logistic processes and the development of infrastructure play an important role in logistics [4, 24, 25] as do changes in society and the availability of skilled personnel [20, 26]. To investigate the future logistics environment of automated trucks, Escherle et al. [12] conducted a Delphi-based scenario study for the year 2030.

The results indicate that by 2030, environmental and social sustainability will be an increasingly important factor that has to be considered when designing future in-hub processes for automated trucks. In this context, the proportion of trucks with electric drives will increase significantly by 2030. According to this study, the transportation of goods in Germany will remain focused on road-transport. A major shift to combined transport

with rail is not expected [12]. In terms of digitalization, the results show that tracking and tracing as well as digital connection along the supply chain will be widespread, and freight and customs documents will be digital across large parts of Europe. Digital coordination of trucks on hub premises will be possible by 2030, however, smaller hubs might still not be able to provide the required infrastructure.

The first application area for automated trucks will be in hub-to-hub transport [12]. However, only a small percentage of trucks will be automated by 2030. Consequently, automated trucks as well as manually driven trucks will be used to deliver goods to the hubs. Regarding in-hub processes, unloading and loading of the truck will still be carried out manually and require personnel by 2030. Unfortunately, the lack of skilled personnel is expected to increase even more in the future [12]. Where public infrastructure is concerned, only limited changes will occur before 2030. The main changes in infrastructure are expected to be the provision of the required charging infrastructure for battery electric vehicles in hub-to-hub transport. As the charging network might not be sufficient to cover all areas of operation, charging might also have to take place at the hubs [12].

1.3 Considered Scenario

Even if it seems counterintuitive, automated driving within the controlled environment of hubs might be more complex than driving between hubs. Given the many different traffic participants and difficult traffic situations [11], driving inside a hub is comparable with driving in a city. Therefore, it is expected that by 2030 automated driving on hub premises will not be possible for many hubs without more substantial changes in hub infrastructure. However, hub operators are not willing or financially not able to make big investments in hub infrastructure in order to enable automated driving [9].

Based on the presented research, we address the following scenario for 2030: automated trucks are used in hub-to-hub transport. The automated truck arrives without a driver at the hub. However, automated driving on the hub premises is not possible. There is mixed transport, meaning automated as well as manually driven trucks deliver goods to the hubs. Given the progress in digitalization, the registration and the coordination of the trucks at the hub takes place digitally. Moreover, all of the freight and customs documents are digital and can be accessed through a digital system. The tasks related to unloading and loading the truck still have to be carried out manually.

As Escherle et al. [11] suggest, investigation is required to determine which of the current tasks will still have to be carried out manually in the future scenario (2030), how the in-hub processes with automated trucks should be configured, and who will be responsible for what task.

1.4 Research Questions

Automation not only replaces but also changes activities that are performed by humans or it introduces new tasks. These tasks should be designed to match human capabilities and requirements [27]. Thus, automated trucks may also change the future roles and tasks of the people involved in the delivery process. It is therefore necessary to identify which of the tasks in and around the automated truck will still have to be carried out

manually in the scenario under consideration and who will be responsible for them. In this context, the organization of future incoming and outgoing goods processes with automated trucks needs to be addressed. Therefore, the research questions of this paper are:

1. How should the incoming and outgoing goods process for automated trucks in hub-to-hub transport be designed?
2. What impact does this process have on the roles and task distribution on the hubs?

These questions about the process that follows the arrival of an automated truck at a hub have received little attention in the literature to date. However, it is crucial that these questions are clarified before automated trucks enter the market to enable automated hub-to-hub transport.

2 Method

In a first step, the remaining manual tasks for the future scenario were identified. To do so, the tasks relating to the current processes at the hubs [11] were examined under the future conditions of the considered scenario (see 1.3). Based on the different aspects of the future state of development, it could be defined whether a task will be digitalized or still require manual operations. Subsequently, seven individual workshops with experts from the logistics industry were conducted. The workshops took place online using a virtual whiteboard and each one lasted approximately one hour.

2.1 Expert Panel

In total, seven experts participated in the workshops, six male and one female. The experts were employees of German car and truck manufacturers as well as logistics service providers. The mean age was $M = 43$ years ($SD = 9.65$) and their average work experience in the logistics field was $M = 18.5$ years ($SD = 8.16$). Table 2 shows their main areas of expertise.

Table 2. Main area of expertise (multiple answers possible).

Main area of expertise	Number of experts
Logistics management	2
Site planning	2
Inbound logistics	2
In-house logistics	4
Innovation	3
Process planning	2
Transport planning	2

2.2 Content of the Workshops

In the introduction, the participating expert was informed about the content and procedure of the workshop and subsequently signed the consent form which was then digitally sent to the workshop leader. After demographic data has been collected, the scenario described in Sect. 1.3 was presented to the experts. The current processes and tasks (Sect. 1.1) were explained followed by the remaining manual and unassigned tasks for the future in-hub processes (Table 3). After the experts had been provided with this information, they were asked how they would organize the in-hub process with automated trucks in the presented scenario based on the information provided and their own experience.

The experts each developed different processes for the integration of automated trucks in the future scenario. For each process, the related task allocation and responsibilities were discussed. Further, the prerequisites, possible problems and limiting factors were documented for each of the developed processes and the associated future job profiles were addressed.

2.3 Data Analysis

The processes developed were documented in detail during the course of each expert workshop. This documentation was further reviewed after the workshops were concluded: for each process, the underlying characteristics were identified and extracted. Following the inductive category development [28] four clusters based on the underlying characteristics could be identified for the processes. With the experts' description of the different processes in the workshops, the four overlying clusters could be further specified. The advantages, disadvantages, corresponding future tasks and roles named by the experts were compiled for each of the four clusters and the corresponding four processes were visualized.

3 Results

The results below present which tasks will be digitalized and which tasks will still require manual operation in the considered scenario. Furthermore, the processes developed for the integration of automated trucks and the related future roles and task allocations are presented.

3.1 Remaining Manual Tasks

With reference to the various phases of the current in-hub processes (Fig. 1), the remaining tasks and the responsibilities in the considered scenario are summarized in Table 3. As Table 3 shows, tasks previously assigned to the truck driver will partially be replaced by the digital system. The remaining manual tasks and responsibilities of the truck driver in terms of unloading and loading the truck as well as the task of driving the truck on the hub premises need to be reassigned, which was addressed in the workshops.

Table 3. Tasks and responsibilities in the phases of the future processes with automated trucks.

Phase	Task	Responsible
Registration	Recognition of vehicle	Digital system
	Exchange of documents	Digital system
	System registration	Digital system
	Information on (un)loading points	Digital system
Driving	Steering truck	**Unclear**
	Navigation on hub	**Unclear**
Unloading	Park truck in correct position	**Unclear**
	Open trailer / detach swap body	**Unclear**
	Unloading	Hub personnel
	Load securing	**Unclear**, poss. hub personnel
	Close trailer	**Unclear**
	Document exchange	Digital system
Loading	Park truck in correct position	**Unclear**
	Open trailer / attach swap body	**Unclear**
	Loading	Hub personnel
	Load securing	**Unclear**, poss. hub personnel
	Close trailer	**Unclear**
	Document exchange	Digital System

3.2 Future Processes with Automated Trucks

A general overview of the processes developed in the expert workshops for the integration of automated trucks into future in-hub processes is shown in Fig. 2. The results show the handling of the trailer as a central distinctive feature. Either automated truck and trailer remain connected or are separated from each other. If truck and trailer remain connected, the truck is used for moving the trailer on the hub. This process is further distinguished between manual steering and remote steering of the truck. If truck and trailer are disconnected, the trailer is moved by a shunting vehicle inside the hub, which is either steered manually or remotely. The resulting four possible processes are further described below. Overall, the processes not including trailer exchange were rated most suitable for the integration of automated trucks by four experts, the processes including trailer exchange by three of the seven experts.

In line with the described scenario, each of the processes presented below starts with the automated truck arriving driverless at the hub and its parking in a predefined position. The arrival of the truck is registered automatically by the system and the hub personnel are notified.

Process 1: Truck and Trailer Stay Connected, Truck is Steered Manually. This processes was described by 5 of the 7 experts and is visualized in Fig. 3.

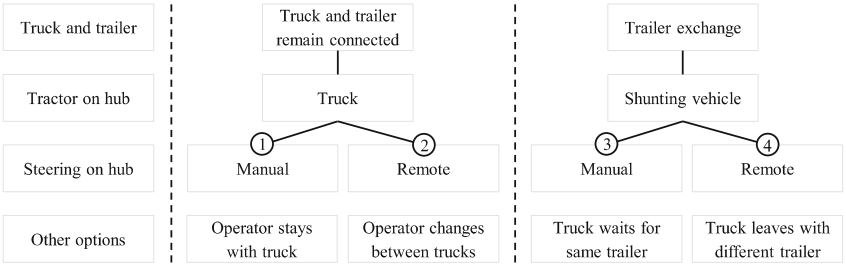

Fig. 2. Overview of the processes developed for the integration of automated trucks into future in-hub processes by the experts of this study.

In process 1, a hub driver gets into the truck and steers it manually on the hub premises. This hub driver remains with the same truck for the whole process and takes over all of the tasks that are currently performed by the conventional driver. The hub driver therefore is responsible for driving the truck to the correct loading and unloading points, and for opening and closing the trailer. Moreover, the driver helps the hub personnel with loading and unloading, and is responsible for correct load securing. When the unloading and loading phases are completed, the hub driver drives the truck back to the handover site, gets out and activates automated driving mode. The truck then leaves the hub in automated driving mode, and the hub driver repeats the process on the next arriving automated truck. The distribution of tasks in process 1 is also listed in Table 4.

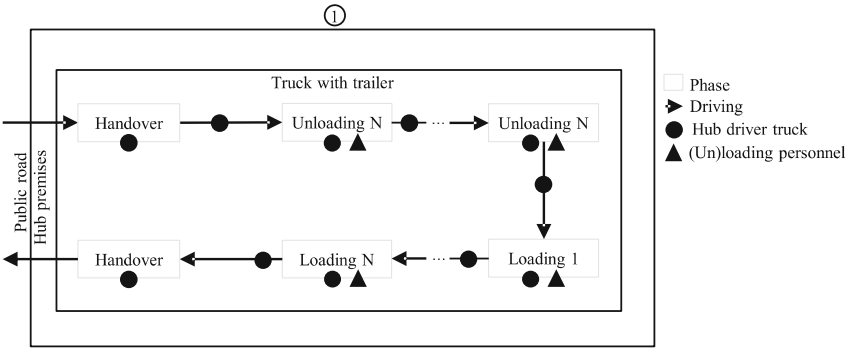

Fig. 3. Visualization of Process 1: Truck and trailer stay connected, truck is steered manually. The symbols refer to the roles involved in each phase.

A variation of this process was also discussed by two of the experts: The hub driver could also change between trucks when they are in the process of (un)loading. However, it could not be clarified how the driver would get from one truck to another. For big hubs in particular, additional vehicles or some sort of shuttle service would be necessary. The experts, therefore, considered this alternative not applicable.

Process 2: Truck and Trailer Stay Connected, Truck is Steered Remotely. This process was described by 6 of the 7 experts. The process is shown in Fig. 4.

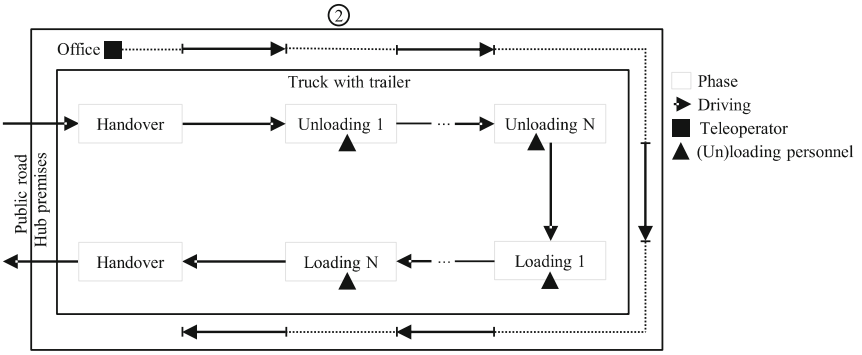

Fig. 4. Visualization of Process 2: Truck and trailer stay connected, truck is steered remotely. The symbols refer to the roles involved in each phase.

In this process, the truck is steered remotely on the hub premises by a teleoperator. The teleoperator connects with the arriving truck and steers it to the first unloading point. There the truck is unloaded by the unloading personnel of the hub. The hub personnel are responsible for opening and closing the truck, for (un)loading and load securing. Meanwhile, the teleoperator can switch to another truck that needs to be remotely steered on the hub premises. When the (un)loading is completed the teleoperator drives the truck to the next point where the (un)loading procedure is repeated. Once loading is completed, the teleoperator drives the truck back to the handover site, and activates automated driving mode. The truck drives off the hub premises and the teleoperator connects with the next arriving automated truck to start the whole process again.

A variation of this process mentioned by two experts is that driving on the hub premises could also be possible with other technical solutions. These could include induction loops or other changes in the hub infrastructure to enable movement of the truck without a driver or teleoperator.

Process 3: Disconnection of Truck and Trailer, Manual Shunting Vehicle. In this process, truck and trailer are disconnected and a manually driven internal shunting vehicle moves the trailer on the hub premises. This process was described by 6 of the 7 experts and is shown in Fig. 5.

Once an automated truck arrives at the hub and reaches its defined position, the trailer is disconnected from the truck with the help of hub personnel. A hub driver transports the trailer with an internal shunting vehicle and brings it to the correct (un)loading points. The (un)loading is done by hub personnel who are also responsible for opening and closing the trailer, as well as for load securing. While the trailer is being (un)loaded, the hub driver of the shunting vehicle can move other trailers on the hub. When loading of the trailer is completed, the hub driver takes the trailer back to the truck, where they are reconnected by personnel on site.

For this process the experts mentioned two alternatives. Either the truck stays at the hub until the same trailer is unloaded, loaded and brought back again. This waiting time could be used to recharge electric trucks. The other option is that the trailer is

exchanged. In this case, after disconnection of the transported trailer, the truck is immediately connected to another preloaded trailer and can drive off directly. The trailer that was transported to the hub is unloaded afterwards.

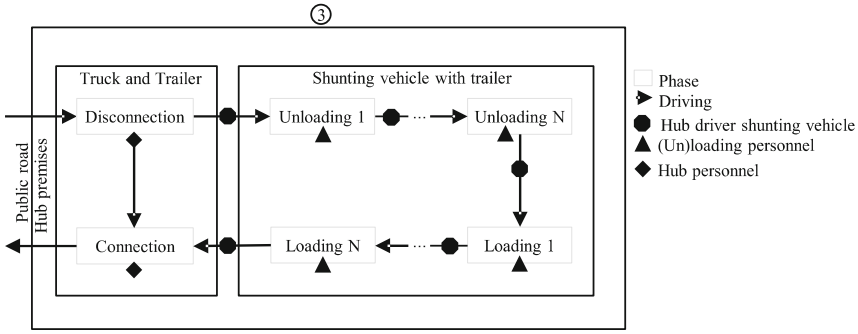

Fig. 5. Visualization of Process 3: Disconnection of truck and trailer, manual shunting vehicle. The symbols refer to the roles involved in each phase.

Process 4: Disconnection of Truck and Trailer, Teleoperated Shunting Vehicle. This process differs from process 3 in that the internal shunting vehicle is steered remotely by a teleoperator. 2 of the 7 experts described this process which is visualized in Fig. 5.

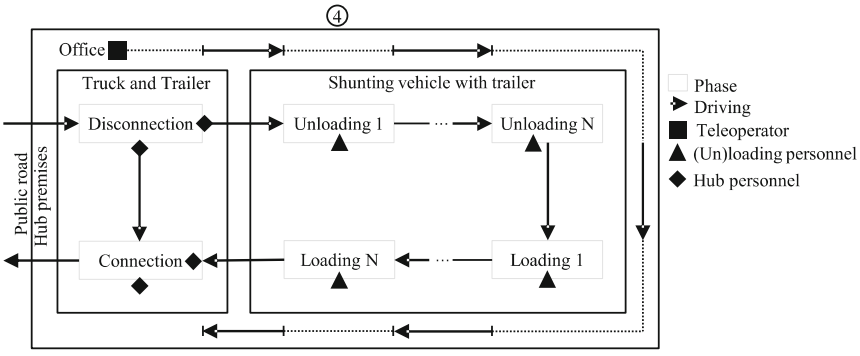

Fig. 6. Visualization of Process 4: Truck and trailer are disconnected, teleoperated internal shunting vehicle drives the trailer on the hub premises. The symbols refer to the roles involved in each phase.

The trailer is disconnected from the automated truck with the help of on-site hub personnel. The trailer is then connected to an internal shunting vehicle that is steered remotely by a teleoperator. According to the experts, hub personnel might be needed to connect the trailer and shunting vehicle. During the following in-hub process, trailer and shunting vehicle remain together. Therefore, the teleoperator drives the trailer to the (un)loading points and can switch steering between different shunting vehicles during

waiting times. The opening, (un)loading, load securing and closing of the trailer is done by hub personnel at the (un)loading points. The teleoperator then takes the shunting vehicle and trailer back to the automated truck. Here, the trailer is disconnected from the shunting vehicle and connected to the truck. Hub personnel might be needed for this step.

Just as in process 3, the automated truck either waits until the same trailer is loaded or the trailer is exchanged for a preloaded one. According to two experts, there might also be other solutions for shunting vehicles moving driverless on the hub premises in the future, such as use of induction loops or changes in the hub infrastructure as already mentioned for process 2.

3.3 Future Roles and Task Distribution

The presented processes indicate that the integration of automated trucks into the in-hub processes still requires on-site personnel. Table 4 shows an overview of the assignment of tasks and responsibilities in the different processes. The task assignment of process 1 is most similar to the current process. In this case, the original driver is replaced by a new role of an in-hub driver. All of the original driver tasks are assigned to this in-hub driver. The role of the (un)loading personnel remains unaffected.

In processes 2 - 4, the person responsible for driving does not stay with the trailer for un(loading). In these processes, the (un)loading personnel are assigned additional tasks. Instead of just (un)loading the trailer, the personnel also have to open and close the trailer and are solely responsible for correct load securing.

With the processes including teleoperation (2 and 4), the new role of the teleoperator has to be introduced. For the processes including trailer exchange (3 and 4), new roles have to be introduced for the disconnection or connection of the trailer. If the shunting vehicle is driven manually (process 3), the role of the in-hub driver of the shunting vehicle is introduced. In addition to driving, this driver is also responsible for connecting and disconnecting the trailer to/from the shunting vehicle. According to the experts, additional hub personnel should take over the (dis)connection of trailers and automated trucks. In the case of teleoperation (process 4), the teleoperator might also need support from on-site hub personnel for the (dis)connection of trailer and shunting vehicle.

4 Discussion

The presented processes are in line with other scenarios in the literature [9], and are subject to different prerequisites and possible problems that were discussed with the experts in the workshops. Furthermore, the roles in future processes and the corresponding job descriptions were further elaborated. The different aspects are described below.

4.1 Future Processes: Prerequisites, Advantages and Open Questions

General. According to the experts, enough available open space on the hub premises is one of the main requirements for the implementation of implement any of the presented processes. In particular, enough space is required for the handover site or the trailer

Table 4. Task distribution, responsibilities and corresponding roles in the different processes.

Phase	Task	Processes				
		current	1	2	3	4
Arrival	Disconnect truck + trailer	-	-	-	◆	◆
	Connect trailer + shunting v.	-	-	-	●	◆ ■
Driving	Steer	⬢	●	■	●	■
	Navigate on hub	⬢	●	■	●	■
Unloading	Park in correct position	⬢	●	■	●	■
	Open trailer	⬢	●	▲	▲	▲
	Unloading	⬢ ▲	● ▲	▲	▲	▲
	Load securing	⬢ ▲	● ▲	▲	▲	▲
	Close trailer	⬢	●	▲	▲	▲
Loading	Park in correct position	⬢	●	■	●	■
	Open trailer	⬢	●	▲	▲	▲
	Loading	⬢ ▲	● ▲	▲	▲	▲
	Load securing	⬢ ▲	● ▲	▲	▲	▲
	Close trailer	⬢	●	▲	▲	▲
Departure	Disconnect trailer + shunting v.	-	-	-	●	◆ ■
	Connect trailer + truck	-	-	-	◆	◆
Number of different roles involved		2	2	2	3	3

⬢ Truck driver ● Hub driver truck ⬢ Hub driver shunting vehicle ■ Teleoperator
▲ (Un)loading personnel ◆ Hub personnel

exchange. Furthermore, this transfer area also has to have the required infrastructure, including clear lane markings, predefined positions that the automated trucks park in, the digital system for registration and planning, as well as an interface between this system, truck, and involved personnel. Depending on hub conditions, the installation of such a transfer area might require high investment. The experts consider it possible that for some hubs the space currently used as a waiting area for manual trucks can be considered for this step. To reduce the risk of congestion and long waiting times, the arrival and processing of trucks should be well planned. There also has to be a solution to the problem of where an automated truck should wait if the transfer area is full. Therefore, an interface between the digital hub system, truck and hub personnel is also required.

Furthermore, the experts address the issue of liability. In the current process the conventional truck driver as well as the (un)loading personnel of the hubs are both responsible for correct loading and load securing. With no conventional truck driver involved in the future process, the responsibility for loading and load securing has to be transferred to the hub personnel in its entirety. This transfer of liability also requires change in German law. In this context, the traceability of the whole loading process

needs to be ensured. In case of inspections, damages or accidents with the load the hub personnel responsible for loading and load securing need to be documented in the system.

Further, with the presented processes for automated trucks more in-hub personnel are required than is the case for the current situation. Therefore, enough personnel for driving the truck on the hub premises, for (dis)connecting trailers and (un)loading is a prerequisite. An open question in this context is who will employ the required personnel. The experts consider both an external service provider and the hub as possible solutions. With hub personnel being exclusively responsible for processing automated trucks in the hubs the common problem of drivers getting lost on the hub premises can be minimized.

Another requirement is that the automated truck still has to provide the option for manual control. In process 1, the hub driver has to get inside the truck to steer it on the hub premises. In processes 3 and 4, manual control might still be necessary for reconnecting truck and trailer. In this step, the truck has to drive backwards to the trailer, meeting it at the correct angle and height. The experts doubt that automation will be sufficiently advanced to cover this use case by 2030 and therefore expect manual driving will still be necessary. Moreover, the experts agree that there will be other use cases where automated trucks have to be driven manually. Examples include technical mistakes, accidents or simply driving the truck on roads where automation is not yet possible. In conclusion, a cabin with steering devices for manual driving is still needed for automated trucks in 2030.

According to the experts, one important factor regarding mixed transport is that the future incoming and outgoing goods process is the same for both manual and automated trucks. Two different processes would not be efficient are not conducive and would result in unnecessary high complexity.

Processes Without Trailer Exchange. Regarding processes 1 and 2 where truck and trailer remain connected, it has to be taken into account that hub personnel are driving the truck on the hub premises. Depending on the ownership of the trucks, this will involve driving of third-party property. In this case, regulations for the procedure in case of damage and respective tracing of responsibilities have to be defined.

Further, it should be noted that because the truck is integrated into the in-hub processes, the time share of automated driving between hubs is therefore less than in the processes with trailer exchange. However, the experts see the general advantage that the in-hub processes require less time and fewer personnel (Table 4) because the trailer exchange step is not a part of the process.

Processes With Trailer Exchange. Regarding the processes that include a trailer exchange (process 3 and 4), a sufficient number of shunting vehicles have to be available. Providing these shunting vehicles will represent a high investment for many hubs. This investment will be even higher for teleoperated shunting vehicles (process 4) for two reasons: firstly, each teleoperated shunting vehicle stays connected to one trailer during the in-hub process because the connection requires the help of an on-site person. Therefore, more shunting vehicles are necessary for the same amount of trailers compared to manually driven shunting vehicles that can switch between trailers while they are being (un)loaded. This is also the case when the shunting vehicle is not teleoperated but the driverless driving on the hub premises is enabled in some other way. Secondly,

teleoperation in general requires the enabling infrastructure which entails even greater investment.

If the truck takes a trailer other than the one it delivered, it can leave the hub in less time when the outgoing trailer is already prepared and preloaded. In conclusion, the time share of automated driving is higher and in total more freight can be transported. Also, the experts note that idle times for trailers are not as expensive as for trucks. To profit from this advantage in processes 3 and 4, the trailer has to be preloaded by the hub personnel, which requires correct planning and time management. Moreover, two trailers have to be available per truck.

Processes With Teleoperation. As mentioned above, teleoperation requires the enabling infrastructure such as the underlying technology, a stable connection, available work space and corresponding training and education for the teleoperator. These prerequisites might require higher investments according to the experts and depend on the development of the technology. It still has to be assessed whether this option is applicable for the different kind of hubs. Also discussion is needed about how the process is handled when technical problems with the system occur. According to the experts, a back-up solution with on-site personnel might be necessary for these cases. In general, processes with teleoperation are desirable but might take longer to implement compared to processes with manually driven vehicles.

4.2 Future Roles and Characteristics

Depending on the process, new roles will have to be introduced. These include the in-hub drivers of the truck or shunting vehicle, hub-personnel for (dis)connecting trailers or the role of the teleoperator. The role of (un)loading personnel already exists in the current process. Depending on which process will be implemented to integrate automated trucks, the (un)loading personnel may be assigned additional tasks. These also include physically demanding tasks such as opening and closing the trailer.

In general, the roles in the future processes have the following advantages: the related future jobs will have the hub as a fixed work location and therefore allow proximity to home and family as well as regular working hours. Also, in the future roles nobody will have to deal with overcrowded highway parking lots as in the current role of truck driver.

Looking at a typical future workday in the presented processes, the workers repeat the same cycle of tasks for each arriving truck. For the hub driver in process 1, this means he or she will have to get in and out of the truck many times each working day, because the in-hub driver is involved in the (un)loading process. This is also the reason for a more diverse set of tasks and responsibilities compared to the in-hub drivers of process 3. It should also be noted that the latter drivers stay with their shunting vehicle the whole time and can settle into it, while the hub driver in process 1 has to change trucks very frequently. The teleoperator in processes 2 and 4 will remain in the same work place. As this will be a completely new job, this new profile is associated with many open questions.

4.3 Limitations

The processes were developed based on the opinions and experience of the experts involved. Even though the experts were selected based on their expertise in the relevant field, there is still the possibility that some factors of the future processes could have been missed due to the expert selection. However, the developed processes are in line with the current trends in logistics [12] and the scenarios found in the literature [9].

Furthermore, the developed processes are based on the future scenarios of Escherle et al. [12]. Therefore, the processes of this paper are based on the following prerequisites: trucks are able to drive automated between the hubs, freight and customs documents are digitalized and a digital system for the registration and coordination of trucks as well as an interface to the personnel on the hubs is available. As Escherle et al. [12] also show, this might not be the case for every hub by 2030 and the processes would have to be adjusted accordingly. Moreover, two of the developed processes include teleoperation. Whether or not this technology will be available and ready for use in hubs by 2030 was not part of the scenario study [12] and is therefore worthy of further investigation.

5 Summary and Outlook

In this research, seven expert workshops were conducted to address the future integration of automated trucks into in-hub processes. The results can be clustered into four main processes that are differentiated based on the following two factors. Either the process includes the exchange of the trailer or not and either the tractor vehicle on the hub is driven manually or remotely. Each of the processes was described and the associated roles were described with their assigned tasks and responsibilities in the process. Moreover, the advantages and disadvantages of the processes were elaborated.

The processes developed in the expert workshops clearly indicate that on-site personnel are still needed for the integration of automated trucks into the in-hub processes. Viewed from a distance, the future processes do not differ significantly from the current incoming and outgoing processes. The requirement that goods have to be transported to different points on the hub will remain unchanged. Even if in-hub driving can be implemented with teleoperation technology or some other solution that enables truck driving driverless on the hub-premises, the underlying process will remain the same compared to processes with manual control.

Viewed in more detail, the roles and responsibilities do change slightly for the different processes. In processes where the in-hub driver is with the trailer for (un)loading he or she can take over related tasks and responsibilities. If this is not the case, the tasks have to be assigned to hub personnel at the different (un)loading points.

As every hub has different prerequisites, an individual decision will have to be made about which process is most suitable and applicable for integrating automated trucks. The fact that hub operators want to avoid major changes and reconstruction measures for the integration of automated trucks [9] could serve as a criterion for deciding which process to adapt for a particular individual hub.

With processes including trailer exchange, waiting times can be reduced [29] and the automated truck can leave the hub premises after a short time. In this way, the truck can fulfil its purpose (automated driving) most efficiently and more goods can be

transported in the same time. However, the trailer exchange concept requires more space and investment in a sufficient number of shunting vehicles. Also, in trailer exchange processes, more hub personnel are needed to handle the (dis)connection of trailer and truck. Technology that allows automated (dis)connection, including an automatic fold out of the trailer supports, would remove the necessity for additional personnel. Therefore, trailer design and functionality represents a further field of research that should be focused on in this context.

Processes that do not include trailer exchange have the advantage that they require less investment, are easy to adapt to current processes and therefore are especially suitable according to the experts. In these processes, there is one step less to be organized and one step less that might potentially be the source of further problems and errors.

Regardless of which of the processes is implemented, the experts recommend that the in-hub processes for manual and automated trucks should be the same.

In the presented scenario and the developed future processes, the role of driver changes from a role spending many hours inside one truck to one in which only short distances are driven inside a hub. Depending on the implemented process, the driver has to change between trucks very often (process 1), has to drive a shunting vehicle (process 3) or even steer remotely from a teleoperation work place (processes 2 and 4). In this context, it should be noted that the hub driver either has to get in and out of a truck many times (process 1) or stays inside a shunting vehicle for most of the time (process 3). As a result, the processes have different requirements for the cabin design of each vehicle. Future research should therefore investigate how the driver cabin or the shunting vehicle should be designed to support the workers in their future tasks and to support their wellbeing.

It is not only the role of the driver that will change, but also other roles that are included into the incoming and outgoing goods processes of the hubs. For example, in processes 2–4, the scope of tasks increases for the personnel at the (un)loading points. Future research should therefore address whether the respective personnel will actually have the capacity and time to carry out these additional tasks and whether these tasks are in line with human capabilities and requirements [27]. Also of interest is which additional qualifications might be required for the related job and the newly introduced roles in the future processes. In particular, the role of teleoperator does not yet exist in current processes and raises many new research questions. These include, for example, how the work place of the teleoperator should be designed to enable safe steering on the hub premises.

As already mentioned, personnel will still play a crucial part in future processes for the integration of automated trucks. However, by the time automated trucks are on the roads, the labor shortage will have become more acute [12]. Future research should therefore investigate whether the related job profiles will be attractive for future workers, which education will have to be provided and how the attractiveness can be enhanced.

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