Tele-operated driving in logistics as a transition to full automation: An exploratory study and research agenda

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Abstract

Experts believe tele-operated driving systems have the potential to improve logistics operations and that it is the next step towards autonomous transport. However, the literature on their applications in logistics operations is still scarce. Therefore, we identified the technical, operational, economic, social, safety and legal requirements for deployment of tele-operated driving systems in logistics operations by means of interviews with various stakeholders in tele-operation technology and software, logistics service providers and research institutions. The result is an explorative study of the deployment requirements of tele-operated road transport. We compliment this paper with a discussion on future implications of teleoperated road transport in supply chain operations. Finally, based on the findings of this study, we identify key areas for further research, which constitute the research agenda for this topic.

Keywords

Tele-operated driving systems, Logistics operations

Introduction

Connected and automated driving is expected to revolutionize transportation and logistics by providing benefits such as safety, traffic efficiency, comfort, and reducing emissions as well as enabling novel concepts such as robo-taxis, car-sharing and truck platooning [1]. Recent advancements in vehicle and communication technologies have enabled connected and automated driving in certain controlled environments (e.g., driving in motorways under normal weather conditions). However, some technological challenges for enabling connected and automated driving in all driving domains and under all conditions remain unresolved.

According to SAE's definitions of driving automation [2], levels 0 to 2 require the driver at all times, level 3 requires the driver to take control in case of automated driving system failures, and level 4 allows automated driving without human monitoring in limited driving domains. However, empirical research into the automated driving system disengagements occurring during the automated vehicle tests in the United States indicate that the existing vehicles are not capable of performing all dynamic driving tasks reliably and flawlessly in all conditions, particularly in complex urban environments [3], [4].

Tele-operated driving (TOD) could be complementary to automated driving (e.g., a tele-operator taking control in particularly complex driving situations) as well as a transition technology to fully automated driving [5], [6]. Modern teleoperation (TO) has been in use since the 1940's and has been applied in various fields, such as space exploration, military operations, mining, surgery and terminal operations [7], [8]. TO refers to a system where a human controls a robot from a distance. In TOD, the robot is a vehicle, which is driven by a human using a communication link via a TO interface [6].

TOD is expected to have major implications for logistics operations. It is suggested in [9] that tele-operated taxi fleets could revolutionize urban mobility by offering a cost-effective and safe door-to-door transportation service. The authors use an empirical evaluation to conclude that the implementation of the service can reduce the number of drivers by up to 27%. TO can also enable passenger car and truck platooning [5], [10], which can significantly reduce logistics operations costs and environmental impact. When it comes to truck drivers, demand in the Netherlands and Belgium is growing steadily while the supply is lagging behind due to poor labor conditions, long working hours and long periods away from home. This has led to persistent shortages of truck drivers [11]–[13]. TOD has the potential to solve these problems by transforming truck drivers to tele-operators, thereby reducing the number of required drivers, reducing vehicle and equipment idle times, and eliminating the need for difficult working conditions and working away from home.

Although the literature on feasibility of TOD for logistics operations is still scarce, many experts believe TO holds great promises for improving logistics services and enabling novel logistics concepts. The purpose of this paper is to define the key requirements for successful deployment of TOD in logistics.

Methodology

At the start of this research, we performed a literature study on TOD as thoroughly described in the introduction, but we found that literature regarding TOD in logistics is scarce [8]. To fill this gap in literature with an explorative overview of requirements for TOD in logistics, we conducted a series of interviews with different stakeholders in the field of tele-operation who are currently participating in pilots for tele-operated road and barge transport under the 5G Blueprint project (https://www.5gblueprint.eu/) to explore the concept of TOD in logistics.

Although this research was conducted to explore the deployment of TOD by logistics end user, we preferred to keep a broad perspective on the TO ecosystem and did not limit ourselves to logistics parties, we also included technology, software providers and research institutions. Within the 5G Blueprint consortium, the technology providers are responsible for the equipment of the tele-operated vehicle, the tele-operation kit with sensors and cameras. The software providers are gathering data and transforming it into usable information for the tele-operator, e.g., speed advice, alerts, location tracker, (3D) maps. Table 1 provides an overview of the number of participants per field.

After their agreement to participate, all parties were requested to choose a two- hour timeslot to discuss their expertise and opinion in relation to TOD. They were asked predefined open questions regarding their expectations, the prerequisites, risks, benefits and opportunities of TOD deployment. The interviews were transcribed and validated by the participants. Analysis of this first round led to an initial summary of the requirements for TOD in logistics. This summary was presented to and verified by the members of the 5G consortium during a brainstorm where additional input could be provided. From the combined results of the interviews and brainstorm session a detailed list of requirements was defined and split into six categories: technical, operational, economic, social, safety and regulatory requirements (figure 1). In the following section, we provide a detailed description of each of the defined requirements for integrating TOD into logistics operations, more specifically, tele-operated road transport.

Table 1 Overview of interview participants per field

Field	**Round 1** **Open questions**	**Round 2** **Brainstorm 5G consortium**
Technology providers	4	5
Software providers	5	6
Mobile network providers		2
Logistics companies	3	3
Research/innovation institutions	1	5
Governmental institutions		3
TOTAL	**13**	**24**

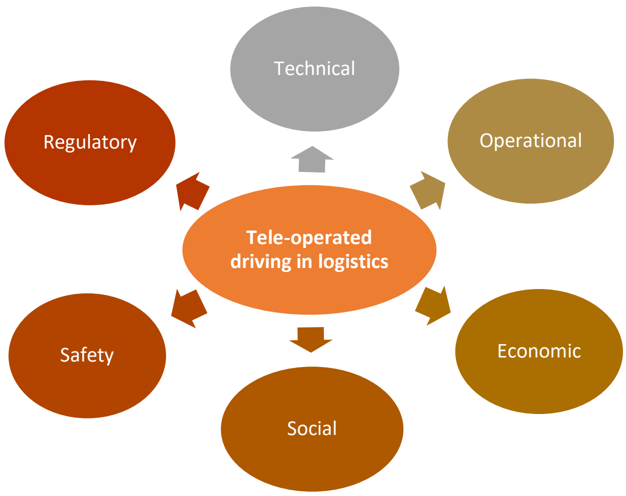

Figure 1 Requirement categories for tele-operated driving systems in logistics.

Requirements of tele-operated driving systems in logistics

Technical requirements

Tele-operation refers to a system where a human being controls a robot from a distance. For TOD, general definitions as well as TOD system design and architecture are provided in [6], [14]. Any tele-operated system is defined by three main elements; the robot, the tele-operation interface, and the communications link [15]. The *robot*, which is the vehicle in case of TOD, integrates mechanical and electronic components. Expectation of the interviewees is that the *tele-operation interface* will consist of several displays with a view of the vehicle surroundings and a dashboard with key metrics. The interface is fed by information collected by the vehicle's lidar and radar sensors, cameras, and on-board processors. However, should any of this hardware fail, the collected information will be incomplete, and it is no longer safe to keep the vehicle on the road. The question remains what should happen if neither the vehicle itself nor the tele-operator are able to initiate a failsafe procedure due to breakdown of key equipment.

The *communications link* for TOD requires overall network stability and coverage, even in remote areas; low latency with semi-real time connection and high bandwidth to transmit a vast amount of high-quality data simultaneously, even in cross border situations. Even with the uprising of 5G, it is still to be validated if this is a feasible expectation [16]. Doubts have been expressed during the interviews regarding the possibilities for full scale deployment, will the connection remain strong enough even if thousands of tele-operated trucks, vessels and other vehicles are relying on 5G.

Operational requirements

To understand the operational implications for TOD in logistics, a basic understanding of the role of a truck driver is needed. Apart from the actual driving, additional activities fall under their remit as represented in figure 2. First and foremost, truck drivers are responsible for their truck and trailer. They check if all wires and tubes are connected, if the tires are safe, if the lights are working. They couple and decouple trailers and make sure both are connected properly. The driver needs to ensure that the cargo is secure, undamaged and in line with documentation. Depending on the goods and loading site, some are expected to load and unload the cargo themselves. They interact with several operators at the loading site for identity checks, documentation, and docking.

On route, a driver fuels the truck when needed, ensures the truck is locked and cargo sealed before moving on. As the tele-operator will only be able to take over task of driving, the remaining activities will require a different approach. According to the interviewees, communication could be digitized but for the time being, vehicle and cargo handling human collaboration will remain a necessity. Agreement with all involved parties on their respective roles and responsibilities will be essential.

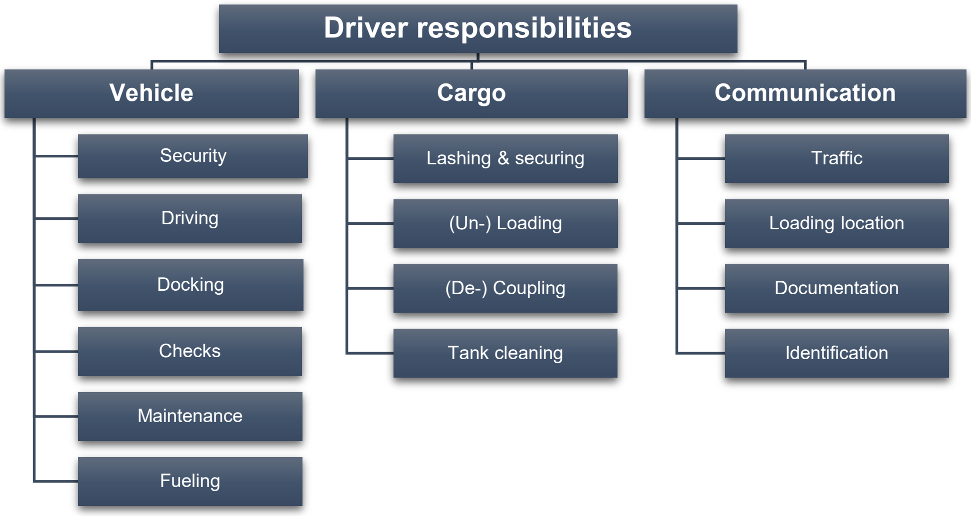

Figure 2 Non-exhaustive representation of truck driver responsibilities

Once the process on site is clear, proper service level agreements will have to be established with the tele-operation center. For example, on (un)loading locations, when a truck is waiting for its slot, the tele-operator can switch to another vehicle, leaving the truck at a standstill. When the warehouse is ready to load, the truck will require immediate assistance to move to loading dock. Any delay will cause obstruction or inefficiency in the loading process. Long haul cross border trajectories will require a 24-hour service to keep the vehicle in motion day and night to guarantee security of truck and cargo. To comply to these conditions, the interviewees find that a centralized tele-operation control center would be the recommended business model. Having a large pool of tele-operators that can carry out different shifts and that can support each other during breaks or in case of emergency, will provide the best service level possible. To timely assign the tele-operators to a vehicle, it will be crucial to install a proper automated planning system in direct contact with the vehicles and loading sites.

Economic requirements

Implementation of TOD in logistics will lead to a significant change in cost of transport and warehousing. To determine the *cost of transport* by means of TOD, first, the cost of a tele-operator needs to be examined. Considering that tele-operator will be required to monitor multiple screens and will receive a vast of visual, audial and perhaps even sensory information, the role is expected to become quite challenging. A better understanding of the required education and day to day activities will be necessary to determine the tele-operator salary. Investment in hardware and software for the tele-operation center will determine the overhead cost. The cost for a tele-operator desk job with increased complexity located in a high tech office needs to be compared to that of a driver whose job might be less complex, but who needs to be paid travel expenses, overtime and overnight allowance.

Second, the amount of idle time that a driver spends in waiting in line at the check-in desk, waiting for and during (un)loading, can be used more efficiently by a tele-operator by virtually jumping on to the next vehicle. Calculation of the amount of idle time and how it is spread over the day will determine the ratio of vehicles to tele-operator. In addition, efficient use of idle time will lead to a drastic decrease of detention costs.

Third, as TOD will rely on close monitoring of the vehicle's vitals allowing a calculation of the ideal speed or gear which can drastically decrease fuel consumption. On the other hand, fuel prices could increase if manual assistance for truck fueling at gas stations is required (see 'operational requirements').

Finally, depending on the service model, the investment and maintenance cost for either a tele-operation kit that can be applied to a legacy vehicle or a new vehicle with built in tele-operation functionality.

The *warehousing cost* will increase if driver activities like cargo handling have to be transferred to a local operator as described under the operational requirements. Or if changes to (digital) infrastructure of the loading location are required such as installing cameras for container identification, a number plate scanner, a dock camera for cargo security, setting up a WMS system that supports electronic documentation and connects all information to the correct cargo truck and storage location.

In addition to the factors mentioned, the interviews pointed out that some changes in *public infrastructure* might be necessary to ensure smooth operation of TOD systems. Continuous and reliable connectivity might require investments in remote and uninhabited areas. All these costs need to be considered in order to assess the economic feasibility of TOD systems in logistics.

Social requirements

Three main factors with respect to the societal acceptance of TOD systems in logistics operations are identified by the experts. The first one is the driver acceptance. TOD systems cause changes in the job description of the drivers and possibly loss of job for drivers that are not willing to accept the transition to become teleoperators. This might lead to dissatisfaction and negative reactions from the drivers. The second factor is the acceptance of the staff in logistics operations. Some interactions with drivers might transform to digital interactions or interactions via tele-presence. TOD systems might face some resistance from the staff who are not used to such encounters. The third key factor is the other road users. Without the driver in the vehicle, eye contact and other visual interactions between the driver and other road users will be eliminated or replaced with digital signs. This might cause a negative attitude towards these vehicles, particularly in case of accidents.

Safety requirements

To guarantee a basic of level of safety, the interviewees stated that a certain amount of autonomy of the tele-operated vehicle cannot be avoided. By programming collision avoidance maneuvers, the vehicle will be able to react autonomously in emergency situations such as immediate risk of collision or loss of connection to the tele-operator. These maneuvers only could already contribute to traffic safety, but more opportunities were mentioned. For example, the prospect of taking the human response time out of the equation and hence decrease the braking distance. Moreover, programming certain restrictions into the TOD systems, such as maximum speed, blind spot alerts or maneuvering conditions can limit the chance of accidents due to human error or driving preferences. On the other hand, interaction with other traffic participants might be difficult at first due to absence of eye contact and could lead to miscommunication. Alternative ways of communication will need to be developed to prevent unexpected human behavior and guarantee public safety.

Regulatory requirements

According to the experts, a comprehensive legal framework stipulating the minimum standards for tele-operation in the logistics industry needs to be defined. This should include *safety requirements* such as the vehicle being able to execute a minimum risk maneuvers autonomously or an emergency procedure that stipulates how the vehicle should be guided to a safe location by local tow services. These safety standards will frame the *technical requirements* of the vehicle and the tele-operation kit of sensors and cameras, including maintenance and licensing. The *labor conditions* for the tele-operator should be defined, including required education and driver's license, working hours and breaks, job level and salary. The biggest concern of the interviewees was related to the *liability regulations* for complex cross border emergencies and the shift in responsibility for operational activities. Insurance companies would have to develop new policies that are accustomed to tele-operated logistics before TOD can become an integrated part of the logistics industry.

Further analysis of operational requirements

In the previous section, we identified operational requirements of tele-operated driving. Those requirements are mainly with regards to driver responsibilities, shown in figure 2. In this section, we further analyse those requirements and suggest possible solutions to re-allocate each one of those responsibilities.

Five general categories of solutions have been identified to cope with responsibilities of truck drivers when they are replaced by tele-operators, namely, teleoperator and the tele-operated vehicle, support operator, automation, digitalization, and transfer of physical tasks to logistics facilities. In the following paragraphs, we discuss how each one of the driver responsibilities can be handled using one or more of the mentioned solutions. Table 2 provides an overview of all responsibilities and re-allocation options.

Responsibility for the vehicle

Security. To access the truck engine or control system, the vehicle itself could request proper identification first, by for example a passport or fingerprint scanner. A second option could be that the teleoperated trucking support operator needs to grant access and can for example open or close the bonnet or fueling cap via the control system.

Driving. Driving and standard handling will be the responsibility of the teleoperator or, in special cases, the trucking support operator.

Docking. Docking could become a fully automated process where the truck can open and close the doors automatically and execute the docking without human assistance. Another option is the principle of tele-operator in-the-loop docking, where some form of human control is applied. In this case, docking would become a combined task of the teleoperated trucking support operator and a local operator to open or close the doors when needed.

Checks and maintenance – The teleoperated vehicle should be equipped with the necessary sensors and technology to feed the correct parameters to the teleoperation control system. Apart from a built-in check, the teleoperator will be responsible for monitoring these parameters. Checks that cannot be executed by the vehicle itself, should be assigned to local support. Ideally, teleoperated trucks would be parked at specialized parking lots in between trips. Those parking lots could offer maintenance, charging/fueling, road assistance or any other specific need from a teleoperated vehicle, including regular checks. The aforementioned specialized parking lots could also offer maintenance packages. Alternatively, the vehicles could be attended to by a specialized maintenance company.

Fueling/Charging. This could become a fully automated process if the fueling station offers automatic fueling. At the moment, robotic fueling for passenger cars and mining trucks are still under development. In the meantime, the process described in Table 2 could be an alternative solution where communication between the trucking support operator and the fueling station is enabled by an on-vehicle screen.

Responsibility for the cargo

Lashing & Securing. Most handling in relation to lashing and securing cargo seems too specific for automation and will require human intervention. Therefore, a local operator either in service of the loading location or assigned by the transportation company will become responsible for these tasks.

Loading and unloading. This process can be automated for most locations. For the remaining locations, the solution would be to shift these tasks to local operators in (un)loading locations.

Coupling and decoupling trailer. This could become an automated handling. Nevertheless, for the moment, most trailers still require manual handling. As long as this is the case, these tasks should be assigned to a local operator. Depending on the (de-)coupling location, this could be either an operator at the (un-)loading location or an operator at the fleet parking.

Cleaning. If sweeping is requested, this should be handled at the loading location by a local operator. If the truck itself requires cleaning or the customer requires a cleaning certificate, the trucking support operator could steer the vehicle towards a nearby cleaning station and leave it there for cleaning.

Responsibility for communication

Traffic. The tele-operated vehicle could be equipped with technology to allow two-way transfer of sound between the tele-operator and the vehicle and thereby its environment.

Loading location. Depending on the level of integration of the teleoperation control system and the loading location's system, estimated time of arrivals and timeslot adjustments might be communicated automatically already. However, when there is no integration, but communication is required, this could be handled by the trucking support operator by sending an e-mail or calling the local planner.

Documentation. For teleoperation to become possible, digitization of all transport documentation would be a basic requirement.

Identification. Before logging on to a vehicle, the teleoperator will need to provide the necessary identification to the control system, which should replace manual identification. This combined with the truck and trailer license plate number, and in case of container transport, the container number, should be enough to identify the driver and the goods. In any case, this process would have to be stipulated in legislation and contractual agreements.

Table 2 Re-allocation options of driver responsibilities

	Driver task	Re-allocation option 1	Re-allocation option 2
Vehicle	Security	TO vehicle	TO trucking support operator
	Driving	TO driver	TO trucking support operator
	Docking	(Partial) Automation	TO trucking support operator with local operator
	Checks	TO vehicle	TO vehicle parking operator
	Maintenance	TO vehicle parking operator	Maintenance company
	Fueling/ Charging	(Partial) Automation	TO trucking support operator with fueling station clerk
Cargo	Lashing & securing	Automation	Local operator
	(Un-) Loading	Automation	Local operator
	(De-) Coupling	Automation	Local operator
	Tank cleaning	Automation	Cleaning facility operator
Communication	Traffic	TO vehicle	TO trucking support operator
	Loading location	Digital	TO trucking support operator
	Documentation	Digital	TO trucking support operator
	Identification	Digital	

Discussion

It should be acknowledged that the requirements were defined based on the current views and understanding on the development of TOD in logistics**.** Technology is evolving constantly, and new solutions are in development. The companies interviewed are desperate for more clarity, information, inspiration and guidance to take the concept of TOD to the next level. OEMs are looking to governments and road authorities to come with a solid legal framework before moving to full scale development, whereas the authorities do not have a firm grasp on the concept of TOD and are reluctant to take unnecessary risks. Even among the technology and software companies we could see differences. For example, some agree that technology should be able to cope with the current road infrastructure without need for investment or adjustment, whereas others rely on intelligent roadside systems and propose separate lanes for tele-operated and autonomous vehicles. Most parties see tele-operated transport as the next step towards autonomous transport, whereas others have lost hope that level 5 autonomy will ever happen. By clarifying the different requirements, we started to pave the path towards tele-operation, but more understanding of the impacts is still needed.

It should be mentioned that apart from the differences and uncertainties, we started to see a glimpse of future logistics. Due to the possibility of 24-hour transportation by tele-operator shifts, transport can be detached from the regular working hours. This could decrease peak hours at the beginning and the end of the day and spread in and outbound flows more evenly. Eliminating driver resting hours could shorten transit times and optimize the transportation company's fleet capacity. Advanced digitization of transport could allow shippers and receivers to prepare for the incoming vehicles and plan their operations in advance. Production flows could be adjusted to the time the goods are expected and preparation for the outbound flow could be started by calling upon a tele-operated vehicle to stand-by for loading at the end of the production line, eliminating the need for intermediate storage. Crossdocking could become the norm, herewith decreasing the need for storage space. Restructuring of supply chains could save time, money and resources. New business models will be developed to support TOD. Tele-operator and vehicle service on-demand could enable efficient outsourcing of certain operations without major investments in vehicles and assets. It could become a shared service for the logistics industry and enable the development of centralized tele-operation centers. On a bigger scale, these centers could be established at strategic locations in the world, allowing 24/7 operations without night shifts but simply by making use of different time zones. On a local level, terminals, warehouses and distribution centers could opt for a fully tele-operated terminal, where dedicated tele-operators could be trained to easily switch between machinery. All these potential changes provide opportunities for new functionalities of TOD in logistics industry.

Research agenda

This explorative research indicates clearly that there is a need to further explore and analyze each of the requirement categories for effective deployment of TOD systems and their implications for logistics operations. The absolute showstopper that cannot be disregarded is the lack of a proper legal framework stipulating deployment and liability conditions. Particularly regarding the transfer of activities from the driver to other actors in the supply chain, logistics service providers need contractual agreements for costs and liability. Active involvement of governmental institutions and road authorities could be a first step in the right direction. They should be made aware of the progressing technology and provide their knowledge on traffic management, road infrastructure and safety to support pilots of TOD systems. When liability rules have been established, we expect OEMs will follow shortly after to bring different types of tele-operation kits and or machines on the market. Preference would be to have a model kit that can used in different industries and for different vehicles, including but not limited to trucks, reach stackers, cranes or forklifts.

Another important research avenue that requires further exploration is business case issues. On one hand, taking the driver out of the vehicle provides flexibility of operations for logistics service providers. On the other hand, transfer of driver activities to other supply chain actors can increase operational costs. The crucial question here is whether extra benefits of TOD outweigh the extra costs of transferring driver responsibilities.

In the meantime, simulations and calculation models can support a full implementation of TOD in logistics. First, it would be advisable to further explore the economic requirements in order to build a solid business case for potential end users such as transportation companies, couriers, terminals, distributors or warehouses. More specifically the ratio of vehicles per tele-operator, which will be determined by the amount of idle time in the respective sector; the expected salary of a tele-operator and the cost for driver activities that are, for example, to be transferred to loading sites. The business cases can define the scenarios in which tele-operated road transport is financially interesting (e.g. cargo, fleet size, travel distance, travel time). This will determine the most suitable business model for the concept of TOD. Large terminals or port areas could choose for a joint operation, while smaller transportation companies might benefit more from a centralized tele-operation center where they have a pool of tele-operators they can hire when required and as such only have to be paid for the time spent operating the requested vehicle.

Once all these requirements are met, TOD can become part of daily logistics operations. Only then will it become accepted by society. Needless to say that some change management and possibly financial compensation might be required towards drivers and operators when the move towards implementation of TOD in logistics is actually made.

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References

1. D. Milakis, B. van Arem, and B. van Wee, "Policy and society related implications of automated driving : a review of literature and directions for future research," *Journal of Intelligent Transportation Systems*, vol. 2450, no. February, 2017, doi: 10.1080/15472450.2017.1291351.
2. SAE International, "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles," 2018.
3. F. Favarò, S. Eurich, and N. Nader, "Autonomous vehicles' disengagements: Trends, triggers, and regulatory limitations," *Accident Analysis and Prevention*, vol. 110, pp. 136–148, 2018, doi: 10.1016/j.aap.2017.11.001.
4. A. M. Boggs, R. Arvin, and A. J. Khattak, "Exploring the who, what, when, where, and why of automated vehicle disengagements," *Accident Analysis and Prevention*, vol. 136, no. July 2019, p. 105406, 2020, doi: 10.1016/j.aap.2019.105406.
5. M. Boban, A. Kousaridas, K. Manolakis, J. Eichinger, and W. Xu, "Connected Roads of the future," *IEEE Vehicular technology magazin*, no. September, pp. 110–123, 2018.
6. S. Neumeier, N. Gay, C. Dannheim, and C. Facchi, "On the Way to Autonomous Vehicles Teleoperated Driving," in *Automotive meets Electronics; 9th GMM-Symposium*, 2018, pp. 49–54.
7. S. Lichiardopol, "A survey on Teleoperation," Eindhoven, 2007.
8. H. L. Chi, Y. C. Chen, S. C. Kang, and S. H. Hsieh, "Development of user interface for tele-operated cranes," *Advanced Engineering Informatics*, vol. 26, no. 3, pp. 641–652, 2012, doi: 10.1016/j.aei.2012.05.001.

9. P. M. D'Orey, A. Hosseini, J. Azevedo, F. Diermeyer, M. Ferreira, and M. Lienkamp, "Hail-a-Drone: Enabling teleoperated taxi fleets," in *IEEE Intelligent Vehicles Symposium*, 2016, pp. 774–781, doi: 10.1109/IVS.2016.7535475.
10. A. K. Bhoopalam, N. Agatz, and R. Zuidwijk, "Planning of truck platoons: A literature review and directions for future research," *Transportation Research Part B: Methodological*, vol. 107, pp. 212–228, 2018, doi: 10.1016/j.trb.2017.10.016.
11. International Transport Forum, "Managing the Transition to Driverless Road Freight Transport," 2017.
12. STL, "Sector institute Transport & Logistics," 2019. https://www.stlwerkt.nl/Media/media/Corporate/Over ons/Sectormonitor-transport-en-logistiek-2019-Q2.pdf.
13. VDAB, "Vlaamse Dienst voor Arbeids Bemiddeling," 2019. https://www.vdab.be/nieuws/pers/openstaandeopleidingsplaatsen-voor-vrachtwagenchauffeur.
14. S. Gnatzig, F. Chucholowski, T. Tang, and M. Lienkamp, "A system design for teleoperated road vehicles," in *Proceedings of the 10th International Conference on Informatics in Control, Automation and Robotics*, 2013, pp. 231–238, doi: 10.5220/0004475802310238.
15. A. F. T. Winfield, "Future Directions in Tele-operated Robotics," *Telerobotic applications*, 2000, [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.144.6045&rep=rep1&type=pdf.
16. M. Sauter, *From GSM to LTEAdvanced Pro and 5G: An Introduction to Mobile Networks and Mobile Broadband*. WILEY, 2017.