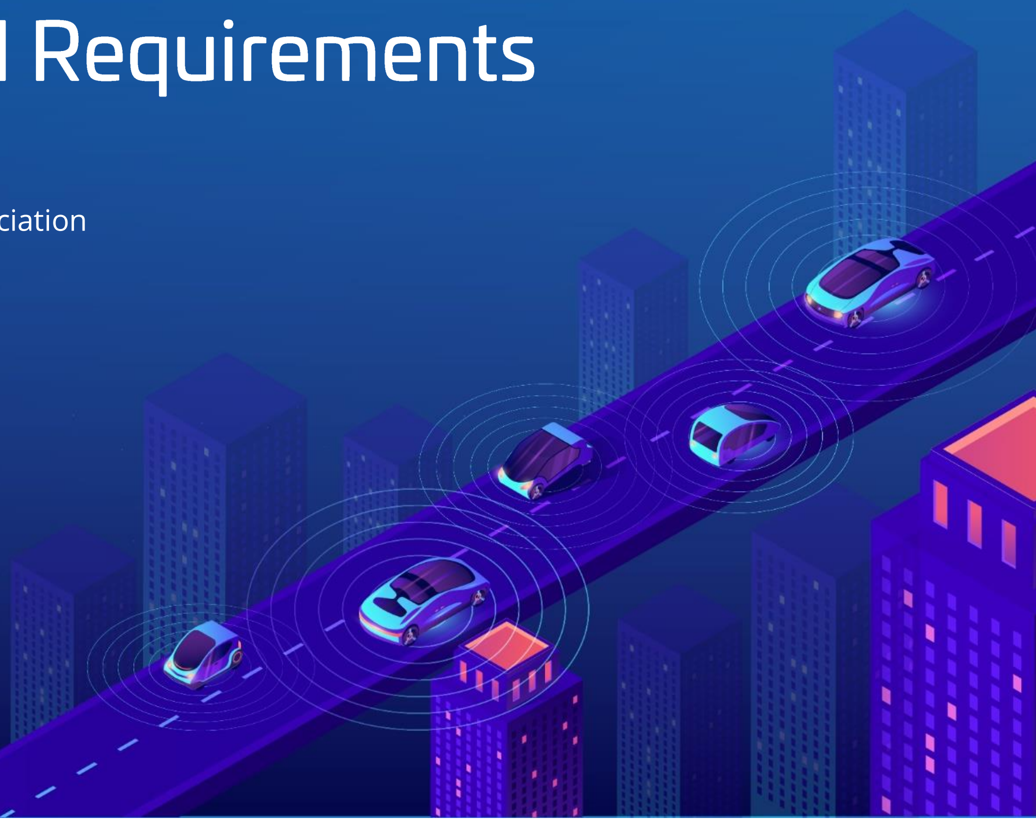
Tele-Operated Driving (ToD): Use Cases and Technical Requirements

5GAA Automotive Association
Technical Report



CONTACT INFORMATION:

Executive Manager – Thomas Linget
Email: liaison@5gaa.org

MAILING ADDRESS:

5GAA c/o MCI Munich
Neumarkter Str. 21
81673 München, Germany
www.5gaa.org

VERSION:	Version 2.0
DATE OF PUBLICATION:	26 August 2021
DOCUMENT TYPE:	Technical Report
EXTERNAL PUBLICATION:	Yes
DATE OF APPROVAL BY 5GAA BOARD:	25 August 2021

Contents

Foreword

This Technical Report (TR) has been produced by 5GAA.

The contents of the present document are subject to continuing work within the Working Groups (WG) and may change following formal WG approval. Should the WG modify the contents of the present document, it will be re-released by the WG with an identifying change of the consistent numbering that all WG meeting documents and files should follow (according to 5GAA Rules of Procedure):

x-nnzzzz

(1) This numbering system has six logical elements:

(a) x: a single letter corresponding to the working group:

Where x =

T (Use cases and Technical Requirements)

A (System Architecture and Solution Development)

P (Evaluation, Testbed and Pilots)

S (Standards and Spectrum)

B (Business Models and Go-To-Market Strategies)

(b) nn: two digits to indicate the year. i.e., 17, 18 19, etc.

(c) zzzz: unique number of the document

(2) No provision is made for the use of revision numbers. Documents which are a revision of a previous version should indicate the document number of that previous version

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1 Scope

This deliverable reports the analysis, extension and classification of a set of Tele-Operated Driving (ToD) use cases. This was done with the aim of providing a shortlist, which will serve as a basis for further activities related to technical requirement derivation and business considerations. The ToD Work Item (WI) aims to describe the requirements and framework needed for ToD service provisioning for automated vehicle operation, covering the possible interfaces and stakeholders. This WI focuses on the tele-operation of vehicles after an incident or in difficult situations (including parking), also potentially taking the network conditions before the incident happened into account. This document reports on the activities of WI tasks T1.1 and T1.2.

A survey on the state of the art was performed by T1.1, analysing existing (pre-)commercial solutions and highlighting major outcomes and guidelines, as useful input to shape and guide ToD developments. A review of the main achievements of previous and ongoing R&D projects in the automotive domain was also made with the same purpose. The survey ends with the lessons learned and the recommendations for the ToD WI.

ToD WI-specific design began with T1.2, where the use cases and scenarios were specified and analysed. ToD use cases [1][2][3][4] from 5GAA WG1 were taken as initial input and extended in the scope of multi-OEM, multi-MNO, and multi-Road Traffic Authority (RTA) scenarios. Additional service operation scenarios were also considered, taking realistic and operational situations into account. For each use case, this deliverable provides its rationale, an overall description, and the related information flows. Finally, this deliverable proposes a subset of scenarios which should be taken as a basis for further ToD XWI activities.

2 References

[1] 5GAA T-180205, Use Case Description, Tele-Operated Driving, Huawei, BMW, Bosch

[2] 5GAA T-180206, Tele-Operated Driving Support, BMW, Bosch, Huawei

[3] 5GAA T-180207, Tele-Operated Driving for Automated Parking, Bosch, BMW, Huawei, CATT, BAIC, China Mobile

[4] 5GAA T-190062, Infrastructure based Tele-Operated Driving, Intel

[5] Alonso Raposo, M., Ciuffo, B., Makridis, M. and Thiel, C., 'The r-evolution of driving: from Connected Vehicles to Coordinated Automated Road Transport (C-ART) – Part I: Framework for a safe & efficient Coordinated Automated Road Transport (C-ART) system', 2017
URL: https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/r-evolution-driving-connected-vehicles-coordinated-automated-road-transport-c-art-part-i

[6] 5GCroCo project: https://5gcroco.eu/

[7] 5GCroCo Deliverable D2.1 'Test Case Definition and Test Site Description Part 1', URL:https://5gcroco.eu/images/templates/rsvario/images/5GCroCo_D2_1.pdf

[8] SAE J3016_202104, Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles

[9] Crash Avoidance Metrics Partnership – Automated Vehicle Research Consortium, 'Automated Vehicle Research for Enhanced Safety – Final Report', https://www.regulations.gov/document?D=NHTSA-2014-0070-0003

[10] XW5-190025: Excel Use Case Document, F2F #12 Turin, Nov 2019

[11] 5GCroCo D4.4, 'Detailed Roadmap of Test Sites – Project Year Two', January 2020

[12] 5GCroCo D5.1, 'Description of 5GCroCo Business Potentials', September 2019

[13] A. Kousaridas, A. Schimpe, S. Euler, X. Vilajosana, M. Fallgren, G. Landi, F. Moscatelli, S. Barmpounakis, F. Vázquez-Gallego, R. Sedar, R. Silva, L. Dizambourg, S. Wendt, M. Muehleisen, K. Eckert, J. Härri, and J. Alonso-Zarate, '5G Cross-Border Operation for Connected and Automated Mobility: Challenges and Solutions', Future Internet, vol. 12, no. 1, p. 5, Dec. 2019

[14] The Boring Company https://www.boringcompany.com

[15] A. Ferrein, S. Kallweit and M. Lautermann, 'Towards an autonomous pilot system for a tunnel boring machine', 2012 5th Robotics and Mechatronics Conference of South Africa, Gauteng, 2012, pp. 1-6
URL: https://ieeexplore.ieee.org/abstract/document/6558466

[16] Développement des véhicules autonomes – L'État s'engage dans 16 nouvelles experimentations
https://www.ecologique-solidaire.gouv.fr/sites/default/files/9918029_D%C3%A9veloppement-VA_Vdef2.pdf

[17] Integrated Transport Research Lab (ITRL): https://www.itrl.kth.se/

[18] Ericsson Blog: 5G tele-operated vehicles for future public transport
https://www.ericsson.com/en/blog/2017/6/5g-teleoperated-vehicles-for-future-public-transport

[19] A. Hjalmarsson-Jordanius, N. Sundin, M. Romell, J. Isacson, and C.-J. Aldén, 'Disrupting Automotive Logistics: Through a Combined Intelligent and Autonomous Transport Solution', presented at the ITS 2017 World Congress Montreal, October 29 – 2 November 2017. http://www.diva-portal.org/smash/record.jsf?pid=diva2:1282159, last visited on 23 April 23 2020.

3 Definitions and Terminology

For this work, it is important to first understand the different types of driving tasks in a road traffic environment [5], and how they set a basis for the different types of ToD, when all or part of the driving tasks are performed by a remote operator. Only then can the (pre-)commercial solutions and our proposed use cases and scenarios be mapped to their correct ToD types.

These driving tasks can be divided into three types of activities [5] [8]:

- **Strategic level operation**, which refers to the travel planning (e.g. to define driving goals and choose the route or mode), considering available options, costs and risks involved.
- **Tactical (or manoeuvring) level operation**, e.g. speed selection, lane selection, object and event response selection, and manoeuvre planning.
- **Operational (or control) level operation**, e.g. longitudinal and lateral control as well as object and event detection and classification.

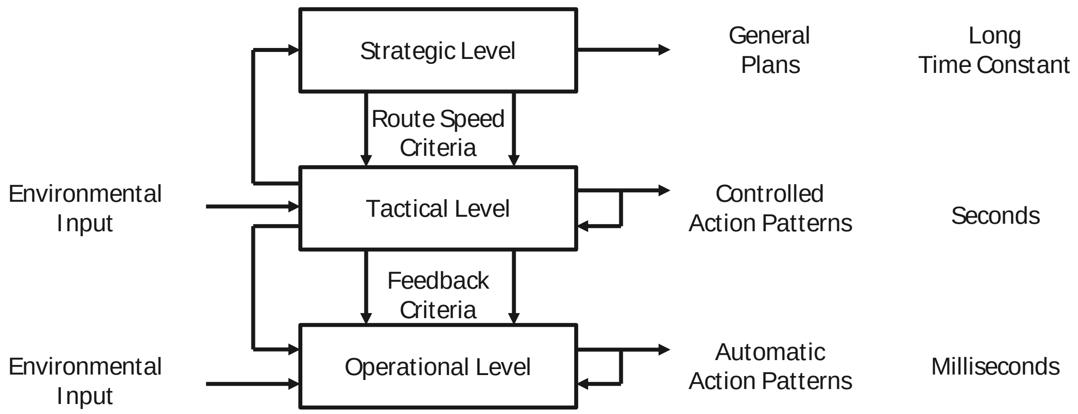

Figure 1: The hierarchical structure of driving tasks, adapted from [5]

According to SAE J3016 [8][1], Dynamic Driving Task (DDT) is defined as the collection of all required real-time Operational level functions, such as basic vehicle motion control, and real-time Tactical level functions, such as Object and Event Detection and Response (OEDR), to operate a vehicle in on-road traffic. The Strategic level function is not part of DDT.

For the purposes of the present document, the following definitions apply:

- **Non-ToD**: the ToD operator is not engaged in the act of driving, i.e. taking no role in the act of driving. All three levels of driving operations, i.e. Strategic level, Tactical level, and Real-Time Operational and Real-time Tactical level are performed by an in-vehicle user [8] or system.
    - Note 1: ‘system’ in this definition refer to ‘driving automation system’ defined in [8].
    - Note 2: in this case the ToD operator may monitor the status of the vehicle and send information to the in-vehicle user or system supporting the act of driving.
- **Dispatch ToD**: the ToD operator takes on the role of **Dispatcher**, which is only to perform the Strategic level operations of driving, e.g. travel planning, route and itinerary selection, while the Tactical and Operational level operations are performed by the in-vehicle user or system.
    - Note 3: For driving automation systems, this type of ToD corresponds to the dispatch [in driverless operation] function defined in [8].

[1] The schematic view of strategic, tactical and operational functions, as well as their relation to the Dynamic Driving Task can be found in Figure 1 of SAE J3016 [8].

- **Indirect Control ToD**: the ToD operator takes the role of **Indirect Controller** (**Remote Assistant**), to perform the Tactical level functions like pathway planning, which corresponds to the remote assistance function defined in [8] for driving automation systems. If needed, the Indirect Controller may also perform Strategic level operations of driving. In Indirect Control ToD, real-time Operational level and real-time Tactical level functions, i.e. DDT [8], are performed by in-vehicle user or system.
    - Note 4: When engaged in the act of driving, the remote operator of Indirect Control ToD may disengage the in-vehicle system from performing DDT, by either taking over the all DDT tasks, i.e., the role of Direct Controller, or by bringing the vehicle to a minimal risk condition [8].
    - Note 5: When Indirect Control ToD is engaged, the ToD operator may also perform Strategic level operation such as reselecting the route, when such operations are needed to complete the act of driving, e.g. to avoid a blocked road.
- **Direct Control ToD**: the ToD operator takes the role of **Direct Controller** (**Remote Driver)**, to perform all or part of real-time operational and real-time tactical functions (i.e. DDT), which corresponds to the remote driving function defined in [8] for driving automation systems. If needed, the Direct Controller may also perform Tactical and Strategic level operations of driving.
    - Note 6: When Direct Control ToD is engaged, part of the DDT functions, e.g. lateral and/or longitudinal vehicle motion control, may be performed by the In-vehicle user or system, e.g. through adaptive cruise control and/or lane keeping, while the ToD operator (Direct Controller) is still responsible for the OEDR task.
    - Note 7: When Direct Control ToD is engaged, the ToD operator (Direct Controller) may also perform Strategic level operations such as reselecting the route and Tactical level operations such as replanning the pathway, when such operations are needed to complete the act of driving, e.g. to avoid a blocked road or get around an obstacle in the road.

Note 8: The Remote Vehicle (RV) operator can be a remote user [8] or a remote system.

This distinction between ToD types is summarised in **Table 1**.

Table 1: The role and engagement of the ToD operator in the act of driving in different types of ToD

ToD Type (Role of ToD operator)	**Act of Driving**		
	Strategic Operation (Travel planning, route and itinerary selection)	Tactical operation (Pathway planning)	Real-time Operational and Real-Time Tactical Functions (DDT incl. OEDR and sustained lateral and longitudinal vehicle motion control)
Non-ToD (No Role)	In-vehicle user or system	In-vehicle user or system	In-vehicle user or system
Dispatch ToD (Dispatcher)	ToD operator	In-vehicle user or system	In-vehicle user or system
Indirect Control ToD (Indirect Controller or Remote Assistant)	ToD operator (if needed)	ToD operator	In-vehicle user or system
Direct Control ToD (Direct Controller or Remote Driver)	ToD operator (if needed)	ToD operator (if needed)	ToD operator (all or part of DDT)

4 Classification Methodology of the Use Cases

Currently we have four basic ToD use cases [1][2][3] [4] which are used as a basis for the work in Task 1:

- T-180205 Use Case Description: Tele-Operated Driving
- T-180206 Tele-Operated Driving Support
- T-180207 Tele-Operated Driving for Automated Parking
- T-190062 Infrastructure based Tele-Operated Driving

The available WG1 descriptions of these use cases have been extended with further details according to the following classification methodology and parameters. The resulting extended use case scenario descriptions will help XWI5 ToD provide input for further ToD XWI activities, as well as to other WGs, e.g. WG1 and WG5, and other XWIs, such as XWI4 STiCAD.

First, the use cases have been divided into two different categories *A* and *B*. This step describes the different types of ToD from the ToD operator to the automated vehicle for performing driving tasks.

A) Category A refers to **ToD Type "Indirect Control"** defined in Section 3
B) Category B refers to **ToD Type "Direct Control"** defined in Section 3

In the second step of classification, the use case categories A and B were analysed in the scope of four different scenarios *A1-A4* and *B1-B4.* The different scenarios reflect the different possibilities on how a ToD service could be acquired and provisioned. Each scenario is identified by a unique combination of parameter settings answering the following questions:

1) What is being transported?
2) Who owns the vehicle?
3) Which environment is the use case executed (i.e. where is the use case executed)?
4) Are vehicles from a single or multiple OEMs?
5) Does service provisioning involve a single or multiple MNOs?
6) Do vehicles operate in different regions managed by different RTAs?
7) Are ToD services provided by single or multiple providers?

The complete set of use case scenarios is found in Annex <A>. This deliverable only focuses on a selected shortlist of them. Definitions of parameters for describing scenarios are provided in Annex <B>.

The following are some example scenarios from Annex <A.2> for the use case *ToD Support* [2]:

1) In scenario *A1/B1:* The service is provided by one ToD service provider to private vehicle owners for transporting passengers on public roads. The vehicles are from a single OEM, supported by the network from one MNO, and operate in areas managed by a single RTA.
2) In scenario *A2/B2:* The service is provided by one ToD service provider to a single OEM fleet for transporting goods on public roads. The vehicles operate in areas managed by a single RTA and can be supported by networks from multiple MNOs.
3) In scenario *A3/B3:* The service is provided by one ToD service provider to a legacy fleet owner (multi-OEM fleet) for transporting passengers on public roads. The vehicles can operate in geographic areas managed by different RTAs and can be supported by networks from multiple MNOs.
4) In scenario *A4/B4:* The service is provided by one ToD service provider to a single OEM fleet for transporting passengers or goods in a confined area or following a pre-determined route. The confined area is managed by a single authority and supported by a network from a single MNO.

Note: Each basic use case may have different scenarios resulting from the second step of the use case classification.

This methodology allows XWI5 ToD to obtain various scenarios for each basic use case that may have different implications on technical requirements and business considerations, e.g. on market potential values and relations with stakeholders. As mentioned previously in this section, further work in ToD XWI on requirement analysis, solution development, and go-to-market strategy will prioritise a limited number of selected use case scenarios, according to the analysis from technical, business, and safety treatment perspectives.

5 Review of Relevant (Pre-)commercial Solutions and Research Projects

5.1 (Pre-)commercial Solutions and Relevance to ToD

Tele-operation is a game-changer for industry productivity and efficiency. This can already be seen in sectors such as agriculture, construction, mining, logistics and just as importantly, transportation. As populations grow, road traffic demand increases and the limitations of the current road transportation network become more apparent. As a result, many initiatives around automated driving and ToD have surged in recent years. One visionary example is the Boring Company concept [14] which proposes to relieve traffic congestion between different parts of cities by building underground transportation corridors, or tunnels, which interconnect them. These tunnels are designed for automated electric vehicles. While some may argue that automated vehicles should remain autonomous without relying on external interactions, such visions clearly call for an increased role of ToD solutions in overall traffic control monitoring, as a temporary support service for vehicles, or by actively driving them to their final destination. Moreover, the 'boring machines' used to build these tunnels may be tele-operated themselves, using theodolites as sensory input for the tele-operator [15].

Similar initiatives, such as by the French railway company SNCF, propose the use of old railway tracks instead of tunnels as transportation corridors for automated vehicles [16]. Here an old railroad is converted into a relatively narrow dual-carriage road with minimal roadside infrastructure and markings. Some argue that only automated shuttles should be used on these new tracks, others imagine L4 private vehicles using these new AV-only facilities delegating the driving task to a third-party service acting as a controller. In both cases, ToD is an essential element as a means to support the safe and reliable operation of these automated vehicles.

In addition to transportation corridor concepts, there are other activities going on with the aim of providing a more sustainable transport ecosystem by connecting electric, automated vehicles in urban environments. Ericsson, for example, in collaboration with Scania, is building a testbed for Intelligent Transport Systems (ITS), as part of activities within the Integrated Transport Research Lab (ITRL) [17]. This testbed currently offers cellular connectivity for two sites: the Kista, high-tech suburb of Stockholm, and in Södertälje, Sweden, respectively headquarters of Ericsson and Scania. These two sites complement each other in terms of the type of ITS applications they will support: Kista is a semi-urban environment with people and vehicle traffic, which allows for realistic testing of ITS. Södertälje offers a safe environment for testing futuristic ITS applications such as Tele-Operated Driving. One of the tests performed was the tele-operation of a bus: Scania presented a demo in November 2016, in which they drove a bus remotely from a vehicle operation centre at Scania's offices using the testbed setup by Ericsson. A tele-operated bus from a command centre presents a proof-point for the high expectations in 5G for industries. It is the first step in realising as-a-service offerings for mobile network operators. Such offerings are expected to increase operators' revenue and growth as connectivity is exposed to vertical markets that include, but are not limited to, the automotive domain [18].

Similar efforts are occurring in the scope of automated fleet management. Here, the Swedish startup Einride has partnered with Ericsson to explore the opportunities of 5G mobile connectivity in the scope of tele-operating automated, all-electric trucks. The two companies demonstrated the technology at the 2019 Mobile World Congress in Barcelona, allowing show-goers to remotely operate a T-pod, Einride's first truck specifically designed for electric propulsion and automated driving, which was physically located in Sweden. This is one of the examples of the role of tele-operation in industrial applications like transport and manufacturing.

Mining is also a sector where ToD plays a big role. Tele-operated excavators, dozers, and other mining equipment are emerging as low-cost/low-risk entry points for companies looking into automation technologies for productivity and safety improvements. Here, companies such as Autonomous Solutions Inc, EEP Elektro-Elektronik Pranjic, Sandvik, among many others, propose solutions which range from tele-remote or autonomous operation of single pieces of equipment, to multi-machine control and full fleet automation, including traffic control capability. Regarding communication; the use of non-public networks, which are usually deployed in factories, could enable rapid deployment of 5G in this sector.

In addition to these projects and initiatives, there are several (pre-)commercial solutions which are also directly or indirectly related to ToD. In order to gain insight, a survey on these existing market solutions was performed. This was done mainly by gathering information given by the respective manufacturer's website, together with press releases and articles. Since most of the investigated solutions are relatively new, technical information about their systems and performance is limited. The following table summarises the results found, including each company's main achievements. They are presented in increasing ToD Type order.

Table 2: (Pre-)commercial solutions related to ToD

Company Name	Services	ToD Operator/ Supervisor	ToD Type	Environment Info/ Communication	Closed Environment/ Predetermined Route	Open Environment with Mixed Road Traffic
EasyMile	-Fully driverless services for local mobility needs -Driverless shuttle around university campus and other closed environments -ToD focus on route management, remote monitoring and supervision	Human (supervisor)	Dispatch ToD	-LIDAR, Cameras, Radars, Differential GPS, Odometry -V2X communication -Communication to supervision centre via 4G network	Yes	No
BestMile	-Vehicle-Agnostic Mobility Services Platform -Deploy, manage and optimise fleets (automated shuttle, robotaxi services) -Automated vehicle matching, ToD routing and dispatching	Human/ Machine (supervisor)	Dispatch ToD	Not mentioned	Yes	Yes
NAVYA	-Two automated vehicles: AUTONOM® SHUTTLE and AUTONOM® CAB -Neither a steering wheel nor pedals -NAVYA LEAD, a supervision service which can oversee shuttle fleets anywhere in the world. Objective is to guarantee service performance and continuity	Human/ Machine (supervisor)	Dispatch ToD	- LIDARs sensors, cameras, GPS RTK, IMU and odometry -V2X communication	Yes	Yes
Tesla	-Level 2, incident data are stored on the vehicle and reported via Wi-Fi when available	No	Dispatch ToD	-Cameras, ultrasonic sensors, a forward-facing radar with enhanced processing	Yes	Yes
Optimus ride	-Customised electric and automated transportation solutions for geo-fenced locations -On-demand vehicle fleet management	Human (supervisor)	Dispatch ToD	-Cameras, lasers, and sensors -Machine vision system	Yes	No
May Mobility	-Operates automated shuttle services -Focus on fixed routes -First mile, last mile solutions	Not mentioned	Not mentioned	Not mentioned	Yes	Foreseen for late 2020
Pony.ai	-Automated vehicle technology company	Not mentioned	Not mentioned	-HD maps, multi-sensor fusion	Yes	Yes

	-Multiple vehicle platforms and applications (robotaxi, long-distance freight trucks)					
Pronto	-Highway safety system for commercial trucking -L2: full adaptive cruise control, automatic emergency braking and proactive lane centre	Human (driver/ supervisor)	Not mentioned	-Cameras and radar	Yes	Yes
2getthere	-Rivium system: L4 automated Park shuttles in Rotterdam -In operation for 12+ years -Operates without safety driver or steward -Remote driving centre which allows monitoring of the fleet and conflict solving when necessary. -Monitored by a single operator (per shift)	Human (driver/ supervisor)	Dispatch ToD , Indirect Control ToD	-Sensor fusion, using 3D camera systems, LiDAR, radar and ultrasound sensors as well as classification	Yes	Extension in mixed traffic foreseen for late 2020
WAYMO	-WAYMO One: commercial automated taxi service -WAYMO Via: Automated fleet for transportation of goods and delivery service -Mostly automated operation but may request remote assistance from an operator	Human (driver/ supervisor)	Dispatch ToD, Indirect Control ToD	-Detailed three-dimensional maps -Sensor fusion, using 3D camera systems, LiDAR, radar	Yes	Yes
Zoox	-Working on creating an entirely new automated vehicle targeted at the robotaxi market -Telemetry and remote-control systems for ToD	Human (driver/ supervisor)	Dispatch ToD, Indirect Control ToD	-Cameras, LiDAR, radar and proprietary sensors	Yes	Yes
Aptiv	-Commercial, automated ride-hailing service in Las Vegas -Telemetry and remote-control systems for ToD	Human (driver/ supervisor)	Dispatch ToD, Indirect Control ToD ToD	-Centralised Sensing Localisation Planning (CSLP): consists of radar, LiDAR, cameras	Yes	Yes
Starship Technologies	-Develops small self-driving robotic delivery vehicles -Food and package deliveries	Human (driver/ supervisor)	Dispatch ToD, Indirect Control ToD ToD	- Cameras, GPS and inertial measurement unit	Yes	No
SEAFAR	-Independent ship management company, offering services to operate unmanned and crew-reduced vessels	Human (driver/ supervisor)	Dispatch ToD, Indirect Control ToD,		Yes	No

	for ship owners and shipping companies -Integrates developed technology in existing or new-build vessels and barges -Operates unmanned barges from a shore control centre, in combination with a mobile intervention unit -Specialises in management of automated barges, including technical management, operational management, monitoring and reporting		Direct Control ToD ToD	Not mentioned		
Aurora	-Offers self-driving platform that combines hardware, software, and data services -Aurora Cloud provides monitoring and support for vehicles and their occupants -Fleet management services -Planning and control software forecasts the intention and motion of actors, determines what the driver tool should do in response, and translates that plan into throttle, brake, and steering commands for the vehicle	Human/ Machine (driver/ supervisor)	Dispatch ToD, Indirect Control ToD, Direct Control ToD	-3D maps, sensor fusion	Yes	Yes
Nuro	-Self-driving vehicle engineered for short neighbourhood trips and for the exclusive purpose of transporting and delivering goods -Remote safety drivers are able to remotely monitor a vehicle and take over if required	Human (driver/ supervisor)	Dispatch ToD, Indirect Control ToD, Direct Control ToD	-Cameras, LiDAR, radar, audio and ultrasonic sensors	Yes	Yes (last mile)
Cruise	-Automated vehicle company -Ride-hailing service	Human (driver/ supervisor)	Dispatch ToD, Indirect Control ToD, Direct Control ToD	-Radar, cameras and LIDAR laser sensors	Yes	Yes
NEOLIX	-Automated delivery shuttles	Human	Dispatch ToD,		Yes	Yes

	-Cloud platform that orchestrates vehicle dispatching, condition monitoring and visualisation, error warning management, and driving data analysis -In the event something goes wrong, it enables remote operators to disengage the shuttles' automated systems	(driver/ supervisor)	Indirect Control ToD, Direct Control ToD	-Sensor fusion, cameras, radar, LiDAR		
VERA	-Automated, electric vehicle -It is controlled and monitored via a control centre -Part of an integrated solution to transport goods from a logistics centre to a port terminal	Human (driver/ supervisor)	Dispatch ToD, Indirect Control ToD, Direct Control ToD	-LiDAR, cameras and radar sensors	Yes	Yes (planned)
Roboauto	-ToD support for automated vehicles in difficult situations (e.g. construction sites)	Human (driver/ supervisor)	Dispatch ToD, Indirect Control ToD, Direct Control ToD	-Onboard Sekonic camera -LTE mobile connection	Yes	Yes
Phantom Auto	-ToD deployment kit (HW and SW) for vehicles, bridges the automation gap for public road deployment -Passenger/Commercial vehicles in open roads -ToD support for yard trucks with difficult manoeuvres -ToD for forklifts and delivery robots (last 50 feet, or 15+ metres)	Human (driver/ supervisor)	Dispatch ToD, Indirect Control ToD, Direct Control ToD	Not mentioned	Yes	Yes
Designated Driver	-Handles situations that require a real-time, highly trained human in control of an automated vehicle -Hardware and software kit: either a standalone white-labelled remote vehicle control unit or complete integration with existing onboard high-resolution cameras, sensors and control units -Tele-operation as a service	Human (driver/ supervisor)	Dispatch ToD, Indirect Control ToD, Direct Control ToD	-Onboard high-resolution cameras, sensors -Six video streams + driving actuations - both Verizon and AT&T's networks using four cellular radios	Yes	Yes
Ottopia	-Offers a tele-operation platform	Human	Dispatch ToD,		Yes	Yes

	-In-vehicle module with Advanced Tele-operator Assistance Systems (ATAS™) -Off-the-shelf hardware with specialised software to run a tele-operation centre	(driver/ supervisor)	Indirect Control ToD, Direct Control ToD	-360 video stream fused in real-time with vehicle and sensor data		

5.2 Research projects addressing connectivity for ToD

This section reviews the many research projects addressing connectivity for ToD with the focus on use cases, the lessons learned from the relevant research activities, and their implications to our work in 5GAA.

5.2.1 5GCroCo

The ToD use case in 5GCroCo project [6] assists automated road vehicles by bringing a ToD operator into the control loop in situations which the automated vehicle cannot handle. The communication for transmitting sensor information and control signals between the automated vehicle and the remove driver is through cellular networks.

Both urban and rural environments, with low and high vehicle velocity respectively, are considered in 5GCroCo. Its ToD use case defines two vehicle control concepts, namely Direct Control and Indirect Control, which respectively match ToD Type ”Direct Control” and ToD Type “Indirect Control” defined in Section 3 of this TR. The former allows a remote operator to control the vehicle at the Operational level by sending steering wheel angle, velocity, turning signals, etc. to the vehicle. The latter allows the remote operator to send trajectory information to the vehicle, while the automated vehicle takes care of Operational level operation when executing the received trajectory.

5GCroCo defines four user stories of the ToD use case: [7]

- User Story 1 – Remotely Controlled Manoeuvring (direct control, low velocity)
- User Story 2 – Remotely Controlled Trajectory-based Driving (indirect control, low velocity)
- User Story 3 – Remotely Controlled Trajectory-based Driving on Rural Crossed Country Road (indirect control, high velocity)
- User Story 4 – Slim Uplink for ToD (indirect control, low velocity)

5.2.1.1 User Story 1 – Remotely Controlled Manoeuvring (Direct Control, Low Velocity)

In User Story 1, the vehicle is assumed to come to a safe stop on its own when encountering a road blockage, e.g. due to an accident of other vehicles. The automated vehicle cannot overcome the road blockage and will hand over the control to the remote operator who manoeuvres the vehicle to pass the road blockage and brings it to a safe stop again. After this, the automated vehicle takes back the control and continues driving.

The remote operator uses the Direct Control ToD for manoeuvring the vehicle in this User Story, which is limited to low velocity (<15km/h) and within a small manoeuvring range (<100m). Figure 2 and Figure 3 from [7] show the schematics and time schedule of User Story 1, respectively.

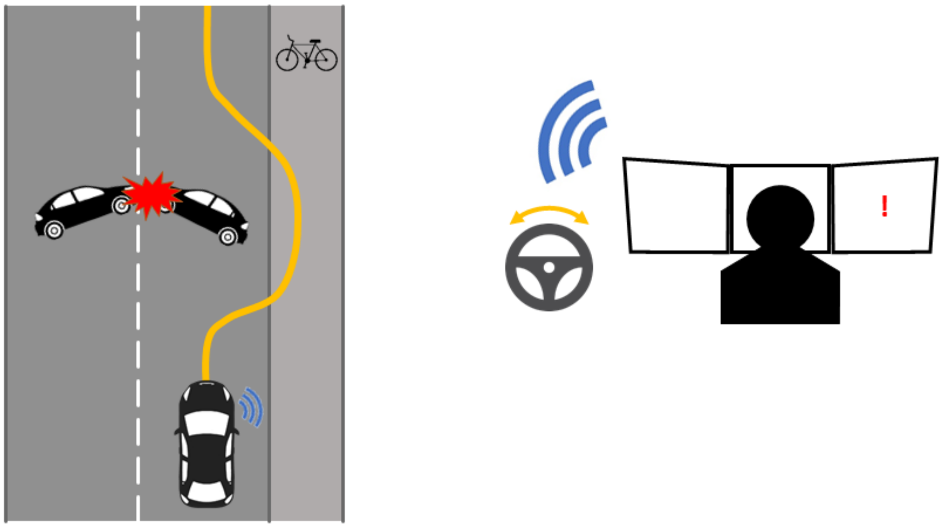

Figure 2: User Story 1 schematics [7]

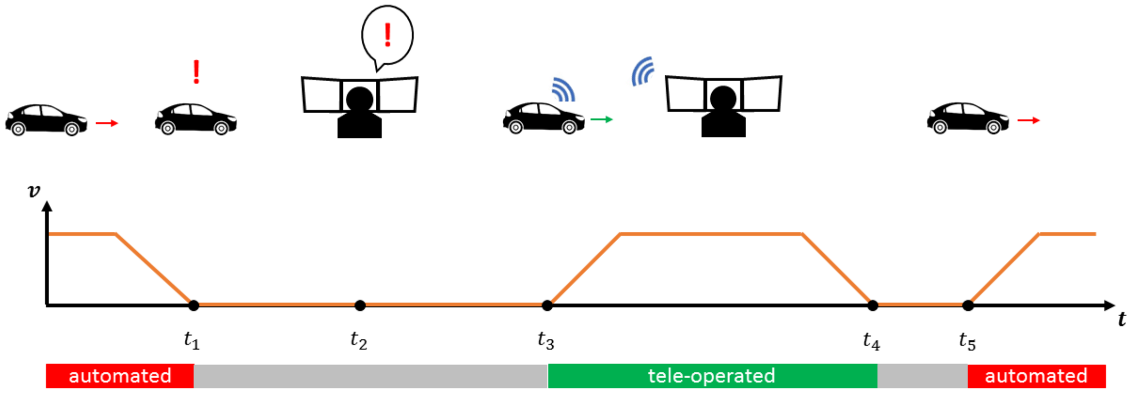

Figure 3: User Story 1 time schedule [7]

5.2.1.2 User Story 2 – Remotely Controlled Trajectory-based Driving (Indirect Control, Low Velocity)

User Story 2 is similar to User Story 1. The difference is that in this story the remote operator uses Indirect Control ToD instead of Direct Control ToD, when guiding the vehicle out of the road blockage. This means instead of the desired steering coordinates and velocity, a trajectory is defined by the remote operator and sent to the vehicle, which will execute the manoeuvre according to the received trajectory.

User Story 2 is also limited to low velocity (<15km/h) and within a small manoeuvring range (<100m). Figure 4 and Figure 5 from [7] show the schematics and time schedule of user story 2, respectively.

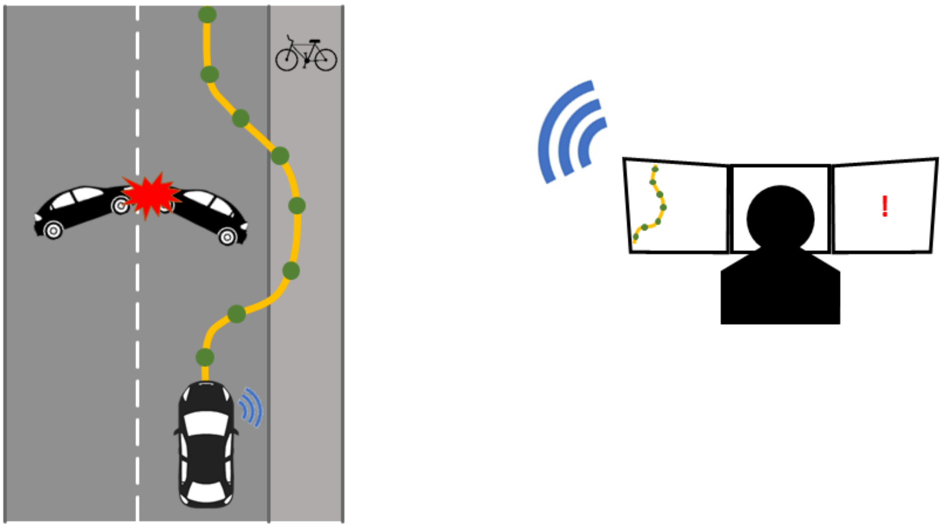

Figure 4: User Story 2 schematics [7]

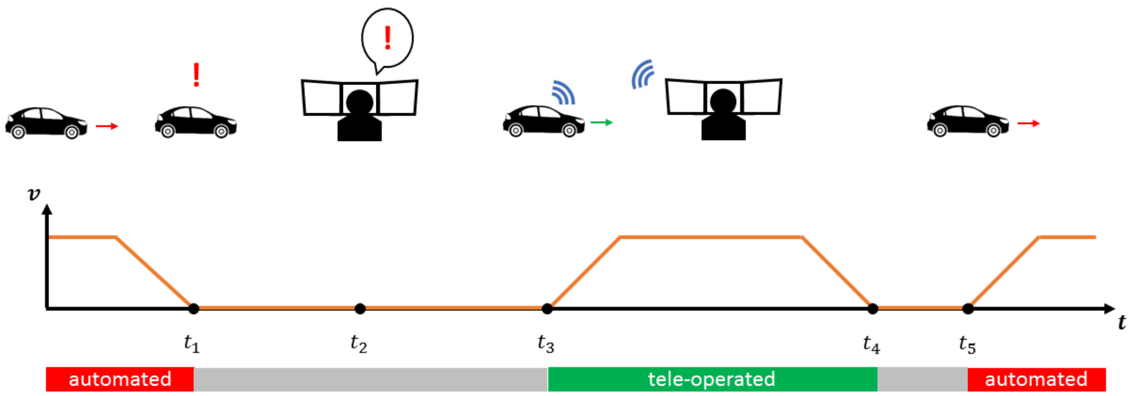

Figure 5: User Story 2 time schedule [7]

5.2.1.3 User Story 3 – Remotely Controlled Trajectory-based Driving on Rural Crossed Country Road (indirect control, high velocity)

In User Story 3, the remote operator controls the vehicle on rural roads with a speed up to 80km/h. During the drive, the vehicle crosses a communication network border, while the remote operator is connected to the vehicle. In this story, the ToD operator uses the Indirect Control ToD and provides the trajectory to the vehicle. One additional requirement to the communication networks in this example is that the ToD operation should continue without interruption due to the handover between network providers.

In this story, the operational range is up to 5000m. Figure 6 and Figure 7 from [7] show the schematics and time schedule of User Story 3, respectively.

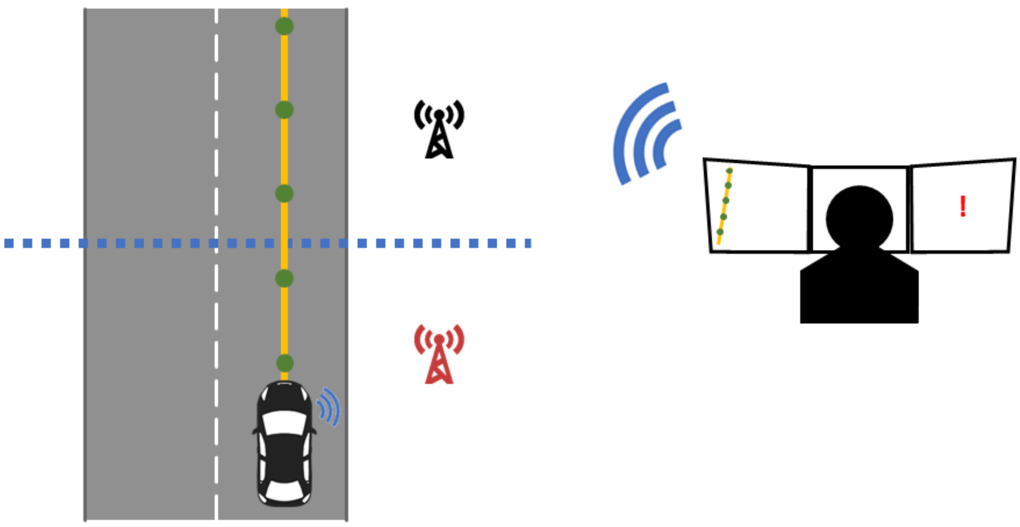

Figure 6: User Story 3 schematics [7]

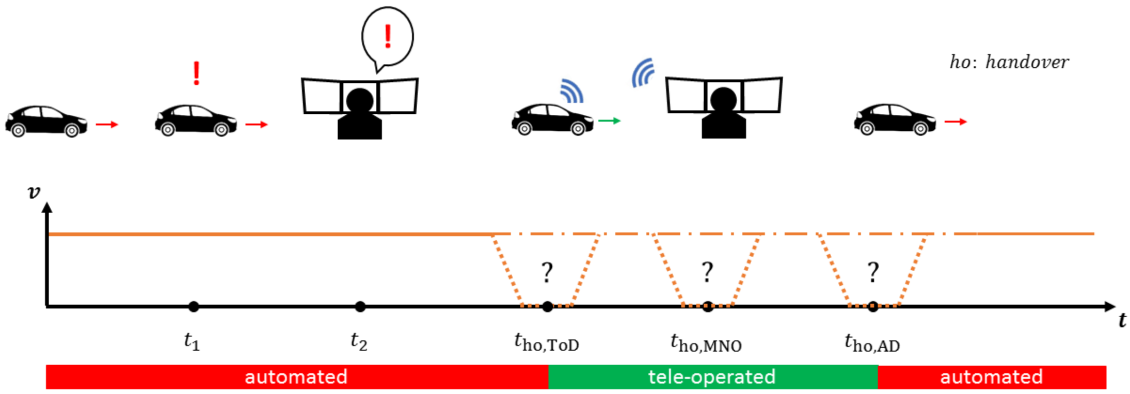

Figure 7: User Story 3 time schedule [7]

5.2.1.4 User Story 4 – Slim Uplink for ToD (indirect control, low velocity)

User Story 4 is similar to User Story 2. The difference is that instead of always using full video, the uplink communication from the vehicle to the remote operator can be reduced to periodic 'still' images, compensated with additional vehicle perceived object information, known as 'Slim uplink'. The main goal is to improve the efficiency and scalability of the uplink data channel, while achieving comparable results to User Story 2.

The remote operator uses Indirect Control for manoeuvring the vehicle in this user story. This user story is also limited to low velocity (<15km/h) and within a small manoeuvring range (<100m). Figure 8 and Figure 9 from [7] show the schematics and time schedule of User Story 4, respectively.

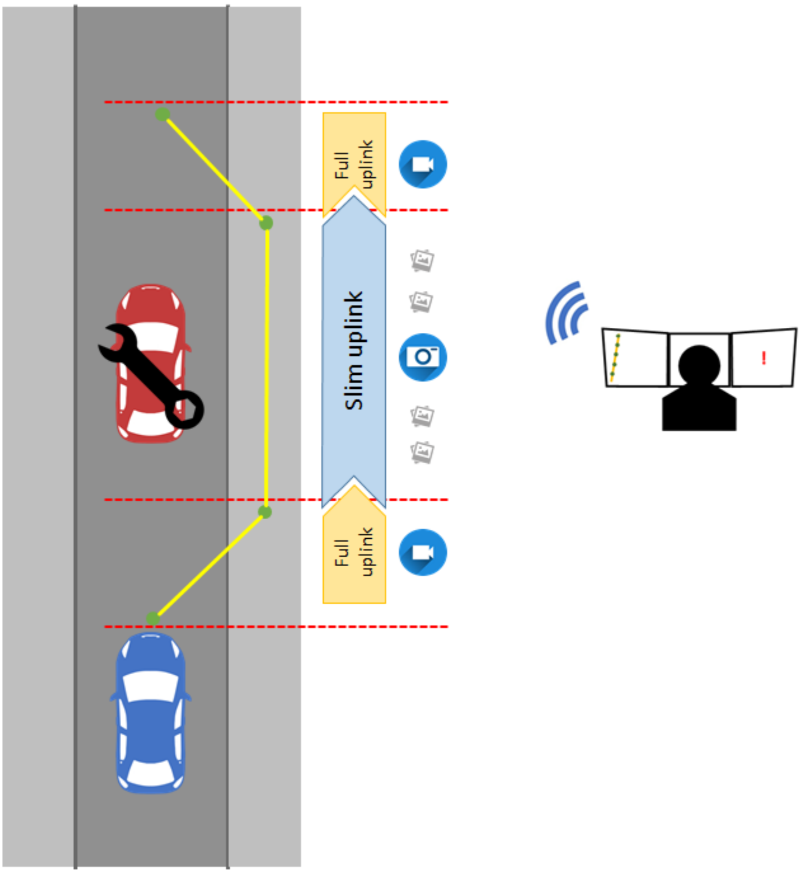

Figure 8: User Story 4 schematics [7]

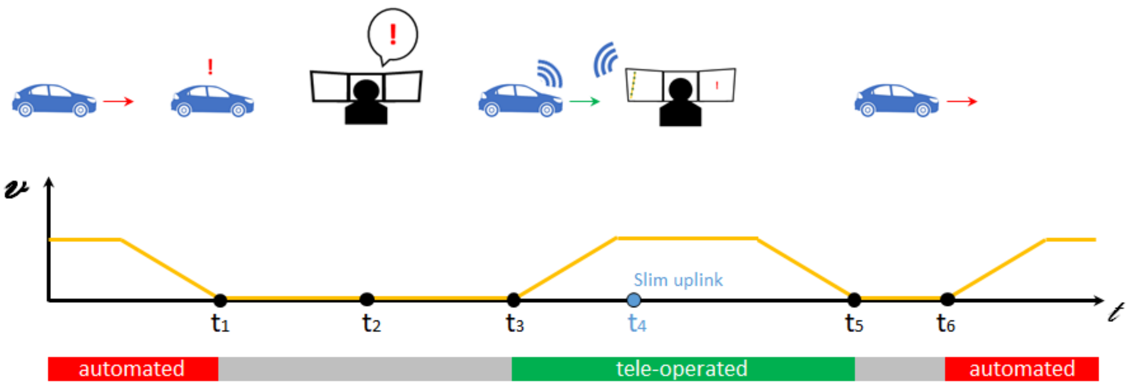

Figure 9: User Story 4 time schedule [7]

5.3 Lessons Learned and Recommendations

We can already see increased traffic in and between cities plus the increase of logistical demands in designated areas, such as ports, warehouses, and factories, just to mention a few. This has brought up the need for automated driving systems, having ToD both as a bridge towards fully automated solutions and as a support for difficult situations and corner cases. Table 1 shows the state of the art of what is currently in the market and their proposed technical solutions. In order to achieve high-scale deployment of this technology, several aspects still need greater focus, mainly mobile network reliability, functional safety and in the case of open roads, coexistence with vehicles with lower automation levels (which also may not be connected to a mobile network). The transportation corridor solutions mentioned in Section 5.1 serve as an effective intermediate step for safety and vehicle coexistence. Using an old railway line as a corridor could be a market opportunity for automated personal vehicles to have a dedicated track and hand over the driving to a ToD service provider in exchange for a toll/fee. The most important aspect for deployment is that this can be safely and reliably done. For this, initiatives such as Ericsson and Scania's ITS testbed are of high importance, since they provide semi-urban and urban environments in which ITS applications, such as Tele-Operated Driving, can be realistically tested and eventually, integrated.

In respect to research projects, 5GCroCo is at the phase of preparing to integrate various software and hardware components for the planned ToD tests and trials that will take place in 2020 and 2021 [11]. Hence, the first recommendations based on its experimentation and validation are expected to be derived in the last quarter of 2020. However, an initial architectural and business analysis can already provide some useful insights for the development of ToD services. According to D5.1 [12] there are presently no business models for Tele-Operated Driving. ToD Type "Direct Control" and ToD Type "Indirect Control" defined in Section 3 of this TR, demand high network reliability that may not be achievable with the current 4G/LTE mobile network standard. However, with the 5G mobile network standard promising to drastically increase reliability, this is subject to change. Furthermore, seamless service along the route, where the vehicle is tele-operated, can be enabled with the 5GCroCo solution on predictive Quality of Service (QoS).

Network slicing, as mentioned in [13], together with QoS prediction solutions, is also applicable for ToD. Instantiating a virtual network for the data transmission can facilitate sufficient and predictable bandwidth, and thus enable improved safety during the tele-operation. Furthermore, network slicing is part of ongoing research in preparation for when computations may be carried out in MEC application servers in order to reduce the data volume transmitted from the vehicle to the vehicle control centre.

In addition, according to [13], ToD has demanding requirements with respect to functional safety, as errors generated by the automated vehicle system might cause injuries to passengers and other road users. Today's concepts for automotive functional safety, mainly defined by ISO26262, do not address the possibility that other vital parts of the system follow a different functional safety approach e.g. aviation, railroads. To keep the possibility of providing functionally, safe ToD; concepts that allow the existence of system elements which are not being developed according to ISO26262, have to be taken into account, while still maintaining functional safety under full control. Functional safety and reliable end-to-end (E2E) QoS communication requirements are essential. Cross-border operations impose significant additional challenges for lag-free data transmission when handing over between MNOs.

Finally, a detailed specification of the interaction between the vehicle and the remote operator is needed, especially for vehicles which belong to different OEMs (i.e. this applies to both Direct and In-direct ToD). In addition, the definition of Operational Design Domain (ODD), as explained later in Section 7.2, is necessary for the safety considerations of a certain ToD function. The ODD defines conditions and constraints under which the considered function is intended to work in a safe manner.

6 ToD Use Cases and Scenarios

6.1 5GAA WG1 Extended Use Cases

As mentioned in Section 1, the goal of this work was to take the existing use cases from WG1 as a basis and to extend them with scenarios which can be deployed through different points in time. The methodology used for this task is described in Section 4, and the complete result of this work can be found in [10].

Additionally, a down-selection and prioritisation process was conducted, taking both business and functional safety aspects into account. More details regarding these specific aspects can be found in Sections 7.2 and 7.3. After a close collaboration with WG5 and the (Safety Treatment in Connected and Automated Driving (STiCAD) team, the down-selection of scenarios was finalised. These are presented in each of the following subsections (as 'Proposed Scenarios') and will be taken as a reference for future architecture and technical requirement analysis in this ToD XWI.

6.1.1 T-180205 Tele-Operated Driving

6.1.1.1 Detailed Description

The goal of this use case is to enable a ToD operator (human or machine) to remotely drive a Host Vehicle (HV). The HV needs to receive and apply the driving instructions sent by the ToD operator. The HV provides the environmental information and data to enable remote driving functionality. This use case corresponds to ToD Type "Indirect Control" and ToD Type "Direct Control".

For instance, a temporary health issue (e.g. illness, headache) of a driver impairs their concentration, reactions and judgement and consequently affects their ability to drive safely. The driver of the vehicle (with some automated capabilities) asks a ToD operator to undertake the control of the vehicle and remotely drive it in an efficient and safe manner from the current location to the destination. The HV starts sharing video and/or sensor data (e.g. from RADAR and LIDAR sensors) either raw or pre-processed and/or performs a situation interpretation to provide an adequate perception of the environment to the ToD operator. Based on the perceived environment, the ToD operator provides the appropriate trajectory and manoeuvre instructions to the HV for efficient and safe navigation to the destination. See Figure 10.

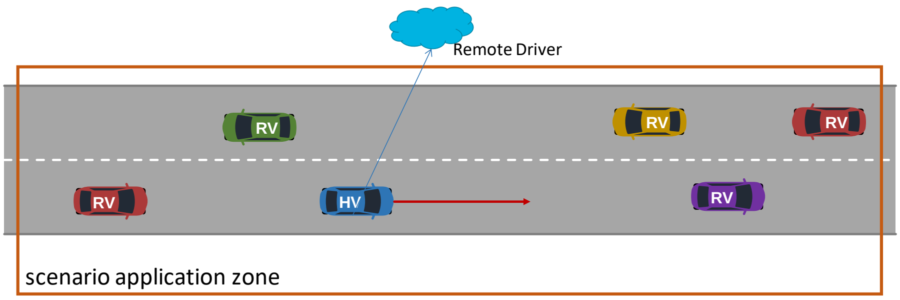

Figure 10: ToD scenario application

6.1.1.2 Message Flow

This message flow (in addition to the message flows in subsequent subsections), assumes that the ToD operator has established an authenticated and secure communication channel with the HV. Three alternative schemes are presented as follows.

Alternative A: If the ToD operator is a machine then

- The ToD operator receives road conditions (e.g. obstacles) and status information of neighbouring Remote Vehicles (RVs) (e.g. location, speed, dynamics, etc.) derived from, for instance, the HV's sensors, status information of the HV (e.g. speed, location), and traffic conditions
- The ToD operator, based on the received information, builds a model of the surroundings (i.e. awareness of the HV's environment) and, taking into account the destination point, selects the trajectory and the manoeuvre instructions
- The HV receives the trajectory and/or the manoeuvre instructions from the ToD operator and executes them, according to HV's onboard security checks
- Feedback is provided to the ToD operator in parallel with the execution of the manoeuvre
- The HV adjusts its trajectory, speed, acceleration, etc. based on received control information. When the vehicle has reached its destination then the remote driving process ends.

Alternative B: If the ToD operator is a human then

- The ToD operator receives video streams (e.g. identifying road conditions, neighbouring RVs) of high-quality status information about the HV (e.g. speed, location)
- The ToD operator, based on the received information, builds situation awareness and, taking into account the destination point, selects the trajectory and manoeuvre instructions
- The HV receives from the ToD operator trajectory and/or the manoeuvre instructions and executes them, according to the HV's onboard security checks
- Feedback is provided to the ToD operator in parallel with the execution of the manoeuvre
- The HV adjusts its trajectory, speed, acceleration, etc. based on received control information, and when the vehicle has reached its destination then the remote driving process ends.

Alternative C (as an extension of Alternative A or B): If the ToD operator has to communicate with a passenger or any person outside of the vehicle (e.g. police) then

- An audio stream is also established between the ToD operator and the vehicle (passenger or outside person)
- The audio stream ends when the communication is no longer needed.

6.1.1.3 Proposed Scenarios

The classification methodology (e.g. seven questions) described in Section 4, was followed for this use case and then, taking go-to-market and functional safety aspects into account, we prioritised two scenarios for further study in this ToD XWI, as follows.

<table>
<tr><th>Scenario</th><th>Detailed Description, Specifics, and Non-functional Requirements</th></tr>
<tr><td rowspan="2">ToD with ‘Remote driving Paths’ (ToD Type “Indirect Control”)

A difficult situation is resolved by a ToD operator who advises the HV how to make decisions for its automated driving task. This can be either by providing paths to the vehicle to drive in an automated manner to the destination, or the ToD operator providing instructions to the HV which will then execute them in its automated driving mode until the final destination has been reached. The ToD operator does not take over control of steering and acceleration. The ToD operator has the possibility to control the brake.</td><td><u>Scenario description</u>

A.4 [10] Sending manoeuvre instructions and trajectory to single OEM fleet in confined area.

• Performing risky/complex manoeuvres
• Creating efficiencies by replacing human drivers on every vehicle
• Complementing L4/L5 mode of automated operation in dangerous or special terrains and conditions
• If mandated by regulation (e.g. when transporting children outside geo-fenced areas)
• When commandeered by authorities

The service is provided by one ToD provider to the OEM fleet owner.

This scenario is identified by the following parameter settings according to the classification methodology introduced in Section 4.

1. What is being transported? → Both passengers and goods
2. Who owns the vehicle? → Car OEM fleet
3. Which environment is the use case executed? → Restricted area or designated route on public road
4. Are vehicles from a single or multiple OEMs? → Single OEM
5. Does service provisioning involve a single or multiple MNOs? → Single MNO
6. Do vehicles operate in different regions managed by different Road Traffic Authorities? → Single RTA
7. Are ToD services provided by single or multiple providers in this scenario? → Single ToD provider</td></tr>
<tr><td><u>Selection of additional requirements/assumptions</u>

• The ToD operator has established an authenticated and secure communication channel with the vehicle.
• The vehicle shall be capable of following remote trajectories, e.g. capable of engaging automated driving at Level 3 [8] or higher.
• Network resources shall be available for the time when the ToD service is needed, and the communication link shall be reliable and encrypted.
• Service continuity shall be guaranteed during the operation of ToD service.
• The vehicle shall receive notifications about expected QoS change (i.e. QoS prediction) and then appropriate adaptations should be applied (e.g. reduce speed, enable safe operation etc.).
• The vehicle shall be able to know its own geographical position and send it to the ToD service provider when required.
• Trustworthy and highly dynamic information about the geographical location of confined areas should be made available to the ToD Service Provider.
• The ToD operator should be informed about any authorised or unauthorised access to confined areas, e.g. by applying admission control.</td></tr>
</table>

ToD with 'Remote Steering' (ToD Type "Direct Control") A difficult situation is resolved by a ToD operator who takes over complete control of the HV until the final destination has been reached. The driving task is 100% on the ToD operator. The ToD operator decides on acceleration, braking, steering, signage, etc. For this case the ToD operator takes over all controls of the HV but is still assisted by the HV's driver assistance functions.	Scenario description B.2[10] Remote driving service to single OEM fleet. • From a certain port to the destination city • From an area outside the city centre, for example the airport, to the city centre (car sharing) The service is provided by one ToD service provider to an OEM fleet owner. This scenario is identified by the following parameter settings according to the classification methodology introduced in Section 4. 1. What is being transported? → Goods 2. Who owns the vehicle? → Car OEM fleet 3. Which environment is the use case executed? → Public road/infrastructure 4. Are vehicles from a single or multiple OEMs? → Single OEM 5. Does service provisioning involve a single or multiple MNOs? → Multi-MNOs 6. Do vehicles operate in different regions managed by different Road Traffic Authorities? → Single RTA 7. Are ToD services provided by single or multiple providers in this scenario? → Single ToD provider
	Selection of additional requirements/assumptions • The ToD operator has established an authenticated and secure communication channel with the vehicle. • The vehicle shall be capable of processing remote actuator commands. • The vehicle shall receive manoeuvre instructions from the ToD operator and execute them, according to vehicle's onboard security checks. • Network resources shall be available for the time when the ToD service is needed, and the communication link shall be reliable and encrypted. • The vehicle shall be able to know its own geographical position and send it to the ToD service provider when required. • The vehicle shall receive notifications about expected QoS change (i.e. QoS prediction) and then appropriate adaptations should be applied (e.g. reduce speed, enable safe operation etc.). • Real-time response and high reliability shall be maintained when the vehicle drives through national borders or needs to roam between different MNOs or operates under the various RTAs of different geographical regions.

6.1.2 T-180206 Tele-Operated Driving Support

6.1.2.1 Detailed Description

The goal of this use case is to remotely support the tasks of a vehicle with automated capabilities (e.g. by providing a driving manoeuvre) for a short period of time, when the vehicle faces highly uncertain situations making decision-making difficult. The difference between this use case and the 'Tele-Operated Driving' use case (described in Section 6.1.1), is that a Remote Driving service is needed in this case for a short period of time.

The two identified operation modes are the following:

- Remote Steering or ‘Direct Control’: This refers to **ToD Type ”Direct Control”** defined in Section 3.
- Remote driving instructions or ‘Indirect Control’: This refers to **ToD Type “Indirect Control”** defined in Section 3.

6.1.2.2 Message Flow

Tele-Operated Driving Support: Remote Steering or ‘Direct control’

If the ToD operator is a machine then

- The HV vehicle provides information about the type of HV, its destination and also information that will enable the ToD operator to build a model of the surroundings to help the ToD operator. This information may include road conditions derived e.g. by HVs’ sensors and cameras, status information of neighbouring RVs (e.g. location, speed, dynamics etc.), and traffic conditions
- If available, secondary information from road infrastructure is accessed to obtain a more holistic view of the situation
- The ToD operator analyses the situation and selects the appropriate trajectory and/or manoeuvre instructions that will help the HV to resolve the corresponding situation.
- The ToD operator sends trajectory and/or manoeuvre instructions to the HV and executes them, according to HV’s onboard security checks
- Feedback is provided to the ToD operator in parallel with the execution of the manoeuvre.

If the ToD operator is a human then

- The HV vehicle provides video streams of high quality (e.g., to identify road conditions, neighbouring RVs) and status information of the HV (e.g., speed, location, destination).
- If available, secondary information from road infrastructure is accessed to obtain a more holistic view of the situation
- The ToD operator analyses the situation and selects the appropriate trajectory and/or manoeuvre instructions that will help the HV to resolve the corresponding situation
- The ToD operator sends trajectory and/or manoeuvre instructions to the HV and executes them, according to HV’s onboard security checks
- Feedback (video, other sensors, HV status) is provided to the ToD operator in parallel with the execution of the manoeuvre.

Tele-Operated Driving Support: Remote Driving Instructions or ‘Indirect Control’

The message flow for this operation mode is basically the same as the one described above, with the difference that the ToD operator does not take control of steering and acceleration. Instead, driving commands, routes or instructions are sent remotely (e.g. ‘ignore lane marking’, ‘pass car blocking the road on the right/left’) to the HV for a short period of time to overcome a dangerous or complex situation on the road.

6.1.2.3 Proposed Scenarios

The classification methodology (e.g. seven questions) described in Section 4 was followed for this use case and then, taking go-to-market and functional safety aspects into account, we prioritised two scenarios for further study in this ToD XWI, as follows.

Scenario	Detailed Description, Specifics, and Non-functional Requirements
	Scenario description

ToD support with 'Remote Driving Paths' (ToD Type "Indirect Control") A difficult situation is resolved by a ToD operator who advises the HV how to make decisions for its automated driving task. The ToD operator will provide instructions to the HV which will then execute them in its automated driving mode. The ToD operator does not take over control of steering and acceleration. The ToD operator has the possibility to control the brake.	A.4[10] Sending manoeuvre instructions and trajectory to vehicle fleet in a confined area **(green zone)** or following a pre-determined route • Performing risky/complex manoeuvres • Creating efficiencies by replacing human drivers on every vehicle • Complementing L4/L5 mode of automated operation • If mandated by regulation (geo-fenced areas) • When commandeered by authorities • In emergency situations The service is provided by one ToD provider to OEM fleet owner. This scenario is identified with the following parameter settings according to the classification methodology introduced in Section 4. 1. What is being transported? → Both passengers and goods 2. Who owns the vehicle? → Car OEM fleet 3. Which environment is the use case executed? → Confined space/restricted area 4. Are vehicles from a single or multiple OEMs? → Single OEM 5. Does service provisioning involve a single or multiple MNOs? → Single MNO 6. Do vehicles operate in different regions managed by different Road Traffic Authorities? → Single RTA 7. Are ToD services provided by a single or multiple providers in this scenario? → Single ToD provider
	<u>Selection of additional requirements/assumptions</u> • The vehicle shall be capable of following remote trajectories, e.g. capable of engaging automated driving of Level 3 [8] or higher. • Network resources shall be available for the time when the ToD support service is needed, and the communication link shall be reliable and encrypted. • The vehicle shall be able to know its own geographical position and send it to the ToD service provider when required. • Trustworthy and highly dynamic information about the geographical location of green zones and other confined areas should be made available to the ToD service provider. • The ToD operator should be informed about any authorised or unauthorised access to the green zone or any other confined area, e.g. by applying admission control.
ToD support with 'Remote Steering' (ToD Type "Direct Control") A difficult situation is resolved by a ToD operator who takes over complete control of the HV. The driving task is 100% on the ToD operator. The ToD	<u>Scenario description</u> B.4[10] Remote driving support to fleet vehicles in a confined area **(green zone)** or following a pre-determined route • Performing risky/complex manoeuvres • Creating efficiencies by replacing human drivers on every vehicle • Complementing L4/L5 mode of automated operation • If mandated by regulation (e.g. geo-fenced areas) • When commandeered by authorities

<table>
<tr><td rowspan="2">operator decides on acceleration, braking, steering, signage, etc. For this case the ToD operator takes over all controls of the HV but is still assisted by the HV's driver assistance functions.</td><td>

- In emergency situations

The service is provided by one ToD provider to a fleet owner.

This scenario is identified with the following parameter settings according to the classification methodology introduced in Section 4.

1. What is being transported? → Both passengers and goods
2. Who owns the vehicle? → Car OEM fleet
3. Which environment is the use case executed? → Confined space/restricted area
4. Are vehicles from a single or multiple OEMs? → Single OEM
5. Does service provisioning involve a single or multiple MNOs? → Single MNO
6. Do vehicles operate in different regions managed by different Road Traffic Authorities? → Single RTA
7. Are ToD services provided by single or multiple providers in this scenario? → Single ToD provider

</td></tr>
<tr><td>

<u>Selection of additional requirements/assumptions</u>

- The vehicle shall be capable of processing remote actuator commands.
- Network resources shall be available for the time when the ToD support service is needed, and the communication link shall be reliable and encrypted.
- The vehicle shall be able to know its own geographical position and send it to the ToD Service Provider when required.
- Trustworthy and highly dynamic information about the geographical location of green zones and other confined areas shall be made available to the ToD service provider.
- The ToD operator should be informed about any authorised or unauthorised access to the green zone or any other confined area, e.g. by applying admission control.

</td></tr>
</table>

6.1.3 T-180207 Tele-Operated Driving for Automated Parking

6.1.3.1 Detailed Description

The goal of this use case is to execute automated parking of vehicles using ToD services. A remote entity, either human or machine, provides the appropriate path and manoeuvre instructions to the vehicle for efficient and safe parking. For this use case two user stories have been identified in [3], which respectively match the scenario categories A (Indirect Control ToD) and B (Direct Control ToD) as defined in Section 3:

- **Tele-Operated Driving for Automated Parking: Remote Driving Paths (Indirect Control ToD)**

  A remote driving centre provides paths to the vehicle in order to drive in an automated manner to the available/predefined parking spot.

- **Tele-Operated Driving for Automated Parking: Remote Steering (Direct Control ToD)**

  A remote driving centre (human or machine) undertakes to park the vehicle, supported by real-time video streaming that is sent from the remotely driven vehicle and sensor information.

6.1.3.2 Message Flow

The basic event flows of ToD for Automated Parking have been defined by WG1 in [3].

For User Story 1, Tele-Operated Driving for Automated Parking: Remote driving Paths (Indirect Control ToD), the basic event flow is

- The HV arrives in the ‘Pick -up/Drop-off area and requests an automated remote parking service by the parking ToD operator
- The parking ToD operator builds a model of the surrounding environment, using information provided by the HV (e.g. sensor data, type of vehicle) and the Parking Management System (e.g. sensors inside the parking area and the high-definition map inside the parking area), and then identifies the appropriate parking spot
- The parking remoter driver estimates the driving path for the available parking spot and sends the driving path to the HV
- The HV receives and executes the driving path instructions from the parking ToD operator according to onboard security checks
- The HV provides updated information about its location, status and sensor information to the parking ToD operator; and the latter monitors the route of the HV and adapts its path, if needed, according to the vehicle and/or the Parking Management System’s feedback.

For User Story 2 Tele-Operated Driving for Automated Parking: Remote Steering (Direct Control ToD), the basic event flow is

- The HV arrives in the ‘Pick-up/Drop-off’ area and requests an automated remote parking service by the parking ToD operator
- The HV transmits the vehicle’s sensor information, status and high-definition video streaming to the parking ToD operator
- The parking ToD operator builds a model of the surrounding environment, using information provided by the HV and the Parking Management System, if available, to identify the appropriate parking spot. Taking into account the destination point, the parking ToD operator selects the manoeuvre instructions
- The parking remote drive periodically transmits the manoeuvre instructions (e.g. steering wheel, speed, acceleration) to the HV
- The HV executes the driving commands received from the parking ToD operator, according to the onboard security checks
- Feedback is sent from the HV to the parking ToD operator in the course of execution of the manoeuvre.

6.1.3.3 Proposed Scenarios

Following the methodology descripted in Section 4, we have identified eight scenarios of the ToD for the Automated Parking use case. Annex <A.3> provides the description and characteristics of each identified scenario. Taking go-to-market and functional safety aspects into account, we down-selected four scenarios for further study in Task 2 and Task 3 of the ToD XWI and provide additional requirements associated with the selected scenarios.

Scenario	Detailed Description, Specifics, and Non-functional Requirements
Scenario 1 ToD for Automated Park with ‘Remote Driving Paths’ (ToD Type “Indirect Control”) for a vehicle fleet from a single car OEM in constrained/confined areas.	<u>Scenario description</u> Scenario A.3 [10] of use case ToD for Automated Parking T-180207. In automotive OEM factories, there is a need to move a fleet of vehicles from one location to another, e.g. transferring newly produced vehicles from the plant line to the rail transport station. [19] ToD can be used to park vehicles at a designated location, e.g. loading docks for a train. This scenario is identified by the following characteristics according to the classification methodology introduced in Section 4. 1. What is being transported? → Goods (no passenger on vehicles) 2. Who owns the vehicle? → Car OEM fleet

	3. Which environment is the use case executed? → Confined space/restricted area (the parking areas are confined areas only allowing authorised staff to enter, e.g. trained workers) 4. Are vehicles from a single or multiple OEMs? → Single OEM 5. Does service provisioning involve a single or multiple MNOs? → Single MNO 6. Do vehicles operate in different regions managed by different Road Traffic Authorities? → Single RTA 7. Are ToD services provided by single or multiple providers in this scenario? → Single ToD provider (ToD service is provided with Indirect Control, i.e. ToD Type "Indirect Control")
	<u>Selection of additional requirements/assumptions</u> In addition to the service level requirements defined in WG1 [3], the following requirements should be considered: • The vehicle shall be capable of following remote trajectories, e.g. capable of engaging automated driving of Level 3 [8] or higher. • Communication links between the ToD operator and the vehicle should be trustworthy and encrypted. • Trustworthy information about the environment, e.g. HD map of the parking area, shall be made available to the ToD operator. • The ToD operator should be informed about any authorised or unauthorised access to the confined area, e.g. by applying admission control. • The vehicle shall be able to know its own geographical position and send it to the ToD service provider when required. • Liability among vehicles, remote operators, and facilities (e.g. parking facility), shall be clarified based on related certification and authorisation of each party.
Scenario 2 ToD for Automated Park with 'Remote Driving Paths' (ToD Type "Indirect Control") for a fleet of vehicles from multiple car OEM in constrained/confined areas.	<u>Scenario description</u> Scenario A.4 [10] of use case ToD for Automated Parking T-180207. In certain areas, such as garages or seaports, automated parking service can be provided to vehicles via ToD with Direct Control. In this scenario, vehicles may be from different car OEMs and using communication services from different mobile network operators. No passenger is in the vehicle when the automated parking service is engaged. The garage or seaport areas are confined and do not allow access to people. For a specific area only, one ToD service provider provides the automated parking service. This scenario is identified by the following characteristics according to the classification methodology introduced in Section 4. 1. What is being transported? → Goods (no passengers on vehicles) 2. Who owns the vehicle? → Legacy fleet provider 3. Which environment is the use case executed? → Confined space/restricted area (the parking areas are confined areas not allowing access to people) 4. Are vehicles from a single or multiple OEMs? → Multiple OEM 5. Does service provisioning involve a single or multiple MNOs? → Multiple MNOs

	6. Do vehicles operate in different regions managed by different Road Traffic Authorities? → Single RTA 7. Are ToD services provided by single or multiple providers in this scenario? → Single ToD provider (ToD service is provided with Indirect Control, i.e. ToD Type "Indirect Control")
	Selection of additional requirements/assumptions In addition to the service level requirements defined in WG1 [3], the following requirements should be considered: • The vehicle shall be capable of following remote trajectories, e.g. capable of engaging automated driving of Level 3 [8] or higher. • The interface between remote operators and vehicles from different OEMs shall be standardised. • Communication links between ToD operators and the vehicle shall be trustworthy and encrypted. • Trustworthy information about the environment, e.g. HD map of the parking area, shall be made available to the ToD operator. • The vehicle shall be able to know its own geographical position and send it to the ToD service provider when required. • The ToD operator should be informed about any authorised or unauthorised access to the confined area, e.g. by applying admission control. • Liability among vehicles, remote operators, and facilities (e.g. parking facility), shall be clarified based on related certification and authorisation of each party. • Authentication and charging solutions may be required for ToD service provisioning. • Privacy protection shall be provided, if applicable.
Scenario 3 ToD for Automated Park with 'Remote Steering' (ToD Type "Direct Control") for a vehicle fleet from a single car OEM in constrained/confined areas.	Scenario description Scenario B.3 [10] of use case ToD for Automated Parking T-180207. This scenario is similar to Scenario 1, i.e. Scenario A.3 [10] of use case ToD for Automated Parking T-180207, except the ToD service is of ToD Type "Direct Control", i.e. 'Direct Control', as defined in Section 3. This scenario is identified by the following characteristics according to the classification methodology introduced in Section 4. 1. What is being transported? → Goods (no passenger on vehicles) 2. Who owns the vehicle? → Car OEM fleet 3. Which environment is the use case executed? → Confined space/restricted area (the parking areas are confined areas only allowing authorised staff to enter, e.g. trained workers). 4. Are vehicles from a single or multiple OEMs? → Single OEM 5. Does service provisioning involve a single or multiple MNOs? → Single MNO 6. Do vehicles operate in different regions managed by different Road Traffic Authorities? → Single RTA

	7. Are ToD service provided by single or multiple providers in this scenario? → Single ToD provider (ToD Service is provided with Direct Control, i.e. ToD Type ”Direct Control”)
	<u>Selection of additional requirements/assumptions</u> In addition to the service level requirements defined in WG1 [3], the following requirements should be considered: • The vehicle shall be capable of processing remote actuator commands. • Communication links between ToD operators and the vehicle shall be trustworthy and encrypted. • Trustworthy information about the environment, e.g. HD map of the parking area, shall be made available to the ToD operator. • The vehicle shall be able to know its own geographical position and send it to the ToD service provider when required. • The ToD operator should be informed about any authorised or unauthorised access to the confined area, e.g. by applying admission control. • Liability among vehicles, remote operators, and facilities (e.g. parking facility), shall be clarified based on related certification and authorisation of each party.
Scenario 4 ToD for Automated Park with ‘Remote Steering’ (ToD Type ”Direct Control”) for a fleet of vehicles from multiple car OEMs in constrained/confined areas.	<u>Scenario description</u> Scenario B.4 [10] of use case ToD for Automated Parking T-180207. This scenario is similar to Scenario 2, i.e. Scenario A.4 [10] of use case ToD for Automated Parking T-180207, except the ToD service is of ToD Type ”Direct Control”, i.e. ‘Direct Control’, as defined in Section 3. This scenario is identified by the following characteristics according to the classification methodology introduced in Section 4. 1. What is being transported? → Goods (no passengers on vehicles) 2. Who owns the vehicle? → Legacy fleet provider 3. Which environment is the use case executed? → Confined space/restricted area (the parking areas are confined areas not allowing access of people). 4. Are vehicles from a single or multiple OEMs? → Multiple OEM 5. Does service provisioning involve a single or multiple MNOs? → Multiple MNOs 6. Do vehicles operate in different regions managed by different Road Traffic Authorities? → Single RTA 7. Are ToD services provided by single or multiple providers in this scenario? → Single ToD provider (ToD service is provided with Direct Control, i.e. ToD Type ”Direct Control”)
	<u>Selection of additional requirements/assumptions</u> In addition to the service level requirements defined in WG1 [3], the following requirements should be considered: • The vehicle shall be capable of processing remote actuator commands.

	• The interfaces between remote operators and vehicles from different OEMs shall be standardised. • Communication links between the ToD operator and the vehicle shall be trustworthy and encrypted. • Trustworthy information about the environment, e.g. HD map of the parking area, shall be made available to the ToD operator. • The vehicle shall be able to know its own geographical position and send it to the ToD service provider when required. • The ToD operator should be informed about any authorised or unauthorised access to the confined area, e.g. by applying admission control. • Liability among vehicles, remote operators, and facilities (e.g. parking facility), shall be clarified based on related certification and authorisation of each party. • Authentication and charging solutions may be required for ToD service provisioning. • Privacy protection shall be provided, if applicable.

6.1.4 T-190062 Infrastructure-based Tele-Operated Driving

6.1.4.1 Detailed Description

The goal of this use case is to remotely support the tasks of a vehicle with automated capabilities (e.g., by providing a driving manoeuvre) for a short period of time, when the vehicle's own sensory or computational capabilities are failing, uncertain or the onboard sensor coverage is not sufficient. The difference in this use case, compared to the use case described with a human operator, is that the remote support relies mainly on environment perception provided by sensors outside the vehicle, which for availability reasons will be fixed sensors under direct control of the infrastructure. Those sensors are the primary information source for the tele-operator. The sensors in the infrastructure are able to produce a temporal and locally complete picture of the environment in real time. This type of infrastructure support is envisioned primarily for vehicles that drive on pre-defined routes like shuttle or bus services. Both Remote Steering (Direct Control) and Remote Driving Instructions (Indirect Control) are supported. Previously described ToD use cases are further extended by allowing a computer program to take over the task of a human tele-operator. This computer program can potentially run close to the vehicle in need (i.e. at the edge, directly connected to the fixed infrastructure sensors) thus reducing the latency between vehicle and controller.

An automated vehicle (e.g. passenger cars, shuttles or buses) may detect a failure in either computing or sensor components that are critical for the automated driving functionality. Without external support, this may lead to a safety function being implemented in the form of a command to come to a complete stop. Depending on where this happens (e.g. on a highway or in front of a traffic light) this can be a mere inconvenience or a safety hazard for the Host Vehicle's occupants or other vehicles' drivers. A human driver could be overwhelmed by this situation e.g. if the HV stops in the far-left lane on a highway and asks for help from a tele-operator. A tele-operator, supported by infrastructure sensors, will be able to assess both the position of the HV and that of other vehicles and pedestrians in the vicinity. Again, this can be either a human operator or a software program applying a similar perception and decision-making stack as the automated driving vehicle itself. The tele-operator will then guide the HV, either by Remote Steering (Direct Control) or Remote Driving Support (Indirect Control), to the nearest safe location e.g. safety lane on the highway or parking spot in the city (See Figure 11). This use case can be potentially extended by accessing other parts of the traffic infrastructure e.g. traffic lights or warnings, and speed limit signs in order to further support the safe driving of the HV.

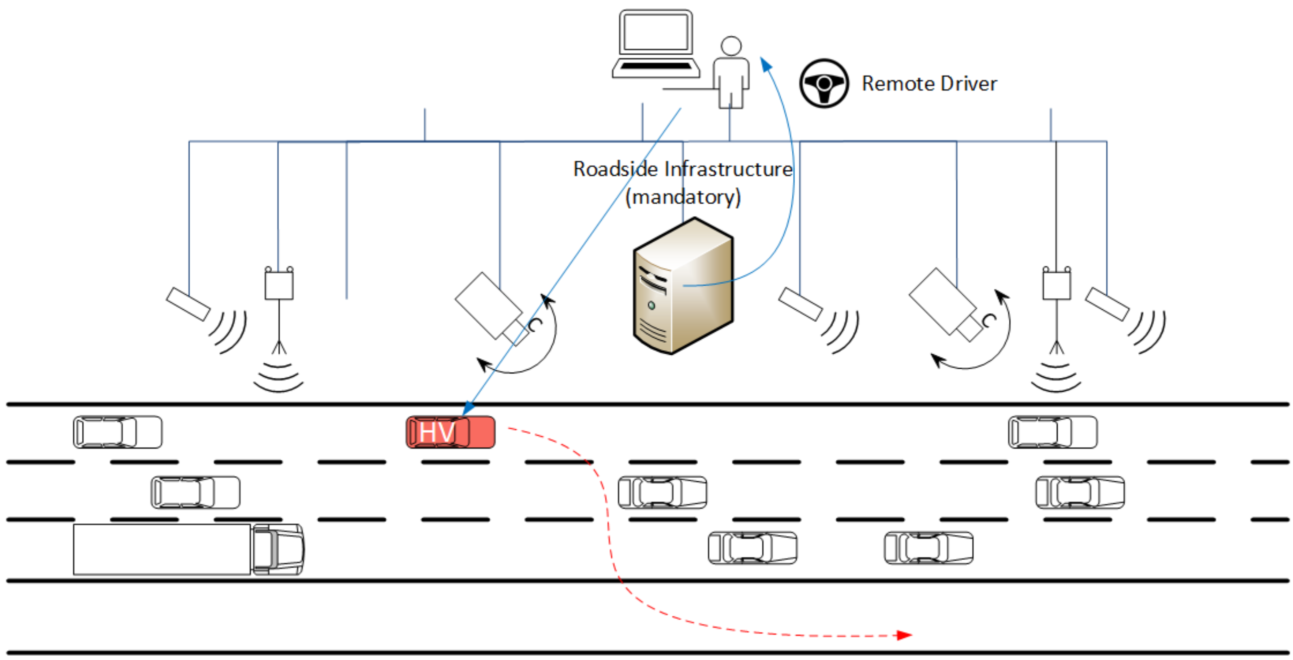

Figure 11: System architecture for infrastructure-based Tele-Operated Driving

6.1.4.2 Message Flow

There are two alternatives regarding the first connection to the infrastructure. It depends on whether the ToD service is the only service provided by the infrastructure or not. If the vehicle uses other services as well, then the initial attachment happens as soon as the vehicle enters the range of the infrastructure (Alternative 1). If the vehicle is only using the ToD services, then the initial connection happens only after an emergency occurs (Alternative 2). There can be further variations, depending on the type of tele-operator – i.e. a human operator or a machine. Here, we distinguish between alternatives a. and b., as below.

Alternative 1

- On entering a zone with infrastructure coverage, the HV and infrastructure perform an initial handshake to establish a secured communication channel and speed up emergency communication
- During the initial handshake, basic technical capabilities of the HV are communicated to the infrastructure to be used for different services that the infrastructure provides, among others, for the tele-operator or remote driving function
- As basic functionality, the infrastructure's sensors track all moving vehicles, including the HV, so its location in case of an emergency is known.

Alternative 2

- After an emergency is detected, the HV and infrastructure perform an initial handshake to establish a secured communication channel and speed up emergency communication.

Alternative a: If the ToD operator is a machine (See Figure 12) then

- The HV vehicle informs the ToD operator about its emergency situation and sends an update regarding its faulty subsystems. Because of the pre-established relationship between the HV and infrastructure, a seamless handover between HV and ToD operator is possible, potentially reducing the speed of the HV
- The necessary information to build a model of the surroundings and the HV's own speed, direction and location is already available to the ToD operator because it is continuously generated by infrastructure sensors. If available, secondary information from other vehicles is accessed to obtain a more holistic view of the situation
- If the automated HV is capable of following complete trajectories, the infrastructure provides one or several safe emergency trajectories to the HV. The HV selects the trajectory based on distance and comfort, and executes it. New trajectories are generated repeatedly until the HV is at its safe destination. Comfort in this instance means

that the HV's automated driving system selects the trajectory that best suites the vehicle's physical characteristics like mass, steering radius, acceleration or braking power

- If the HV cannot process trajectories, then the ToD operator takes control over the vehicle's actuation.
- Feedback is provided to the ToD operator in parallel with the execution of the manoeuvre.

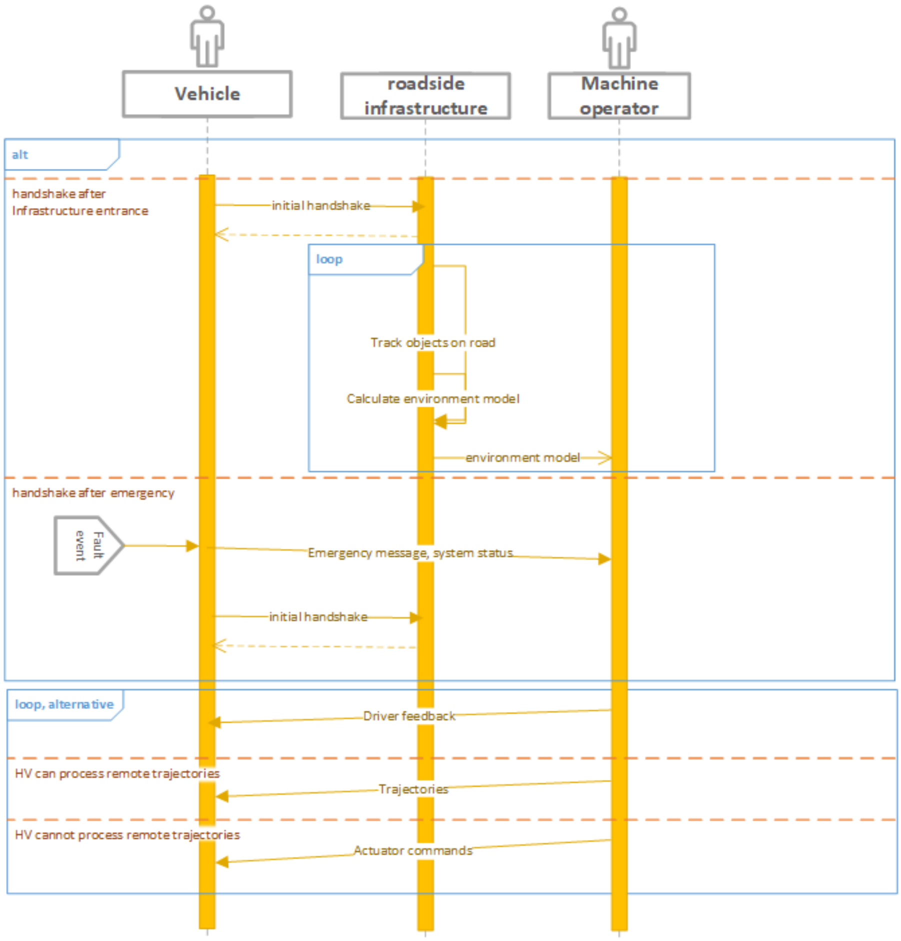

Figure 12: Message flow for infrastructure-based Tele-Operated Driving – ToD operator is a machine

Alternative b: If the ToD operator is a human (See Figure 13) then

- The HV needs to stop before a human driver can take over
- The HV sends an emergency message to the human remote operator
- Based on infrastructure sensors including cameras, a virtual view of the environment is provided to the ToD operator similar to a video game. This can be augmented with raw video streams. Real camera data from the infrastructure is added. The infrastructure sensor data can be augmented by sensor data from other vehicles
- The ToD operator analyses the situation and selects the appropriate trajectory and/or the manoeuvre instructions that will help the HV to resolve the corresponding situation where uncertainty is high
- The ToD operator sends commands to the actuator and the HV executes them, according to HV's onboard security checks
- Simulated feedback data and video data from an appropriate infrastructure camera is provided to the ToD operator in parallel with the execution of the manoeuvre.

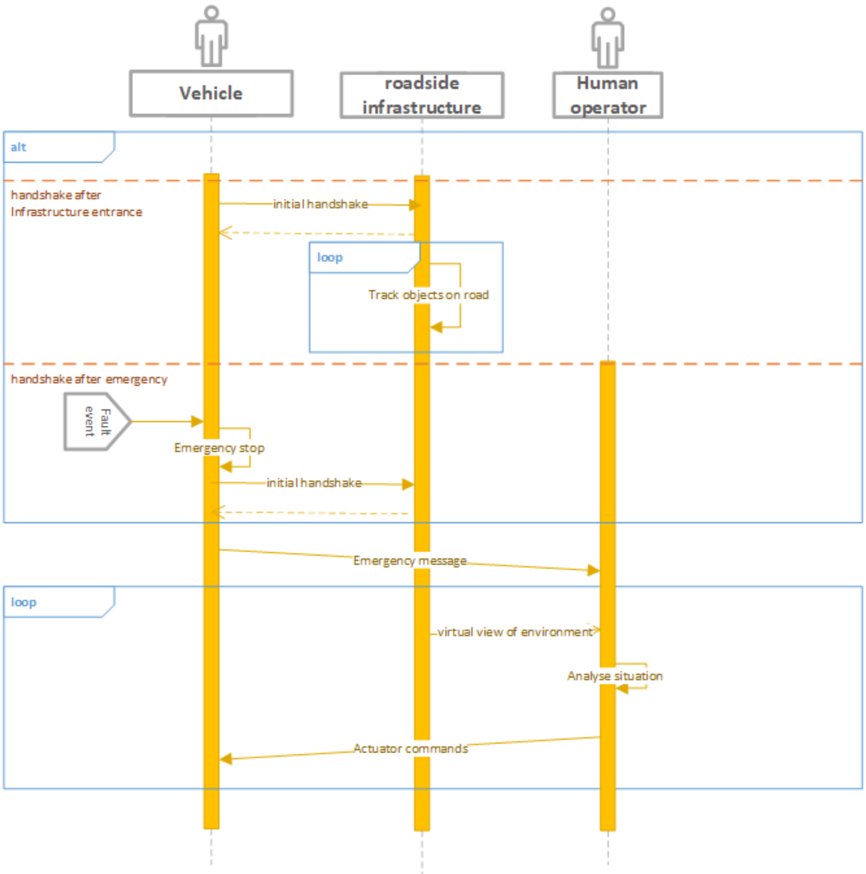

Figure 13: Message flow for infrastructure-based Tele-Operated Driving – ToD operator is a human

6.1.4.3 Proposed Scenarios

This scenario is a reaction to an emergency of an automated driving vehicle.

When an automated vehicle detects a failure in a critical sub-system it prepares a status report for the tele-operator together with its geo-position, performs the necessary safety function (e.g. slow down or stop) and transmits all information to the tele-operator. Assuming the incident location is covered by infrastructure sensors, the tele-operator retrieves a real-time picture of the road environment around the HV. Based on the perceived situation and the capabilities of the vehicle, the ToD operator can provide the appropriate trajectory and manoeuvre instructions to help the automated vehicle to move to a safer location. This scenario has two instantiations.

Most of the details about the following scenarios are already given in sections 6.1.4.1 and 6.1.4.2.

The classification methodology (e.g. seven questions) described in Section 4 was followed for this use case and then, taking go-to-market and functional safety aspects into account, we down-selected two scenarios for further study in this ToD XWI, as follows.

Scenario	**Detailed Description, Specifics, and Non-functional Requirements**
Scenario 1 Infrastructure based ToD (remote operator is human)	<u>Scenario description</u> A.2[10] Remote operator is human. A human operator in a remote driving centre drives a vehicle to a safe location, e.g. an emergency lane (if on highway) or a parking spot at the road side (if in the city).

<table>
<tr>
<td>A human operator in a remote driving centre drives a vehicle to a safe location, e.g. an emergency lane (if on highway) or a parking spot at the road side (if in the city).

The driver is supported by fixed infrastructure sensors that provide a simulated driving environment similar to a computer game because the vehicle's own forward facing camera might no longer be available.</td>
<td>The driver is supported by fixed infrastructure sensors that provide a simulated driving environment similar to a computer game because the vehicles own forward facing camera might no longer be available.

• In a public area or special zones like harbours, airports, or factory grounds
• Provided by a remote operator associated with the road section or zone
• Supporting vehicles from different automotive OEMs
• Using a single MNO network

This scenario is identified by the following characteristics according to the classification methodology introduced in Section 4.

1. What is being transported? → Both passengers and goods
2. Who owns the vehicle? → Car OEM fleet
3. Which environment is the use case executed? → Public road + confined space/restricted area
4. Are vehicles from a single or multiple OEMs? → Single OEM
5. Does service provisioning involve a single or multiple MNOs? → Single MNO
6. Do vehicles operate in different regions managed by different Road Traffic Authorities? → single RTA
7. Are ToD services provided by single or multiple providers in this scenario? → Single ToD provider</td>
</tr>
<tr>
<td></td>
<td><u>Selection of additional requirements/assumptions</u>

• Service subscription and payment may be required either through the vehicle OEM or vehicle owner.
• Authentication shall be required for the subscribed service.
• Trustworthy information about the environment, e.g. HD map of the parking area, shall be provided to the remote operator.
• The interface between remote operator and vehicles from different OEMs shall be standardised.
• A mutually authenticated and secure communication session between the vehicle and the local remote operator (via OEM backend system) shall be available.
• Liability among vehicles, remote operators, and facilities (e.g. parking facility), shall be clarified based on related certification and authorisation of each party.
• Privacy protection shall be provided, if applicable.
• Vehicle shall be capable of processing remote actuator commands or following remote trajectories.</td>
</tr>
<tr>
<td>Scenario 2

Infrastructure-based ToD (remote operator is machine)

A machine operator in a remote driving centre or at the edge near the vehicle drives a vehicle to a safe</td>
<td><u>Scenario description</u>

B.2[10] Remote operator is machine.

A machine operator in a remote driving centre or at the edge near the vehicle drives it to a safe location, e.g. an emergency lane (if on a highway) or a parking spot at the roadside (if in the city).

The machine uses fixed sensor input to generate an environment model and plans the driving path similar to the automated driving algorithms inside the vehicle.</td>
</tr>
</table>

location, e.g. an emergency lane (if on a highway) or a parking spot at the roadside (if in the city). The machine uses fixed sensor input to generate an environment model and plan the driving path similar to the automated driving algorithms inside the vehicle.	In this case raw sensor data like video streams do not have to be sent to a remote cloud location but can be processed locally close to the sensors. • In a public area or special zones like harbours, airports, or factory grounds • Provided by a remote operator associated with the road section or zone • Supporting vehicles from different automotive OEMs • Using a single MNO network This scenario is identified by the following characteristics according to the classification methodology introduced in Section 4. 1. What is being transported? → Both passengers and goods 2. Who owns the vehicle? → Car OEM fleet 3. Which environment is the use case executed? → Public road + confined space/restricted area 4. Are vehicles from a single or multiple OEMs? → Single OEM 5. Does service provisioning involve a single or multiple MNOs? → Single MNO 6. Do vehicles operate in different regions managed by different Road Traffic Authorities? → Single RTA 7. Are ToD services provided by single or multiple providers in this scenario? → Single ToD provider
	<u>Selection of additional requirements/assumptions</u> • Service subscription and payment may be required either through the vehicle OEM or vehicle owner. • Authentication shall be required for the subscribed service. • Trustworthy information about the environment, e.g. HD map of the parking area, shall be provided to the remote operator. • The interface between remote operator and vehicles from different OEMs shall be standardised. • A mutually authenticated and secure communication session between the vehicle and the local remote operator (via OEM backend system) shall be available. • Liability among vehicles, remote operators, and facilities (e.g. parking facility), shall be clarified based on related certification and authorisation of each party. • Privacy protection shall be provided, if applicable • Vehicle shall be capable of processing remote actuator commands or following remote trajectories.

7 Requirements for ToD scenarios Under Study

This section presents a summary of the technical requirements which were identified in each of the prioritised scenarios found in Section 6. The focus of this initial activity is to highlight those requirements which have still not been covered by previous work in WG1, taking specific operational scenarios and cross-x environments (e.g. multi-OEM, multi-MNO, and multi-RTA) as a basis. As a result, the requirements in this section are in addition and complementary to the ones described in the original ToD use case descriptions [1][2][3][4]. Further work on technical requirements will be performed in Tasks 2 and 3 of this XWI.

7.1 Functional Requirements

Communication and Network

- The remote operator shall establish a mutually authenticated and secure communication session with the vehicle.
- Service continuity shall be guaranteed during the operation of ToD service.
- The communication link shall be reliable and encrypted.
- The interface between remote operator and vehicles from different OEMs shall be standardised.
- Real-time response and high reliability of the communication session shall be maintained, when the vehicle drives through national borders, or needs to roam between different MNOs or operate under different RTAs of different geographical regions.
- The network shall be able to send notifications about expected QoS changes (i.e. QoS prediction) to vehicles and the remote operator, if such notifications are available.

Information

- The remote operator shall receive reliable information about the vehicle's capabilities before the ToD service takes place.
- Trustworthy information about the environment, e.g. HD map of the parking area, green zones, shall be made available to the remote operator.
- The remote operator should be informed about any authorised or unauthorised access to the confined area, e.g. by applying admission control.

Vehicle

- The vehicle shall be able to know its own geographical position and send it to the ToD service provider when required.

For ToD Type "Indirect Control"

- The vehicle shall be capable of following remote trajectories, e.g. capable of engaging automated driving of Level 3 [8] or higher.

For ToD Type "Direct Control"

- The vehicle shall be capable of processing remote actuator commands.
- The vehicle shall receive manoeuvre instructions from the remote operator and execute them, according to vehicle's onboard security checks.
- The vehicle shall be able to receive notifications about expected QoS changes (i.e. QoS prediction), if such notifications are available, and then appropriate adaptations should be applied (e.g. reduce speed, enable safe operation etc.).

Remote Operator

- The remote operator shall be able to receive notifications about expected QoS changes (i.e. QoS prediction), if such notifications are available, and then appropriate adaptations should be applied.

Other Requirements

- Liability among vehicles, remote operators, and facilities (e.g. parking facility), shall be clarified based on related certification and authorisation of each party.
- Service subscription and payment may be required either through the vehicle OEM or vehicle owner.

- Authentication shall be required for the subscribed service.
- Authentication and charging solutions may be required for ToD service provisioning.
- Privacy protection shall be applied, if applicable.

7.2 Preliminary Considerations for Safety Requirements

Safety considerations, in the way they are treated in the automotive industry, are observed in three major areas. The first is functional safety which takes into account all hazards caused by a malfunction of safety related Electrical/Electronic (E/E) systems. The second part deals with potentially hazardous behaviour caused by the intended functionality or performance limitation of a system that is free from the faults addressed in the functional safety domain. The third major area is security, which deals with the protection against attacks. See Figure 14:

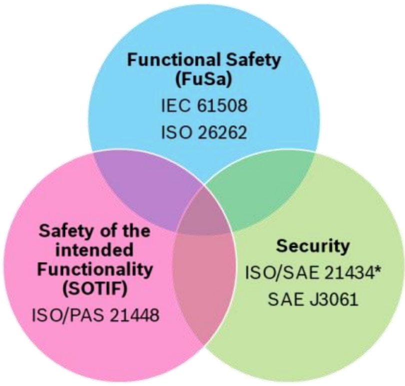

Figure 14: Three major areas for safety considerations

The major functional safety standards (e.g. ISO26262, IEC61508 and ISO/PAS21448) mainly deal with parts inside the vehicles themselves and, furthermore, assume that all major parts performing a certain function are under the control of the developer and manufacturer of the function and the underlying system. In tele-operation, however, the overall system consists not only of the vehicle but also of the Vehicle Control Centre (VCC) in the backend and the communication network connecting the vehicle with the VCC. As the VCC and the communication network are outside the vehicle and the automotive domain and as the communication network but potentially also the VCC are not under the control of the OEM developing and manufacturing the system, new challenges arise from a safety point of view.

This is especially true in an overall system as complex as that underlying a tele-operation use case; safety cannot be considered as separate or detached from other performance-influencing factors, such as function availability and timing considerations. The solutions developed need to find trade-offs between those factors in an economically reasonable range.

Figure 15: Performance-influencing factors for safety analysis

From a safety point of view, there are two major variants of tele-operation systems. One is the so-called Direct Control of the vehicle from the backend. In this case, the operator in the VCC has direct access to the actuators in the vehicle and therefore functional safety treatment tends to be more complex than in the Indirect Control case where the VCC generates, for instance, new driving trajectories or adds new areas to the allowed driving horizon.

For the safety analysis of the tele-operation systems, it is very important to know the Operational Design Domain in light of the function. The ODD defines conditions and constraints under which the considered function is intended to work in a safe manner. A safe system must be able to monitor all factors forming the ODD (e.g. weather conditions, road conditions) and stop (fail-safe state) the function or reduce the function capabilities (safe operational state) whenever the system is outside of its ODD. As this directly influences the availability of the function, special care is needed in defining the ODD (reducing the ODD offers greater safety assurance but tends to reduce availability).

A detailed analysis of the safety requirements and potential new methods for assuring safety in a connected and distributed system like the one underlying the tele-operation function will be carried out in the XWI STiCAD.

7.3 Preliminary Considerations for Business Requirements

For T-180205 Tele-Operated Driving, in regard to considerations such as

- Alternative A: If the ToD operator is a machine
- Alternative B: If the ToD operator is a human, then
- Alternative C (as an extension of Alternative A or B): If the ToD operator has to communicate with a passenger or any person outside the vehicle (e.g. policeman)

To the extent that the ToD service is discretionary and is requested on different occasions (i.e. addressing an emergency, seeking convenience or for luxury/entertainment) it must be interpreted as a premium service. The necessary ingredient for service delivery is the incorporation of tele-operation capabilities in the vehicle by the OEM. Regardless of whether the ToD capability is mandated or not, it is up to the commercial policy of the OEM to factor the service in the price of the vehicle or sell it as an add-on. Depending on who owns the vehicle, an individual or a fleet operator, the pricing scheme and the service packaging will differ.

If the vehicle is owned by an individual, and the price of ToD is factored into the vehicle's price, then it is likely that there will be a 'fair use' policy (e.g. the individual is entitled to 1 hour of ToD a month, and every hour exceeding this limit will be charged $100). If, on the other hand, the ToD service is presented to consumers as an add-on, there is a range of potential offerings, including 'passes' (once a day/week/month/year on a fair-use policy), 'pay-as-you-go', 'recurring subscriptions' (monthly rolling), and 'hybrid plans' (subscription with bundled usage that can be extended in pay-as-you-go fashion). In all cases, the party that acts as the ToD service owner is the OEM, regardless of whether the actual service delivery has been outsourced by the OEM to a specialised third-party company.

If the owner of the vehicle is a fleet operator, then they will bear the cost of the service. If the vehicles in the fleet come from the same OEM, it is likely that the OEM itself will offer the service (even outsourced, as described above), or alternatively a specialised ToD service provider will. Similarly, if the fleet includes vehicles from different OEMs, most likely a ToD service provider will deliver the service. In either case, the ToD service will cover all automated vehicles in the fleet through a bulk agreement, offering for example 1000 hours of tele-operation per month to be available to a 1000-vehicle fleet in a shared pool fashion. The contract governing this service, regardless of whether it is offered by the OEM or by a ToD service provider, will most likely be a multi-year agreement. In the event it is the OEM offering it, ToD may be just one of the various services it will offer the fleet operator. In which case, the price will be incorporated in the price of the whole deal, covering the vehicles and a basket of ancillary services, such as ToD.

The cost of cellular communications used in the ToD service delivery will burden the OEM where the vehicle is owned by an individual, and where the OEM offers ToD to a fleet operator. On the other hand, if the fleet operator is offered the service by a ToD service provider, they must also pay this cost by cutting an enterprise connectivity deal with an MNO.

Regarding alternatives A, B, and C, it is likely that services delivered by humans will be pricier. On the other hand, the existence of alternative C will not affect the business side of the ToD deal, as communication of a remote concierge (in Alternative A) or a ToD operator (in Alternative B) with the passengers or authorities will be just a feature of the core ToD service.

For T-180206 Tele-Operated Driving Support, in regard to use cases:

- ToD support with ‘Remote Driving Paths’ (ToD Type “Indirect Control”)
- ToD support with ‘Remote Steering’ (ToD Type ”Direct Control”)

To the extent that the ToD service is discretionary and is requested in different emergency situations, it is priced as a premium service. The fleet operator is the party that pays the ToD service provider, and the price is set through a wholesale agreement that covers the entire vehicle fleet. A typical way to cost it is to set a price per minute, whereby the fleet operator buys x thousands of minutes at a bulk price for a number of years to serve any and all vehicles in their fleet. Depending on the relative power and relationships between fleet operator and ToD service provider, the fleet operator will be charged either for the whole amount of x thousand minutes of ToD or only for the amount of minutes within this ‘bucket’ that were actually consumed. The price varies depending on whether the ToD service provider offers Direct or Indirect Control of the vehicles. The Direct Control service is priced higher as it involves additional effort on the part of the ToD operator and liability on the part of the ToD service provider. In the Indirect Control case, the price is lower as effort and skills required on the part of the ToD operator may be considered less demanding and liability is shared more heavily by the vehicle OEM, given that the automated vehicle is responsible for executing the commands issued in a safe and secure manner. Finally, communication expenses for the support of the ToD service on the vehicle side are borne by fleet operators, through a wholesale agreement with an MNO.

For T-180207 Tele-Operated Driving for Automated Parking, in regard to use cases:

- ToD for Automated Park with ‘Remote Driving Paths’ (ToD Type “Indirect Control”) for vehicle fleet from a single car OEM in confined areas (e.g. automotive OEM factories)
- ToD for Automated Park with ‘Remote Driving Paths’ (ToD Type “Indirect Control”) for a fleet of vehicles from multiple car OEMs in confined areas (e.g. garages or seaports)
- ToD for Automated Park with ‘Remote Steering’ (ToD Type ”Direct Control”) for vehicle fleet from a single car OEM in confined areas (e.g. automotive OEM factories)
- ToD for Automated Park with ‘Remote Steering’ (ToD Type ”Direct Control”) for a fleet of vehicles from multiple car OEMs in confined areas (e.g. garages or seaports)

Regarding business model considerations, the analysis carried out above applies for these use cases too. Of course, in particular cases we may see variations, as follows:

- ➢ If, for example, in the first use case the confined area is the OEM’s factory, then it is likely that the OEM can perform the remote driving task itself, in which case there is no monetary exchange with a ToD service provider
- ➢ Likewise, in the second use case, if the confined area is a port, then it is likely that the ToD service will be offered by an entity performing additional port operational tasks. In this case, the price of the ToD task may be absorbed in the price of a bundled service towards the fleet operator.

For T-190062 Infrastructure-based Tele-Operated Driving scenarios:

- Infrastructure-based ToD (remote operator is a human)

- Infrastructure-based ToD (remote operator is a machine)

Regarding business model considerations, what changes in the analysis factoring in infrastructure-assisted ToD is that the road operator offering the infrastructure is applying an extra charge to cover their service, to be borne by the fleet operator. This charge may differ depending on whether the ToD driving is carried out by a machine or a human. Further, to the extent that the ‘coupling’ of vehicle and infrastructure is mandatory when the vehicle is entering the infrastructure-equipped stretch of the highway, the charge for the coupling itself can be perceived as an extra ‘toll/flat fee payment’ covering the whole fleet for a long period of time. If and when there is a need for the actual ToD service delivery (i.e. in the event of an emergency), there can be a separate charge issued to the fleet operator covering the premium remote driving service, most likely on a per-minute basis (where again it is possible to cut a bulk agreement between ToD service provider/road operator and fleet operator).

8 Conclusions

This deliverable sought to expand on tele-operation use cases for vehicles transporting people and/or goods on public roads and/or restricted areas, in order to prepare the requirements for an end-to-end ToD service solution which also covers both stakeholder and ToD service provider needs.

For this purpose, the available ToD use cases introduced in WG1 were enhanced thanks to strong collaboration with WG5 and STiCAD XWI teams and their expertise. Related (pre-) commercial and R&D engagements have also been taken into account. The added value on each ToD use case is captured as additional requirements for down-selected use scenarios taking the business and functional safety aspects into account. These are presented as ‘Proposed Scenarios’ and will be taken as a reference for future architecture and technical requirement analysis in this ToD XWI.

Additional service operation scenarios were also considered, taking realistic and operational situations as a basis. For each use case, this deliverable provides its rationale, an overall description, the possible networking approaches, and the related information flows as a function of multi-OEM, multi-MNO, and multi-RTA scenarios.

To complete the holistic view on the enhanced ToD use cases in this deliverable, a common definition of the different ToD Types, based on [5] and [8], has been provided, with the aim of understanding the different levels of ToD driving tasks. Further on, the deliverable gives insights into preliminary considerations for the safety requirements of two major variants of tele-operation systems, from both a safety and functional safety point of view. Finally, some insights into business model considerations and go-to-market strategies for each use case are presented.

9 Definitions, Symbols and Abbreviations

9.1 Symbols

For the purposes of the present document, the following symbols apply:

<Symbol> <Explanation>

9.2 Abbreviations

For the purposes of the present document, the following abbreviations and acronyms apply:

DDT Dynamic Driving Task

E/E Electrical/Electronic

HD High Definition

HV Host Vehicle

ITS Intelligent Transport Systems

LoA Level of Automation

MNO	Mobile Network Operator
OEDR	Object and Event Detection and Response
OEM	Original Equipment Manufacturer
ODD	Operational Design Domain
QoS	Quality of Service
RTA	Road Traffic Authority
RV	Remote Vehicle
STiCAD	Safety Treatment in Connected and Automated Driving
ToD	Tele-Operated Driving
VCC	Vehicle Control Centre
WG	Working Group
XWI	Cross-working Group Work Item

Annex <A>: ToD User Scenarios

A.1 Scenarios of ToD

ID	Scenario Description	Priority WG5	Safety Complexity	What is being transported?		Who owns the vehicle?			Where can the UC is executed?		Manufacturer of vehicles		MNO Networks		Road Traffic Authorities (RTAs) of different geographical regions		ToD Service Provider	
		* : Low ** : medium ***: high	* : Low ** : medium ***: high	Passengers	Goods	Private	CAR OEM Fleet	Legacy Fleet provider	Public road / infrastructure	Restricted area or designated route on public road	Single OEM	Multi OEM	Single MNO Network	Multi MNO Networks	Single RTA	Multiple RTA	Single ToD service provider	Multiple ToD service providers
A.1	Sending **maneuver instructions and trajectory to private vehicle** • In emergency situations • When driver is impaired or unable to drive for any other reason The service is provided by one ToD service provider to private vehicle owners.	*	**	✓		✓			✓		✓		✓		✓		✓	
A.2	Sending **maneuver instructions and trajectory to single OEM fleet** • From a certain port to the destination city • From an area outside the city center, for example the airport, to the city center (car sharing) The service is provided by one ToD service provider to OEM fleet owner.	**	**		✓		✓		✓		✓			✓	✓		✓	
A.3	Sending **maneuver instructions and trajectory to legacy fleet (multi-OEM)** • In emergency situations • When driver is impaired or unable to drive for any other reason The service is provided by one ToD provider to legacy fleet owner.	**	***	✓				✓	✓			✓		✓	✓	?	✓	
A.4	Sending **maneuver instructions and trajectory to** single OEM fleet in confined area • Performing risky/complex manoeuver • Creating efficiencies by replacing human drivers on every vehicle • Complementing L4/L5 mode of autonomous operation in dangerous or special terrains and conditions • If mandated by regulation (e.g. when transporting children outside geo-fenced areas) • When commandeered by authorities The service is provided by one ToD service provider to OEM fleet owner.	***	***	✓	✓		✓			✓	✓		✓		✓		✓	

ID	Scenario Description	Priority WG5	Safety Complexity	What is being transported?		Who owns the vehicle?			Where can the UC is executed?		Manufacturer of vehicles		MNO Networks		Road Traffic Authorities (RTAs) of different geographical regions		ToD Service Provider	
		* : Low ** : medium ***: high	* : Low ** : medium ***: high	Passengers	Goods	Private	CAR OEM Fleet	Legacy Fleet provider	Public road / infrastructure	Restricted area or designated route on public road	Single OEM	Multi OEM	Single MNO Network	Multi MNO Networks	Single RTA	Multiple RTA	Single ToD service provider	Multiple ToD service providers
B.1	**Remote driving support service to private vehicle** • In emergency situations • When driver is impaired or unable to drive for any other reason The service is provided by one ToD service provider to private vehicle owners.	**	***	✓		✓			✓		✓		✓		✓		✓	
B.2	**Remote driving support service to single OEM fleet** • From a certain port to the destination city • From an area outside the city center, for example the airport, to the city center (car sharing) The service is provided by one ToD service provider to OEM fleet owner.	***	***		✓		✓		✓		✓			✓	✓		✓	
B.3	**Remote driving support service to legacy fleet (multi-OEM)** • In emergency situations • When driver is impaired or unable to drive for any other reason The service is provided by one ToD provider to legacy fleet owner.	**	***	✓				✓	✓			✓		✓	✓	?	✓	
B.4	**Remote driving support service to** single OEM fleet in confined area • Performing risky/complex manoeuver • Creating efficiencies by replacing human drivers on every vehicle • Complementing L4/L5 mode of autonomous operation in dangerous or special terrains and conditions • If mandated by regulation (e.g. when transporting children outside geo-fenced areas) • When commandeered by authorities The service is provided by one ToD service provider to OEM fleet owner.	**	***	✓	✓		✓			✓	✓		✓		✓		✓	

A.2 Scenarios of ToD Support

ID	Scenario Description	Priority WG5	Safety Complexity	What is being transported?		Who owns the vehicle?			Where can the UC is executed?		Manufacturer of vehicles		MNO Networks		Road Traffic Authorities (RTAs)		ToD Service Provider	
		* : Low ** : medium ***: high	* : Low ** : medium ***: high	Passengers	Goods	Private	CAR OEM Fleet	Legacy Fleet provider	Public road / infrastructure	Restricted area or designated route on public road	Single OEMs	Multi OEM	Single MNO Network	Multi MNO Networks	Single RTA	Multiple RTA	Single ToD service provider	Multiple ToD service providers
A.1	Sending **maneuver instructions and trajectory to private** vehicle •Perform risky/complex manoeuver •Emergency control service •When commandeered by authorities •In emergency situations The service is provided by a single ToD service provider to private vehicle owners.	*	**	✓		✓			✓		✓		✓		✓		✓	
A.2	Sending **maneuver instructions and trajectory to single OEM fleet** •Perform risky/complex manoeuver •Emergency control service •When commandeered by authorities •In emergency situations The service is provided by one ToD provider to OEM fleet owner.	**	**		✓		✓		✓		✓			✓	✓		✓	
A.3	Sending **maneuver instructions and trajectory to legacy fleet (multi-OEM)** •Perform risky/complex manoeuver Emergency control service •When commandeered by authorities •In emergency situations The service is provided by one ToD provider to legacy fleet owner (multi-OEM).	*	***	✓				✓	✓			✓		✓		✓		✓
A.4	Sending **maneuver instructions and trajectory to vehicle fleet in a confined area (green zone)** or following pre-determined route: •Performing risky/complex manoeuver •Creating efficiencies by replacing human drivers on every vehicle •Complementing L4/L5 mode of autonomous operation in dangerous or special terrains and conditions •If mandated by regulation (e.g. when transporting children outside geo-fenced areas) •When commandeered by authorities •In emergency situations The service is provided by one ToD provider to OEM fleet owner.	***	**	✓	✓		✓			✓	✓		✓		✓		✓	

ID	Scenario Description	Priority WG5	Safety Complexity	What is being transported?		Who owns the vehicle?			Where can the UC is executed?		Manufacturer of vehicles		MNO Networks		Road Traffic Authorities (RTAs)		ToD Service Provider	
		* : Low ** : medium ***: high	* : Low ** : medium ***: high	Passengers	Goods	Private	CAR OEM Fleet	Legacy Fleet provider	Public road / infrastructure	Restricted area or designated route on public road	Single OEMs	Multi OEM	Single MNO Network	Multi MNO Networks	Single RTA	Multiple RTA	Single ToD service provider	Multiple ToD service providers
B.1	**Remote driving support service** to private vehicle •Perform risky/complex manoeuver Emergency control service •For passengers who suddenly cannot drive by themselves (ill, intoxicated, otherwise unfit) •When commandeered by authorities •In emergency situations The service is provided by a single ToD service provider to private vehicle owners.	*	***	✓		✓			✓		✓		✓		✓		✓	
B.2	Remote driving support service **to single OEM fleet** •Perform risky/complex manoeuver Emergency control service •For passengers who suddenly cannot drive by themselves (ill, intoxicated, otherwise unfit) •When commandeered by authorities •In emergency situations The service is provided by one ToD provider to vehicle fleet owners.	**	***		✓		✓		✓		✓			✓	✓		✓	
B.3	**Remote driving support to legacy fleet (multi-OEM)** •Perform risky/complex manoeuver •Emergency control service •When commandeered by authorities •In emergency situations The service is provided by one ToD provider to legacy fleet owner (multi-OEM).	**	***	✓				✓	✓			✓		✓		✓		✓
B.4	Remote driving support to fleet vehicles in a confined area **(green zone)** or following pre-determined route: •Performing risky/complex manoeuver •Creating efficiencies by replacing human drivers on every vehicle •Complementing L4/L5 mode of autonomous operation in dangerous or special terrains and conditions •If mandated by regulation (e.g. when transporting children outside geo-fenced areas) •When commandeered by authorities •In emergency situations The service is provided by one ToD provider to fleet owner.	*	**	✓	✓		✓			✓	✓		✓		✓		✓	

A.3 Scenarios of ToD Services for Automated Parking

ID	Scenario Description	Priority		What is being transported?		Who owns the vehicle?			Where can the UC is executed?		Manufacturer of Vehicles		MNO Networks		Road Traffic Authorities (RTAs)		ToD Service Provider	
		WG5	STiCAD (Complexity)	Passengers	Goods	Private	CAR OEM Fleet	Legacy Fleet provider	Public road/ infrastructure	Restricted area or designated	Single OEM	Multi-OEM	Single MNO Network	Multi-MNO Networks	Single RTA	Multi-RTA	Single ToD Service Provider	Multiple ToD Service Providers
A.1	ToD (Indirect Control) for Automated Parking in public parking facilities, e.g. automated valet parking instruction, provided by a single ToD service provider to private owners of vehicles from a single OEM.	*	**	✔		✔			✔		✔		✔		✔		✔	
A.2	ToD (Indirect Control) for Automated Parking in public parking facilities for vehicle fleet from single car OEM, e.g. taxis, company fleets, etc. provided by multiple third-party ToD service providers.	*	**	✔			✔		✔		✔			✔		✔		✔
A.3	ToD (Indirect Control) for Automated Parking for vehicle fleet **in constrained/confined area**, e.g. **OEM factory site** provided by one ToD service provider. **Authorised people (trained workers) can enter the area.**	***	**		✔		✔			✔	✔		✔		✔		✔	

ID	Scenario Description	Priority		What is being transported?		Who owns the vehicle?			Where can the UC is executed?		Manufacturer of Vehicles		MNO Networks		Road Traffic Authorities (RTAs)		ToD Service Provider	
		WG5	STiCAD (Complexity)	Passengers	Goods	Private	CAR OEM Fleet	Legacy Fleet provider	Public road/ infrastructure	Restricted area or designated	Single OEM	Multi-OEM	Single MNO Network	Multi-MNO Networks	Single RTA	Multi-RTA	Single ToD Service Provider	Multiple ToD Service Providers
A.4	**ToD (Indirect Control) for transportation company instructing** multiple vehicles from **different OEMs with multiple contracts with MNO**s to park at a certain spot on a **port/ship**. This company has **one designated ToD provider** which controls those different vehicles. **No people can enter the area.**	**	***		✔			✔		✔		✔		✔	✔		✔	
B.1	ToD (Direct Control) for Automated Parking in public parking facilities, e.g. automated valet parking provided by a single ToD service provider to private owners of vehicles from a single OEM.	**	***	✔		✔			✔		✔		✔		✔		✔	
B.2	ToD (Direct Control) for Automated Parking in public parking facilities for vehicle fleet, e.g. taxis, company fleets, etc. provided by multiple third-party ToD service providers.	*	***	✔			✔		✔		✔			✔		✔		✔

ID	Scenario Description	Priority		What is being transported?		Who owns the vehicle?			Where can the UC is executed?		Manufacturer of Vehicles		MNO Networks		Road Traffic Authorities (RTAs)		ToD Service Provider	
		WG5	STiCAD (Complexity)	Passengers	Goods	Private	CAR OEM Fleet	Legacy Fleet provider	Public road/ infrastructure	Restricted area or designated	Single OEM	Multi-OEM	Single MNO Network	Multi-MNO Networks	Single RTA	Multi-RTA	Single ToD Service Provider	Multiple ToD Service Providers
B.3	ToD (Direct Control) for Automated Parking service for vehicle fleet in constrained/close area, e.g. **OEM factory site** provided by one ToD service provider. **Authorised people (previously trained workers) can enter the area.**	***	**		✔		✔			✔	✔		✔		✔		✔	
B.4	ToD (Direct Control) for Automated Parking service for multiple vehicles from **different OEMs** with **multiple contracts with MNOs** to park at a certain spot on a **port/ship**. This company has **one designated ToD provider** which controls the different vehicles. **No people can enter the area.**	***	***		✔			✔		✔		✔		✔	✔		✔	

A.4 Scenarios of Infrastructure-based ToD

ID	User Story	Example Services	Priority	What is being transported?		Who owns the vehicle?			Where can the UC is executed?		Manufacturer of vehicles		MNO Networks		Road Traffic Authorities (RTAs)		ToD Service Provider	
	Description		* : Low ** : medium ***: high	Passengers	Goods	Private	CAR OEM Fleet	Legacy Fleet provider	Public road / infrastructure	Restricted area or designated route on public road	Single OEM	Multi OEM	Single MNO Network	Multi MNO Networks	Single RTA	Multiple RTA	Single ToD service provider	Multiple ToD service providers
A.1	**Infrastructure based ToD(remote operator is human)** A human operator in a remote driving center drives a vehicle to a safe location, e.g. an emergency lane (if on highway) or a parking spot at the road side (if in the city). The driver is supported by fixed infrastructure sensors the provide a simulated driving environment similar to a computer game because the vehicles own forward facing camera might no longer be available.	Parking on emergency lane of highway or at the curbside in the city by human operator.	*	✓		✓			✓		✓		✓		✓	?	✓	
A.2		Parking on emergency lane of highway or at the curbside in the city by human operator. Owner is fleet management OEM	**	✓			✓		✓		✓		✓		✓	?	✓	
B.1	**Infrastructure based ToD(remote operator is machine)** A amchine operator in a remote driving center or at the edge near the vehicle drives a vehicle to a safe location, e.g. an emergency lane (if on highway) or a parking spot at the road side (if in the city). The machine uses fixed sensor input to generate an environment model and plan the driving path similar to the automated driving algorithms inside the vehicle. In this case sensor raw data like video streams don't have to be send to a remote cloud location but can be processed locally close to	Parking on emergency lane of highway or at the curbside in the city by machine, owner is private.	*	✓		✓			✓		✓		✓		✓	?	✓	
B.2		Parking on emergency lane of highway or at the curbside in the city by machine, owner is fleet management OEM.	**	✓			✓		✓		✓		✓		✓	?	✓	

Annex <B> ToD Parameter Definition

The below given specification parameter definitions are used in [1] and should be applied to the enhanced description of ToD use cases.

Parameter	Parameter Comment, Definition and Clarification
Priority	Priority of the use case in the 5GAA study of ToD services. Priority should be based on a business perspective, taking into account actual implementation times of all relevant components. High priority = go-to-market time of 3-5 years.
Technical complexity	The extent to which the features are difficult to implement. Some identified technical challenges are linked to interoperability, and cross-x domain. Note: x stands for automotive Original Equipment Manufacturer (OEM), Mobile Network Operator (MNO), or Road Traffic Authority (RTA).
CAR OEM fleet	Fleet of vehicles from one automotive OEM.
Legacy fleet provider	Provider of vehicle fleet that may consist of vehicles from different automotive OEM brands.
Public road/infrastructure	In contrast to restricted areas or confined areas, public roads are road, street or thoroughfare or any other place that the public has a right to access. Note: RTA is the contact point for legal regulations for public road / infrastructure.
Restricted area or designated route on public road	Confined areas with restricted access control, such as terminal areas and ports, or dedicated lanes and tracks in a non-confined area.
Multi-MNO networks	When more than one Mobile Network Operator (MNO) is involved during the ToD operation. There are two potential scenarios which will be considered, depending on the individual case: 1. Roaming: specifically, roaming contracts have to be considered 2. Multi-SIM implementation in the vehicle (more than one connection)
Multiple RTA (Multi-RTA)	When more than one Road Traffic Authority (RTA) is involved during the ToD operation. This can happen in the following scenarios:

	1. Cross-border scenario 2. Occurs in the same country on certain roads (i.e. Germany)
ToD service provider	The stakeholder in charge of providing the ToD services. Important from the OEM side: one single point of contact for ToD service provider. According to WG5 BARN Report, a ToD service provider is defined as “the suppliers of the ToD System for Automated Passenger Cars, which includes an ECU to be integrated into vehicles, and they operate a remote operation service manned by human operators that is consumed by end users. … The ToD service is being delivered through a remote control centre…”
Multiple ToD service providers	ToD providers could be different depending on the area, or country.
Service Level Latency (ms)	WG1 Whitepaper on use cases defined Service Level Latency as: “Measurements of time from the occurrence of the event in scenario application zone to the beginning of the resulting actuation. Depending on implementation, this includes one or more of [the] following: - processing of the event into information by the information generator - communication of the information to end-user - processing of the information by the end-user - time to actuation driven by the result of processing of the information” End-to-end latency must be considered. This means there is one or more stakeholders to be considered in the calculation, bringing the ToD service provider into the loop. This stakeholder has **not been** considered in WG1’s previous latency calculations.
Functional Safety Requirements	Map to STiCAD functional diagram describing the direction and to what extend it is needed for the vehicle, mobile network and backend.
Permission Management	Permission should be related to the ToD application, to control the vehicle, and mainly interfacing ToD service provider and OEM, and possibly legal authorities