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Next generation connectivity for enhanced, safe & efficient transport & logistics

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Abstract

This deliverable extends the preliminary business model analysis performed in a previous task of 5G-Blueprint. In addition, it builds on all the other business- and governance-related work of the project. More specifically, it provides a discussion of the feasibility of teleoperated transport Use Cases and their challenges across different deployment scenarios. For these Use Cases and scenarios, the report provides a discussion of validated business models, which is based on extensive, dedicated expert consultations. This qualitative analysis is complemented by a quantitative business case analysis that assesses the financial feasibility of specific deployments of teleoperated transport Use Cases under the defined deployment scenarios.

Keywords: business models, business case, deployment strategy

Document Revision History

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V1.1	10/09/2024	Updating of relevant sections to include impact of sharing 5G network infra and costs with other use cases and sectors	P. Camps, E. Kenis, W. Vandenberghe

Disclaimer

Project co-funded by the European Commission under H2020-ICT-2018-20		
Nature of the deliverable:	R	
Dissemination Level		
PU	Public, fully open, e.g. web	√
CI	Classified, information as referred to in Commission Decision 2001/844/EC	
CO	Confidential to 5G-Blueprint project and Commission Services	

* R: Document, report (excluding the periodic and final reports)

   DEM: Demonstrator, pilot, prototype, plan designs

   DEC: Websites, patents filing, press & media actions, videos, etc.

   OTHER: Software, technical diagram, etc

EXECUTIVE SUMMARY

This report builds up upon and extends the work carried out in the 5G-Blueprint project focusing on the business models and economic feasibility of 5G-enabled teleoperated transport Use Cases. The primary objectives of this report are as follows:

- **Validated business models**. The report describes a set of validated business models that are technically, financially, and organizationally viable. These models incorporate the roles of key actors within the previously-defined value network of 5G-based teleoperated transport. Establishing feasible business models is essential to define how services can be delivered to benefit various stakeholders and incentivize their adoption of teleoperated transport.

- **Assessing investment business cases.** The report evaluates the business case for investing in teleoperated transport Use Cases under different scenarios, taking into account all essential elements such as infrastructure, equipment, and operational costs.

- **Deployment Scenarios and feasible adoption timeframes.** The report investigates the realistic conditions and timeframes for the adoption and scaling of teleoperation Use Cases in various settings, including ports, warehouses, roads, waterways, and cross-border areas. It defines a series of realistic deployment scenarios and their associated economic and technical challenges.

- **Value Propositions.** The report explores the value proposition that 5G-based teleoperation offers to different stakeholders and identifies their motivations and potential role to contribute to the necessary investments and orchestration efforts to set up the new business ecosystem.

- **Blueprint for Adoption.** The report aims to serve as a blueprint for adoption beyond the project's geographical scope, providing clarity on the business case and feasible business models for deploying teleoperated transport Use Cases in different scenarios.

First, we present a validated and extended version of deployment scenarios for teleoperated transport Use Cases which serve as reference for the analysis of business models and the associated cost allocations. We present 6 scenarios, classified based on their geographical coverage and whether they refer to land or waterway transport operations. Second, on the basis of the deployment scenarios, we identify a validated series of teleoperated transport Use Cases that are expected to be feasible at different periods of time, along with their respective anticipated challenges from a business and technological perspective. To address the identified hurdles, the report elaborates on value propositions to incentivize key actors to invest in early deployments of essential infrastructure elements and take up key uncertain value network roles. By providing more clarity on these aspects, the present work helps make the business models and any potential deployment roadmap more realistic.

Validation interviews were conducted to assess the feasibility and sensibility of the business models at the technical, financial, and operational levels. The interviewed stakeholders provided feedback on several factors that contributed to a further finetuning of the proposed business models. Sections 4.1 to 4.4 of the report present the outcomes of the validation interviews, offering a series of validated business model options for the different deployment scenarios.

In small-Scale Scenarios (e.g., in port terminals), realistic business models involve site owners setting up their TO centre infrastructure and adopting TO for internal operations with their own trained personnel. Joint ventures of site owners or transport companies can be viable arrangements to share costs and to increase the scale of operations to slightly larger scenarios such as short-distance shuttle runs. However, external investment support can be crucial.

In contrast, the business model targeting a specialized, internationally-minded TO service provider that provides an integrated TO service to logistics companies and vessel or truck owners is seen as the easier model to implement and scale to teleoperated transport along roads and canals in the in the long term. However, incentivising the appearance of such an entity (still) might require co-financing to reduce the risk that the necessary infrastructure will be available.

For longer-distance and cross-border transport, TO becomes feasible when combined with high automation. A specialized TO service provider is the most practical model for scaling up in the short term from the previous scenarios, while large transport companies are the most logical actor. Transport companies would be the main beneficiary of adopting teleoperation in logistics, in terms of financial and labour shortage aspects, but also the ones that are at higher risk of losing competitive advantage if they react too passively to innovation. Alternative disruptive models might emerge but are only seen as feasible in the longer term; for instance, digital platform models where OEMs or mobility service providers provide match-making for TO trips cargo and vehicle owners and logistics customers.

The business models for 5G connectivity service providers are more straightforward, although several realistic options exist. The TO service provider or vehicle owner are likely to pay for 5G connectivity via a recurrent subscription, with options for fixed fees or tiered pricing. In the longer-range scenarios, public Mobile Network Operators (MNOs) or Use Case-specific Mobile Virtual Network Operators (MVNOs) could provide the 5G services. Regarding 5G network infrastructure ownership and deployments, the business model options consider single-operator deployments, network sharing agreements between operators, or the involvement of third parties (i.e., neutral hosts). Setting up multi-lateral commercial agreements for roaming among MNOs remains a crucial governance challenge that needs to be solved.

Regarding the cost-benefit analysis, the report builds on previous work by assessing the impact of adopting teleoperation Use Cases on current costs and allocating these costs to different business models. It complements earlier assessments by examining the technical and economic feasibility of deploying a 5G network and teleoperation technology. We can identify the following key findings for each of the studied road transport scenarios:

- **Scenario L1 - Terminal Teleoperation**: In this smaller-scale scenario, such as logistics hubs or port terminals, financial benefits can be realized even for internal operations within one terminal. However, cooperation and investment sharing would likely be required if a private 5G network needs to be built or upgraded. Notably, moving passenger cars within logistics sites can yield substantial economic gains, provided automakers integrate TO technology from the assembly stage. Outsourcing the TO service to external providers is less sensible in this limited context.

- **Scenario L2 - Short-Distance Shuttle Runs with trucks**: The business case for this scenario depends on area-specific characteristics and the existence of significant operational inefficiencies such as waiting times within or around a port. Achieving sufficient scale and addressing inefficiencies are crucial, while external funding and commercial opportunities from alternative 5G-based Use Cases will play a significant role in achieving deployment and profitability.

- **Scenario L3 - Highways Within National Borders**: Highly autonomous vehicles operating on highways, combined with TO for more complex entry and exit stretches and, potentially, as a preferred back-up solution, bring significant cost-efficiency, with salary cost reductions outweighing infrastructure and equipment expenses. However, 5G infrastructure investments stress the importance of achieving a large-scale operations, possibly involving multiple companies for a positive business case, and of finding alternative UCs for MNOs to allocate the expenditures across a larger client base.

- **Scenario L4 - Cross-Border Road Corridors**: This scenario offers substantial cost-efficiency gains from TO and Autonomous Driving (AD). Although 5G network infrastructure costs are substantial, profitability potential is high, particularly in TEN-T highway corridors. Job redundancies may occur, requiring legislative attention to ensure equitable benefits.

The costs related to 5G connectivity, especially the capital expenditures required to deploy or upgrade network infrastructure are a key element to consider when elaborating on the business models and business case of teleoperation, and their impact will depend on the share of such costs that is allocated to TO service delivery compared to other 5G-based Use Cases. Overall, 5G network infrastructure investments represent a significant financial challenge under our conservative assumption that alternative 5G Use Cases that share the network infrastructure in the identified geographic settings may be limited. Such investments require upfront capital expenses and face a chicken-egg problem. Therefore, financial estimations must consider business models that not only identify the parties that can realistically take up the key teleoperation roles but also incorporate the role of investment kickstarters and orchestrators to reduce initial risks and establish a conducive business environment.

In conclusion, this report provides a comprehensive overview of validated business models, deployment scenarios, and a cost-benefit analysis for 5G-based teleoperated transport Use Cases. It offers a blueprint to consider the economic feasibility of adopting teleoperated transport Use Cases in different contexts; in other words, a valuable resource for stakeholders seeking to understand the potential of teleoperation in various scenarios and its economic implications.

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ABBREVIATIONS

AD	Autonomous driving
BM	Business model
CACC	Cooperative Adaptive Cruise Control
CAD	Connected and automated driving
CAPEX	Capital Expenditures
CCAM	Cooperative, connected and automated mobility
COD	Coverage on demand
EF	Enabling functions
ETA	Estimated time of arrival
FTE	Full-time employee
HMI	Human-machine interface
ICO	International Car Operators
JV	Joint venture
MaaS	Mobility as a service
MNO	Mobile network operator
MVNO	Mobile virtual network operator
OEM	Original equipment manufacturer
OPEX	Operational Expenditures
PN	Private network
QoS	Quality of service
RAN	Radio Access Network
ROI	Return on Investment
SIM	Subscriber Identification Module
SLA	Service-level agreement
SP	Service provider
TCO	Total cost of ownership
TO	Teleoperation
UC	Use Case
UL	Uplink
VRU	Vulnerable road user

Note: *'Lx' and 'Wx' refer to the Land-based and Water-based scenarios detailed in §3.1.*

1 INTRODUCTION & CONTEXT

1.1 Scope and goals of the deliverable

The overall objectives of the 5G-Blueprint project consist of technological, regulatory, and business objectives. They include the design and validation of both a technical architecture and business and governance models for cross-border teleoperated transport based on 5G connectivity. The present deliverable uses input from the technical work of the project but contributes to its business objectives by providing a validation of the defined business models and business case of 5G-based teleoperated transport Use Cases. In addition, it will provide input for the parallel tasks working on governance and practical deployment recommendations.

More specifically, the goals of the present work are the following:

- Describe a **set of validated business models** that are considered technically, financially and organisationally viable and that incorporate the role of the main actors in the value network of 5G-based teleoperated transport. Exploring feasible business models is necessary to clarify ways in which services can be provided in a way that benefits different stakeholders and incentivizes them to take up the identified key roles in the value network.

- **Assess the business case** of investing to deploy teleoperated transport Use Cases under the different scenarios by incorporating all the main necessary elements (including infrastructure, equipment, operational costs, etc.). While there is potential for cost savings in the logistics sector and thus potential demand from TO applications, the business case remain uncertain.

- **Investigate the realistic conditions and time frames under which teleoperation Use Cases may be adopted** and scaled in different settings (including ports, warehouses, roads, waterways, and cross-border areas) by defining an updated list of **deployment scenarios** and their associated economic and technical challenges.

- **Understand the value proposition** that 5G-based teleoperation can provide to the different relevant stakeholders, and identify their potential motivations to contribute to finance the investments required to enable the studied Use Cases in practice.

- **Serve as a blueprint** for adoption beyond the geographical scope of the project, i.e. in other EU countries, by providing more clarity on the business case of teleoperated transport and the feasible business models to deploy the studied Use Cases in the different scenarios.

To accomplish these objectives, this deliverable has relied on both desk research from related projects and, more importantly, input from project partners, Advisory Board members and external experts. Through structured interviews and workshops, the input from experts in 5G-Blueprint's consortium and Advisory Board has been gathered and is reflected in the analysis. The project's consortium includes the following stakeholder types: national and regional authorities, road and port authorities, research institutes, mobile network operators, infrastructure providers, vehicle OEMs, TO tier 1 suppliers, information service providers, and logistics companies.

1.2 Relation with related work in 5G-Blueprint and similar projects

In terms of content, the present deliverable is interlinked with all the other tasks of 5G-Blueprint's 'WP3: CAM governance and business models'. It mostly builds on D3.2: Delineation of business models [1], which provided the preliminary description and analysis of

business models for 5G-based teleoperation. In addition, it builds on the outcomes of D3.1 [2], which provided a preliminary identification of the business case for direct teleoperation of trucks and the value network for 5G-based TO, and on the results of D3.3 [3], which conducted a thorough scenario-based techno-economic analysis to assess the deployment costs for the different Use Cases of the project. Lastly, the results of this report will provide insights to define the project's recommendations regarding deployment requirements and actions, which will be published in the respective report of 5G-Blueprint's 'T3.5: Roadmap for deployment and governance'.

Additionally, this deliverable has also taken into account the activities of the other work packages of 5G-Blueprint, particularly to understand technical and governance challenges in terms of infrastructure, 5G networks and in-vehicle technology, as well as to understand the characteristics of the different Use Cases and enabling functions.

Finally, the present work also took into account the relevant findings of previous and ongoing EU projects focused on cross-border, 5G-enabled CCAM, which besides the scope of the technologies and environments considered, often share the objectives and concerns of 5G-Blueprint regarding business aspects as well. For instance, in Saakel et al. [4], which studied the results of 5G-CARMEN, 5GCroCo and 5G-MOBIX, the lack of clear business models is identified as a main concern of car manufacturers, while the lack of revenue models for 5G CAM services is considered a key financial gap. Another conclusion from the study of these similar projects is that the role of and potential benefits for logistics companies needs to be studied further [4]. Additionally, 5G-ROUTES also identifies the need to define value network-wide (i.e., multi-layered) business and revenue models for V2X Use Cases based in 5G and in a cross-border environment [5].

1.3 5G-Blueprint's Use Cases and Enabling Functions

The current report considers the following Use Cases (UCs) which either revolve around or support 5G-based teleoperation. Each of these Use Cases is being tested in a real-life environment in at least one of the project's pilot sites, which are located in the Vlissingen, Antwerp and Zelzate port sites.

- **Remote control of (semi-) autonomous barges**. This refers to the remote navigation of barges by a captain in the shore control centre. The barges partly rely on automation, reducing crew requirements for crew interventions. We consider barge navigation in rivers and canals along national and cross-border waterways, as well as docking in a port.

- **Teleoperation (and remote takeover) of trucks**. This refers to a situation in which a remote operator takes control of a distant vehicle, transmitting signals to the vehicle from a remote-control centre using 5G connectivity.

- **Teleoperation of harbour vehicles**. Traditionally, cranes and vehicles have a cabin where an operator sits. Remote operation improves the vision of all vehicle operators thanks to the perspective from different cameras and functionalities such as zooming. In addition, teleoperation increases also the safety of the crane operator, who does not have to sit in the cabin anymore, but can operate it safely from a remote station. It can also increase operational efficiency, as a teleoperator can more easily change control from one vehicle or crane to another. With (semi-) autonomous cranes and vehicles, a remote operator can provide supervision and only take control when necessary. Additionally, we also consider the teleoperation of other vehicles that handle cargo in ports and logistics sites, such as reach stackers, forklifts and terminal tractors.

- **Automated docking**. This refers to a system for docking articulated vehicles within warehouses and distribution centres by integrating 5G technology. Automated docking can lead to efficiency and safety increases. First, it can be executed faster than manual docking. Second, the use of truck coordinates rather than a driver's view increases precision. Third, by increasing visibility and allowing the docking manoeuvre to be performed from both the truck's left and right angles, it can increase site capacity.

- **CACC-based platooning of trucks**. In a platoon, two or more trucks follow one another in close proximity. This is achieved by using a combination of adaptive cruise control, lane-keeping system and V2V communication. The system is aimed at being partly automated wherein the lead vehicle can be driven by a driver in the cabin or a teleoperator and the following vehicle(s) can be automated.

This deliverable will not only focus on the remote control UCs, but will also consider the supporting role of automated docking, platooning, and 5G-Blueprint's enabling functions.

The purpose of the Enabling Functions (EFs) is to support the aforementioned Use Cases and facilitate teleoperated transport by communicating on-site data to the remote operator through a dashboard (EF1). The information (and dashboard) is made available to the remote operator through a screen in its remote station. The information provided by the EFs is complementary to one another, and together aim to increase the safety and efficiency of teleoperated road transport.

Enabling function	Functionality and data provided to the dashboard
EF1	Enhanced Awareness dashboard (HMI)
EF2	Vulnerable road user (VRU) interaction. It also warns the remote operator of an approaching VRU, particularly if there is a collision risk.
EF3	Timeslot reservations at intersections. It also provides speed advice based on traffic data and the booked intersection timeslots.
EF4	Distributed perception supporting higher environmental awareness. It provides a dynamic map of the vehicle's surroundings based on data collected by one or more vehicles' sensors, radar, lidar, cameras.
EF5	Active collision avoidance. It provides warnings for imminent danger in order to avoid collisions.
EF6	Container ID recognition
EF7	ETA sharing
EF8	Logistics Chain Optimization

Table 1. 5G-Blueprint's list of enabling functions

D3.3 [3] presented the network requirements of each Use Case and EF in term of uplink capacity. For the UCs, the maximum required uplink capacity, per vehicle, is between 78 and 80 MBps. For EF4 and EF5, this was 1 MBps. However, these requirements reflect the case where all optional features to provide high-quality teleoperation services are included (e.g., high quality of the video streams). In other words, this represents a worst-case scenario.

1.4 Structure of the deliverable

The present deliverable is structured as follows. After the present introduction, Section 2 explains the methodology behind the business model and business case analysis. Section 3 presents the validated deployment scenarios (section 3.1) together with the discussion of a feasible timeline for the deployments of teleoperated transport Use Cases along with its associated challenges (section 3.2). Section 3.3 discusses the value proposition of TO for different stakeholders as well as their motivations and concerns to contribute to finance the

necessary investments to kickstart deployments. Section 4 presents the outcomes of the validation interviews and workshops conducted under this task; the result is a series of validated business models are defined and discussed for each of the deployment scenarios described in the previous section. Section 5 complements the qualitative analysis of business models through a business case analysis that builds on all the previous tasks of 5G-Blueprint's 'Business and governance' work package to develop a new tool to estimate all the main costs of deploying teleoperated transport use cases. In addition, section 5 applies said tool to real-life examples for each of the uncertain land-based scenarios. Finally, section 6 provides a series of conclusions and recommendations.

The figure below shows the logic of the deliverable in a graphical way. Each section incorporates the learnings of the previous ones and builds upon it.

Introduction & context		
Goals and relation with other work	Use Cases	Methodology

Where & when to deploy	
Deployment scenarios	Feasible timeframe of deployment per UC

Who benefits & will invest	
Value proposition to different stakeholders	The problem of kickstarting investments

Business models
Validated business models for each deployment scenario

Business case
Assessment of the overall business case of deploying TO Use Cases in each scenario

Conclusions and recommendations

Figure 1. Structure and logic of the D3.4 report

2   METHODOLOGY & ASSUMPTIONS

2.1   Qualitative validation

The qualitative part of the business model validation exercise consisted mainly of a series of stakeholder consultations in the form of workshops/focus groups and individual interviews. Feedback from experts from our consortium partners was the main source of knowledge behind the present validation. A total of 17 project partners, comprising the vast majority of those belonging to industry/policy stakeholder types, were engaged through these dedicated consultations. Furthermore, we organized a dedicated workshop with the project's advisory board, involving experts of the telecommunications, transport and smart mobility sectors. Lastly, we also interviewed a Dutch transport company external to 5G-Blueprint, in order to receive input from people from the industry but not involved in the project.

In addition, we used sessions during the physical plenary meetings of the project to conduct short discussions about specific topics, such as 'who could kickstart investments in teleoperated transport', 'what is the value proposition of teleoperated transport Use Cases to each stakeholder type', 'the business case of enabling functions', 'further validation of feasible Use Cases for each deployment scenario and timeline'. This allowed us to present our preliminary findings and ask about any remaining unclear aspects to all consortium partners, including those that did not participate in interview rounds. All said and done, each 5G-Blueprint partner was present at least once during all these stakeholder consultations, and the entire process spanned from February to July 2023.

For all the above consultations, the task leader prepared dedicated material to provide background to participants and structure the discussions. Examples of such material include the standard interview guide, which we provide in Annex A for illustration purposes – note that this template was slightly modified for specific stakeholder types –, templates for the discussion sessions, and a white board template to guide the discussion and facilitate simultaneous input during the workshop with the Advisory Board (see Annex B).

To complement the expert consultations, we conducted a small desk research of related literature, comprising recent deliverables of related EU CAM projects that had been published after our delivery of 5G-Blueprint's D3.2 [1] about the preliminary business models. Therefore, the intention was to complement the thorough literature review of that report with some up-to-date findings.

2.2   Quantitative validation – business case analysis tool

For its part, the quantitative part of the present analysis relied on expert input from consortium partners, a brief scan of online sources for missing figures, and the development of a cost model that underlies the business case tool which will be described in the following lines. For the development of this cost model, we built on the efforts in the previous WP3 tasks: putting together and complementing the cost-benefit analysis of previous deliverables, which had different focuses. The ultimate goal was not to develop a more thorough model than what each task endeavoured to prepare, but to have a simple user-friendly tool that, if required, can be easily adapted to specific environments or Use Cases and therefore can be used as a blueprint to be replicated in any other EU area (or even beyond) and that provides a comprehensive understanding of all the cost elements associated with the adoption of teleoperated transport.

Section 5 provides an extensive illustration and practical application of the described business case tool[1].

The main sources of the information are the outcomes of previous deliverables of 5G-Blueprint: D3.1 [2], D3.2 [1] and D3.3 [3]. In addition, new information was collected in the context of the present task, either from our stakeholder consultations or desk research.

Below we present a graphical explanation of all the cost elements that are included in the model, along with a list of the main values and sources of each element. For more specific formulas we refer to D3.1 [2] for the required Full-Time Employees (FTEs) calculations and D3.3 [3] for the calculations related to TO and 5G infrastructure[2].
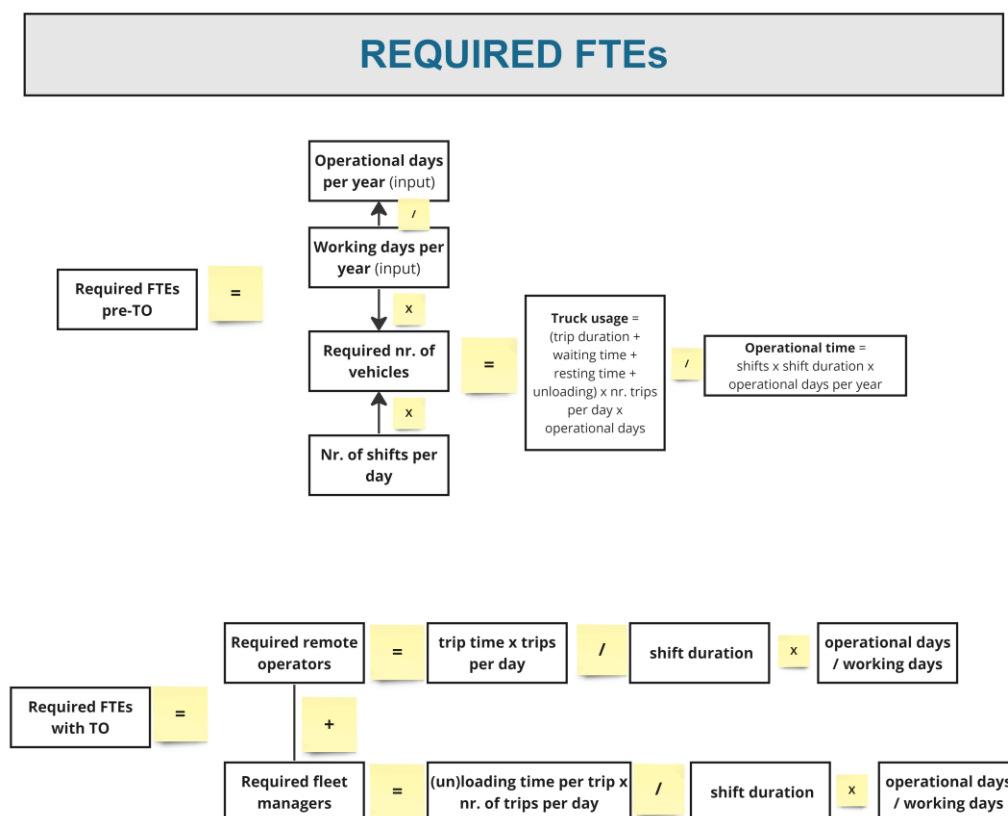
Figure 2. Calculations behind the required FTEs before and after TO

5G AND OTHER COSTS

Automated docking costs	=	In-truck equipment (positioning)	+	Infrastructure changes at site (if required)

CAPEX RAN	=	New site deployments	+	RAN site upgrades

+

5G network deployment	=	OPEX RAN	=	Power consumption	+	Hardware maintenance

+

Overhead costs (marketing, HR, finance, etc.)

X

5G network costs per user	←	Nr. of users (adoption level)

5G connectivity service	=		X

Profit margin
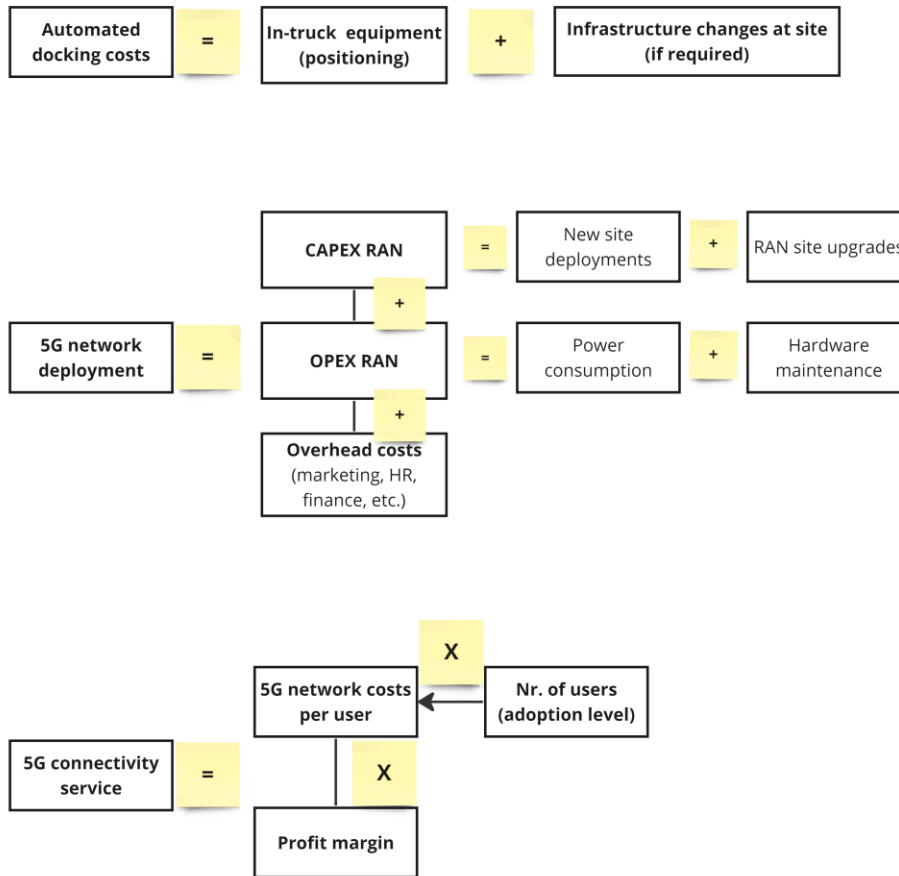
Figure 3. Calculations behind 5G and automated docking cost elements

TELEOPERATION COSTS

TO equipment costs =

Required TO stations = **Required remote operators** / **Nr. of shifts per day**

X

TO station cost = **TO kit / station + maintenance** + **Dashboard (EF) services subscription/fees**

TO center costs

Rent = OPEX: TO-ready room + energy + internet + wages

Buy = Control setups to deploy + IT system + Non TO furniture + OPEX: office space + energy + internet + wages

nr. of remote operators = Vehicles served / TO-to-vehicle ratio

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TO salary costs =

Salary remote operators = Trips x (trip time + TO idle time) x operational days x hourly salary

+

Salary fleet managers = Trips x (un)loading time x operational days x hourly salary

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Vehicle equipment costs =

Required nr. of vehicles

X

Extra costs per TO vehicle = Purchase cost premium or retrofit cost / lifespan + Insurance premium (10%) + Maintenance premium

Figure 4. Calculations behind TO equipment and infrastructure elements

Using the calculations of all the above cost elements, we input them into the business case tool. We adapted such tool to the specifics of each deployment scenario, e.g. in terms of Use Cases, additional variables for long-haul transport (such as the inclusion or not of a driverless part of the trip), or whether 5G deployments were calculated on the basis of kilometres or squared kilometres.

To be able to perform the calculations of the elements above, we need reference values for all the most granular variables. For the elements listed above, we relied on standard quantities based on the estimations performed in previous 5G-Blueprint reports – which relied on expert input or literature reviews. For other elements that are tied to the operational characteristics of each transport company, and for which values are expected to fluctuate substantially while also be known by the potential user of the tool, we rely on input from the user's own knowledge. By relying on use input as much as possible, we tried to make the tool more adapted to a specific deployment area and context, and thus more realistic for each specific user. This also allows the tool to be closer to its goal of being a 'blueprint' for any potential deployment across Europe. Such a tool will be useful for any logistics actor exploring the possibility of adopting teleoperated transport and helps reduce uncertainty about the business case around the Use Cases studied by the 5G-Blueprint project.

Below we list the elements for which the tool asks input from the user by providing a pre-defined list of options from which the user must select one. These represent the different Use Cases, deployment or business model options that the tool supports.

- **Transport type**: including "containers", "cargo (pallets)", "(ISO) tank". The cost model relies on different figures and assumptions for each of these elements, e.g. in terms of the costs of purchasing a trailer, the (un)loading times, the need for support at the site, etc., which vary by transport type.

- **Equipment/vehicle type**. Here, the user can select among different Use Cases supported by the tool, namely: barges, cranes, skid steers, reach stackers, passenger cars and terminal internal tractors in the case of scenario 1, or barges and trucks in larger scenarios. Again, many of the underlying values and assumptions vary by vehicle type.

- **Remote control centre type**. Here the user can choose whether the TO centre will be built 'inhouse' by the company adopting teleoperation, or be 'outsourced' to an external TO service provider. In practice, the difference lays in the fact that outsourcing entails higher 'salary' costs per remote operator (we assume a 20% premium), but the external company takes care of the costs of deploying TO equipment and the infrastructure costs from the TO centre; the transport company just rents the installations. In other words, in the 'outsource' option we assume that the TO service provider covers the costs of the required investments in the different elements of a TO centre, i.e. the remote stations (which include TO control kits and the dashboard information service) and the office rental expenses.

- Choosing the **5G network deployment model**: including coverage-on-demand and, for smaller scenarios L1, L2/W2[3], also the option of private network deployments. In our cost model, the main difference between the two deployment models is that setting up a private network on a site also entails deploying new infrastructure belonging to the core network, in addition to RAN infrastructure deployments. Therefore, the cost of a private network will be higher than the coverage-on-demand model. However, the feasibility of one option or another will depend on the availability of public 5G networks in a specific area as well as customer preferences; in other words, an MNO may not always be ready to offer coverage-on-demand in a specific site and for the specific customer demands in terms of service and network requirements.

- **Adoption forecast expectations**. Here the user can choose the assumed evolution of adoption in terms of number of vehicles becoming connected to the network over the 10 years that the model considers for infrastructure investments. The definition

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[3] A description of the reference deployment scenarios is provided in section 3.1.

of the adoption expectation scenarios and the forecasts of specific vehicle amounts covered over time were formulated in D3.3 [3] using the Bass Diffusion Model. There are 2 options to choose from: a pessimistic/realistic scenario and an optimistic one.

Below we list those elements for which the tool also asks input for the user but the values to be entered are open. They refer to operational aspects that will be fairly specific to each potential user and deployment area.

- **Trips/operations** (average no./day); e.g., how many containers a crane moves, or how many deliveries a truck makes from point A to point B.

- **Trip duration** (in hours): this refers to the driving/operational part of the trip, excluding waiting and resting times

- **Salary of the manual driver** (per hour).

- **Waiting time per trip** (in hours); this represents a main source of idle time that we want to optimise with remote operation, together with (un)loading times. Note that (un)loading times are assumed and incorporated within the model for each type of transport (i.e., container, pallets, tank)

- **Resting time per trip** (in hours); this is mostly relevant for long-haul transport.

- **Shifts** (no./day)

- **Shift duration** (h/shift)

- **Operational days** (no./year); this will be used to calculate the number of FTEs needed to perform the required operations, when compared to the actual working days for each employee, which are assumed to be 235 per year according to the estimation made in 5G-Blueprint's D3.1 [2][4].

- **Vehicle maintenance** (€/year). The tool provides a suggested value (8,500€) to the user, which is taken from the estimation made in 5G-Blueprint's D3.1 [2]. Incremental maintenance expenses from the introduction of TO technology in comparison to current vehicles are only calculated for trucks, also based on the estimations in [2] (see Annex C).

- **Vehicle insurance** (€/year). A suggested value for trucks (5,000€) is also included here, once again coming from the estimation made in [2]. The insurance premium for TO-enabled vehicles and equipment is assumed to be 10% (see Annex C).

- **Idle time per trip** (in hours) with TO. This is the time that the remote operator will be idle while waiting for a vehicle or machine to become available to be teleoperated. While the goal would be to assign the remote operator to a different vehicle once the previous one becomes idle, in practice it will be challenging, especially at a small scale of operations, to optimise operations to the point where the operator is almost always busy operating a vehicle.

- **Salary remote driver**. Here, the user is suggested to assume the same hourly wage rate as the manual driver's, if the salary of a remote driver is unknown or hard to estimate.

- **Non-clearance rate**. This applies only to longer-range scenarios that rely on automated driving (i.e., scenarios L3/W3 and L4/W4). This rate refers to the percentage of trips in which the TO needs to take over the control of the driverless vehicle on the highway due to challenging weather or road conditions that impede

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[4] Actual working days will vary per country and job type within the logistics sector, depending on labour agreements, a country's legally-minimum annual holidays and bank holidays, characteristics of the job (e.g., the nature of the job is not the same for a captain, a truck driver or a crane operator), etc.

the vehicle's on-board system to perform the driving autonomously. An explanation is provided in section 5.3. The user is suggested to assume a rate between 1 and 5%.

- **Size of the area to be covered by 5G network deployments**. This is presented in the form of km^2 in scenarios L1 and L2/W2, in which the deployment will be done around a site such as a port terminal and its surroundings, and in the form of kilometres in the longer-range scenarios, in which the RAN deployments will be done alongside highways and canals. Our cost model calculates the 5G network deployment costs based on the estimations of RAN infrastructure costs per km or km^2 in each scenario which were derived in the techno-economic analysis of Chiha et al. (2022) [3].

Here we provide a visual representation of **the tool's look and structure**. We refer the reader to check the excel files provided in addition to the present report to get a clear feeling of the actual tool and a better understanding of how it works.

The first image presents the tab 'UC operational business case' for scenario L1. In this tab, the users of the tool can select the relevant variables for their envisioned deployment setting and enter the specific operational details and economic context that applies to them. This tab will allow them to calculate the business case for the selected deployment scenario and for each type of Use Case or vehicle. On the right hand side, one can observe the nature of the outputs provided: first, a comparative assessment of the change in required FTEs between the status quo of manual driving and a context in which teleoperated transport is adopted (and automation in longer scenarios); second, an assessment of the incremental costs or benefits that arise from the adoption of our teleoperated transport Use Cases. Naturally, as the tool becomes populated, actual values start to appear (examples can be seen in section 5).

Figure 5. Example of the business case tool 'UC operational business case' tab for scenario L1

The outputs of each UC will need to be aggregated manually (per vehicle/UC) in the a different tab of the spreadsheet named 'TOT business case' tab, which is presented in the following image. This tab allows the user to aggregate the output from each of the calculations made via the previous tab, as well as to calculate the total business case across all the adopted UCs and after taking into consideration all infrastructure investments. This will need to be done manually, because some settings will involve only one UC or vehicle type while others may involve a combination thereof. In addition, in this tab the user will need to select some 'general variables' that apply to their context. These variables represent common investments/assumptions that will be shared across UCs and vehicles, e.g. the 5G network or

the TO centre. Moreover, these costs will depend on the scale of the deployment (in terms of vehicles and remote operators).
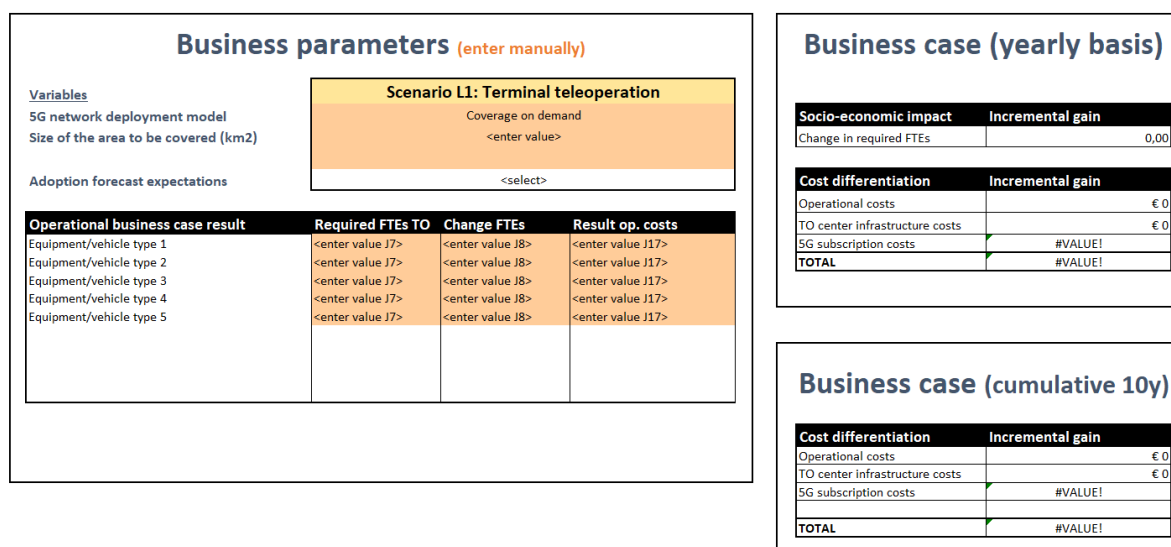
Figure 6. Example of the business case tool 'Total business case' tab for scenario L1

This tab provides a calculation of the total business case, once all the considered UCs and cost elements have been considered. First, it requests the user to select the remaining assumptions for the infrastructure-related variables.

The output consists of the following: (i) a total figure of the impact of adopting teleoperation (and automation where relevant) on the number of required FTEs for a specific scale of operations; and (ii) a total figure of the incremental costs, i.e. an answer to the question of whether the business case would be positive or negative for that specific scenario, the specific company operations selected, and the specific deployment area. The tool allows to see a breakdown of each main cost element and vehicle and assess where the main sources of incremental costs and benefits lie. It provides such output for the cumulative period of 10 years that the model considers, and also at the annual level by aggregating and dividing CAPEX and OPEX equally through the years. This is assumed to reflect better the position of a transport service in the cases in which elements are rented or 5G services are purchased via a subscription.

For the long-range scenarios L3, L4 and W4[5], we include the effect of autonomous driving on the number of FTEs required and consequently on incremental salary costs. This is calculated by finding out the length, in hours, of the trip that happens on the highway (the user can input this value) and deducting from it the percentage of times when it is assumed that a remote operator will need to take over control of the self-driving vehicle because of challenging weather or road conditions. The tool suggests the user the assumption of a range between 1% and 5% for this exceptional remote takeover on the highway. In turn, this part of the trip where the truck or barge drives autonomously is deducted from the driving time that otherwise the remote operator would be responsible for. As is the case with the previous scenarios, the required FTEs and salaries after the introduction of TO are calculated on the basis of this driving time by the remote operator.

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[5] The deployment scenarios used throughout this deliverable are described in section 3.1.

2.2.1 Quantitative validation: assumptions

A main limitation of the present cost model is that we are forced to accept simplifying assumptions when choosing which underlying cost figures and cost elements to include in the business case tool.

Annex C presents a table listing many of the underlying cost values included in the model. However, many of these values rely on assumptions, which we explain a bit more below.

Specific costs that were asked by consortium partners to remain confidential due to their being commercially sensitive are excluded, but the reader can reach an understanding of the process through which we arrive to each figure via the figures included in section 2.2 and by checking D3.3 [3] for more detailed explanations on the underlying calculations.

We list a series of assumptions related to 5G infrastructure below. Most of the following assumptions come from the techno-economic model in D3.3 [3], which has been used throughout the present analysis to calculate infrastructure costs. More detailed assumptions behind the calculations such model can be found in that deliverable.

- However, it needs to be stressed that the allocation of 5G network investment costs, when required, to teleoperation services, is pivotal in the overall judgement of their business case. The present analysis is based on the representative context of the locations studied in the project. Nevertheless, in the absence of more accurate information, we also consider – rather conservative – assumptions, which should be taken into account when replicating the assessment in other locations. The cost of the spectrum acquisition was not considered in the cost modelling, since it was very hard to allocate potential prospective spectrum cost to a specific Use Case. In addition, auction prices for licenses fluctuate highly across countries and wireless technology generations, depending on several uncertain factors such as competition levels, expected future profits from all UCs, the availability of financial resources by MNOs, etc.

- Regarding connectivity session handovers, it was challenging to quantify the additional effort required for manual configurations at border sites, thus this was also not included in the analysis. It is an added cost, but only happens once a trip, besides the associated maintenance costs. However, the actual cost depends on the technical solution that would be implemented, and this would need to be looked at further by experts. It is also unclear to what extent these costs can be optimised with 5G compared to 4G.

- Due to a lack of cost data available in the literature on the deployment of 5G private networks based on user UL (uplink) capacity requirements, costs for the 5G private network option are based on an extrapolation from the costs of deploying RAN infrastructure using coverage-on-demand. Based on expert input from the consortium, core network elements can be roughly assumed to be about 20%, on average, of the total CAPEX (upfront investment). In contrast, RAN is about 40%, the rest being backhaul, installation and commissioning, financing, etc. This is a rough approximation with a considerable margin of error rather than an accurate assessment, but it gives a picture on the basis of which to make a comparison across deployment approaches.

- In the port, it was assumed that 1 TO barge can be served at the same time per port terminal, and 4 cranes can be operated simultaneously for each terminal, while between 4 and 8 TO internal trucks/skid steers can be supported simultaneously for each terminal (for pessimistic and optimistic cases, respectively)

- The length of the port entrance was assumed to be 4 km, and the width 1.3 km.

- Truck speed in docking is assumed to be 10 km/h.

- Average barge speed is assumed to be 13 km/h.

- 50% of existing macro-cells' UL capacity is used by other applications, so 50% is free and to be used for TO Use Cases.

- The macro cell inter-site distance is 2 km.

- Each macrocell is a tri-sector and each cell has 16 beams following the RAN hardware installed by Telenet in the port, but in reality, on the UL only 8 streams simultaneously can be offered.

- The lifetime of network equipment is considered to be 10 years.

Automated docking. We elaborate a bit more on automated docking costs, which were added during the development of the business case tool of the present task. The required elements to enable automated docking can be divided into 2 different categories:

First, in-vehicle technology, which can be further subdivided into the following two aspects:

- Technology needed for localization. Since an accuracy of ±5cm is needed, 5G-Blueprint is carrying out tests using Real-Time Kinematic (RTK) technology, which corrects the GPS signal by the RTK component. While the project is using a high-end, expensive 'plug-and-play' device for research purposes (which costs approx. 90kEUR), a scalable solution would be using commercial off-the-shelf RTK receivers, which cost approx. 300 EUR. Nevertheless, these are not 'plug-and-play, hence they would require integration efforts (e.g., postprocess the signal to increase robustness). Additionally, at least one RTK receiver would be needed per vehicle (i.e., 2 for a semitrailer truck), or more if accuracy needs to be improved further (depending on the context). In the present cost model, we assume that 2 receivers will be installed in each vehicle (i.e., a cost of 1200 EUR for a semitrailer truck). In terms of integration work, we assume it is accounted for and done simultaneously with the integration of the hardware elements that are required to enable TO in trucks.

- Technology required to control the vehicle remotely, i.e. devices to enable remote communication and physical actuation in the vehicle (i.e., steering angle, gas, brake, gear, lights). If not already incorporated by the OEM in the production line, this would need to be retrofitted. However, since these devices are also needed for teleoperation, we do not need to consider these costs as an additional investment for automated docking.

Second, another main source of costs would be infrastructure changes at the site itself, i.e. a sort of "control tower" that communicates with the vehicle and provides it with the destination (i.e., the dock number). Even though providing an estimation of such costs proved challenging given the potential peculiarities of each site, the expert project partners believe such investments to be very small. For these reasons, we do not incorporate such costs in the business case calculation tool.

Furthermore, we made the decisions to exclude certain cost elements from our cost model. This is because they are too uncertain to properly quantify. The list below illustrates our assumptions in this regard.

- The specific cost of training operators is also not explicitly included in our model. However, it must be noted that the option of outsourcing the TO service implicitly incorporates such costs in the higher prices that the external service provider

charges for the TO service. In the in-house deployment setting, part of the estimated profits will need to cover the expense of training employees to be licensed to perform remote operations.

- Fuel consumption is assumed to remain equal. The electrification of fleets will simultaneously raise vehicle prices and reduce fuel consumption in the near future. The effect of autonomous driving is expected to improve the efficiency of driving, but this remains uncertain and hard to estimate in transition periods where manual drivers and driverless vehicles will coexist.

- In our examples, we have also assumed that the wages of remote drivers will be the same as those of current manual drivers, which we use as reference. However, in the business case tool the user is free to input a specific hourly wage rate for the each of the two job positions. In the future, market forces may impact driver wages in either direction. On the one hand, lowering the driver shortage and making the job more attractive will reduce the current demand-supply imbalance and, all else equal, reduce wages. On the other hand, collective bargaining, amongst other factors, can increase them.

- In the long-haul scenarios, we have not taken into account the possible effects of CCAM on a vehicle's useful life. On the one hand, higher uptime may lead to a shorter useful life of the vehicle from a higher yearly usage, and thus increase yearly depreciation expenses. On the other hand, "smart" driving and predictive maintenance may optimise vehicle wear and maintenance, increasing a vehicle's useful life compared to manual driving. Therefore, these factors work in opposite directions, and their resulting combined effect is unclear.

- Regarding the costs associated with the fuelling of driverless trucks, we assumed that TO service providers would need to reach agreements with gas/charging stations. Since the needs in terms of workforce will also be largely context-dependent, our cost model does not include such costs.

- We also assume no extra costs for the modification and/or upgrade of (digital) road infrastructure, such as having dedicated lanes, as it needs to be explored further what specific changes would be required in each context – in terms of deployment scenario, type of road, country, etc. – before a reasonable estimation of the associated costs can be done. Nevertheless, it needs to be noted that part of the estimated profits in the larger road scenarios will need to be transferred to "purchase" this new fuelling support service via the revenue-sharing agreements between TO service providers and gas/charging stations discussed in the business model sections. This can give rise to co-investment arrangements or revenue sharing agreements.

It would be interesting for further research to include in the cost model for teleoperation the externalities caused by the adoption of teleoperated transport Use Cases. For instance, De Clerck et al. [6] expand the Total Cost of Ownership methodology by not only including all the costs related to owning and operating a vehicle but also accounting for external costs borne by society. Their Total Cost for Society measure includes externalities that arise from the impact of (the use of) the technology, such as GHG emissions, air pollution, noise pollution, accidents and congestion. In the analysis of TO with 5G, it would be interesting to also quantify the costs/benefits resulting from the impact of the technology on the shortage of employees in logistics (job vacancies filled). However, including costs related to GHG emissions and air pollution is tricky because the electrification trend is assumed to be happening in parallel.

In addition, we have not quantified any positive externalities from the reduction of accidents. Regarding road accidents, expert opinion on the impact of TO was far from conclusive, as the introduction of TO in a mixed context where remotely driven vehicles coexist with manual

drivers is expected to have an uncertain effect in the initial phases of adoption.

Moreover, we have made the conservative assumption that in the long-term, in longer-haul scenarios, the costs of equipping vehicles still refer to current values based on retrofitting, although the time span until these Use Cases become a reality should offer enough time for OEMs to incorporate the technology into their trucks, which is expected to lower costs substantially.

Another issue is the assumption of which current manual tasks will become automated or remotely operated in the future. A more thorough analysis of how current driver roles may be transformed in a driverless scenario will be conducted in 5G-Blueprint's D3.5; in the present analysis, we make the simple assumption that the remote operator can communicate with the police and grant access to the vehicle or the cargo when necessary, similar to what we assume for fuelling at gas stations.

Lastly, we discuss the assumptions behind the location of TO centres, which represents another factor affecting the business case. For instance, companies may be tempted to locate TO centres in a country where salaries are much lower. The relevant questions underlying the discussion are the following: how large is the realistic coverage of a single centre? How far away can they be located from the vehicles?

According to the project's internal discussions, there are two main aspects to this issue. First, in terms of connectivity, tests show it is still somewhat unclear: probably they could be located far away from vehicles, but an issue could be the reliability of the network in terms of ensuring that there is a continuous, stable low-latency connection. Second, having a large-scale, centralised location may reduce the knowledge of the remote drivers of the traffic and road conditions in an area. Traffic managers already work from a remote station, but they need a sense of a certain country's road users' behaviour, local regulations, etc. In that sense, national authorities may also put boundaries in terms of geographical spread requirements with the reasoning to guarantee safety.

One TO centre could manage a few EU countries with similar infrastructure and weather conditions. Maybe a TO centre specialised for areas with harsh weather like the Nordics, or different road types or mountain areas. On the other hand, for motorways, driving conditions are pretty similar across the EU.

In our analysis, we assume that the TO centre is located in the area of operation, and that salaries of manual drivers and teleoperators are linked. Nevertheless, the business case tool allows the user to select the values of both jobs' salaries.

Finally, there are also cost implications from the question on how many centres need to be deployed compared to having a centralised centre. However, our cost model makes the simplifying assumption that TO centres do not achieve economies of scale neither for space used nor for rent and energy consumption costs, and these costs are assumed to be standard and independent on the location of the deployment. Therefore, whether the user envisions a deployment with multiple centres or a centralised one does not influence the resulting cost estimations in our business case tool.

2.2.2   Quantitative validation: limitations

A main limitation is that the 5G infrastructure costs rely on calculations that are tied to many assumptions based on specific deployment areas, which in this case were mapped to the project's pilot sites. Therefore, the derived costs per (squared) kilometre rely on underlying assumptions of number of vehicles covered, which in turn depend on the length of each trip,

the speed at which the vehicles travel, the efficiency of port equipment, the availability of current network infrastructure, etc. 5G network infrastructure needs would therefore vary, in practice, by all these and other assumptions, and also by the actual adoption in terms of number of vehicles connected. However, here we extrapolated a fixed deployment cost per (squared) kilometre, a simplifying working assumption to be able to create a blueprint that can be adapted to different contexts. Therefore, conclusions need to be used with care, but decision-making can be confident when the business case shows a large deviation from neutrality in either (positive or negative) direction, and when the user is well aware of the main assumptions and limitations of the model.

As shown in Saakel et al. [4], the selection of deployment areas (such as corridors or road segments), which sits behind the calculations that normalise 5G infrastructure costs per km, affects the resulting costs and makes the comparison of results across similar cross-border CCAM projects challenging. Another element that creates such a challenge is that deployment costs are calculated based on country-specific prices. The authors also show how radio planning and the choice of frequencies affects the resulting RAN deployment costs across different CCAM studies.

The margin of error of our calculations increases with forecast time, as assumptions about the scale of adoption of far-away Use Cases become increasingly uncertain. For instance, TO centre costs will depend on the number of control set-ups to install and the number of operators that will work in the centre. This depends heavily on the TO adoption over time.

It must also be noted that this analysis presents the return on the financial investment but excluding the important risk element of said investment and the associated organisational changes.

Lastly, we often start by considering the conservative assumption to assign the expenses of deploying 5G network infrastructure entirely to the teleoperated transport UCs that we study, an assumption that is subsequently relaxed in later steps of the analysis to show a more realistic setting and allow for the comparison between both cases, which – hypothetically – can apply to different locations and/or at different points in time. In practice, MNOs may split such costs among a larger pool of applications and UCs (e.g., consumer ones such as infotainment for car passengers) that could share, to some extent, the same infrastructure. However, after our expert consultations, we found that the telecommunications industry does not exhibit enough confidence in the commercial prospects of such alternative UCs to assume that these alternative revenue sources will be available within the studied timelines and within the geographical areas that we consider for potential TO deployments. Section 3 will present several deployment scenarios and an evolutionary path for different UCs and deployments in different geographic settings. Earlier deployments are expected to become feasible in or around logistics hubs, such as port areas, within and across state borders. Later deployments will take place along highway corridors or waterways. All these represent areas where deploying infrastructure for constant coverage is expensive, and where user density is considerably lower than in urban areas. In addition, it must be considered that TO has strict needs in terms of latency, uplink bandwidth and reliability, and other UC may not share these specific network requirements.

3 VALIDATED DEPLOYMENT SCENARIOS, USE CASES AND ADOPTION TIMELINE

This section will present a validated and extended version of deployment scenarios for teleoperated transport Use Cases which will serve as reference for the analysis of business models and the associated cost allocations. We present 6 scenarios, classified based on their geographical coverage and whether they refer to land or waterway transport operations.

In a second step, on the basis of the deployment scenarios, we identify a validated series of teleoperated transport Use Cases that are expected to be feasible at different periods of time, along with their respective anticipated challenges from a business and technological perspective. Altogether, the description of deployment scenarios and feasible Use Cases will support the validated business models analysis by bounding the theoretically wide range of possible business cases and situations for which to envision 5G-Blueprint's relevant business models and estimate their associated costs, while at the same time keeping such simplification realistic.

Finally, this section tackles two central hurdles identified before, namely (i) the need to elaborate on the value propositions offered by TO to incentivize certain actors to take key uncertain value network roles, and (ii) the need to elaborate more on who will provide financing to kickstart investments. By providing more clarity on these aspects, the goal is to expand the business models described before and make them, as well as any potential deployment roadmap, more realistic.

3.1 Deployment scenarios

To facilitate the analysis of business models and their associated costs, a set of reference scenarios was defined in previous deliverables and updated in the current report. Making assumptions in terms of deployment scenarios will allow us to simplify the business model analysis when considering an evolutionary approach, better differentiating between feasible Use Cases at each stage, location and type of transport.

In the previous report of the preliminary business models (D3.2), three discrete reference scenarios were defined to narrow the scope of all the possible situations in which teleoperated transport could be deployed. In the current report, these scenarios are extended in order to account for the most important variables where a distinction in terms of business or economic aspects needs to be done. The resulting 6 scenarios will allow to account for the complexity of teleoperated transport in a clearer manner, as well as to align with the more recent and ongoing works of other tasks from 5G-Blueprint's Business and Governance Work Package.

Our deployment scenarios of reference are thus classified based on the geographical coverage and the type of the teleoperated transport operations. Below we provide a brief classification and description of the deployment scenarios. We distinguish between Land-based (L) and Water-based (W) scenarios:

- **Scenario L1 – Terminal teleoperation**: Teleoperation takes place on private premises like port terminals or in-land distribution centres. It involves the remote operation of vehicles or equipment that are strictly used in private sites, such as RTG cranes, terminal tractors, or skid steers. The 5G connectivity can be made available through private or public networks.

- **Scenario L2 – Short-distance Shuttle Runs with a pre-defined trajectory.** This scenario involves the teleoperation of trucks in a geographically limited area with numerous (short distance) transports; for example, the transport of containers by

truck within a port area or industrial zone with interconnected supply/manufacturing chains. Examples would be major European ports and manufacturing or chemical plants, where TO would cover short transports within the site and to and from distribution centres and warehouses in the area. In this scenario, remotely operated vehicles may drive on public roads for part of the trip. Potentially, these frequent trips may also involve truck platooning.

- **Scenario L3 – Highway within national borders.** This includes the transport of containers by road over a major national transport axis, using teleoperated trucks and potentially also involving truck platooning. Since public roads most often cover a significant part of such transport axis, 5G connectivity providers must cover these segments to enable teleoperation.

- **Scenario L4 – Cross-border road corridors**. In this scenario, which includes and extends the coverage of the previous one, the transport of containers over the road with TO trucks is done across multiple countries. TO across borders poses additional challenges. Crucially, in order to avoid any loss of control, TO and 5G connectivity providers need to ensure a seamless handover of connectivity and remote control/monitoring sessions. Therefore, this scenario entails the highest complexity for the challenge of guaranteeing continuity of service, but it also offers the largest geographical reach.

- **W2 – Barge transport (short haul)**: Remote operation of vessels, by a captain from an on-shore centre, to transport goods in and around large port environments. For instance, short trips involving the moving containers from one bank to the other. The name of this scenario – i.e., W2 – was chosen due to its resemblance with L2.

- **W3/W4 – Barge transport within a country and across borders**: This scenario consists of the inland waterway transport of goods through rivers and canals via teleoperated barges. This scenario includes waterways where a significant volume of transport flows is present, for example a canal between two ports in the same country or across borders (for example, a river that crosses several EU countries). The vessel may be completely unmanned or retain a limited amount of crew on-board.

Scenarios L1 and L2 were originally grouped in a single one, but it makes sense to split them, because the nature of the operations in each scenario, as well as their operational and technical feasibility, are different. In terms of technical feasibility, driving to external warehouses with remotely-driven trucks is seen as only being realistic farther away in the future compared to using TO for skid steers, cranes, etc. within a site.

Between L3 and L4, the main difference at the business level –besides the larger scale, demand and potential benefits– will be the extra complexity from the cross-border factor and the fact that regulations can be more permitting in one EU member state than in another one; therefore, Use Cases involving TO transport within one country can be expected to be feasible to be deployed in a relatively shorter term.

In the two "waterway" scenarios, we will focus on the main differences compared to road transport scenarios, given that barge transport offers a relatively higher readiness level for deployment in real traffic conditions.

Using these discrete deployment scenarios we can progressively analyze and compare the technical and economic feasibility of providing teleoperated transportation at different scopes of deployment, in terms of geographical scale and types of transport. This will also help define a roadmap for implementation.

The figures below show the evolutionary path of the different deployment scenarios, indicating the increase in geographical scope as part of moving to higher scenarios. The arrow can also be understood to represent that larger scenarios will only become feasible for deployment

farther away in the future. In the case of waterways scenarios, the flatter curve of the arrow represents the fact that larger scope deployments are available already in the shorter term, although challenges still remain in waterway transport, especially for cross-border transport. A more detailed discussion of the feasible Use Cases in each scenario over time is presented in the following section.
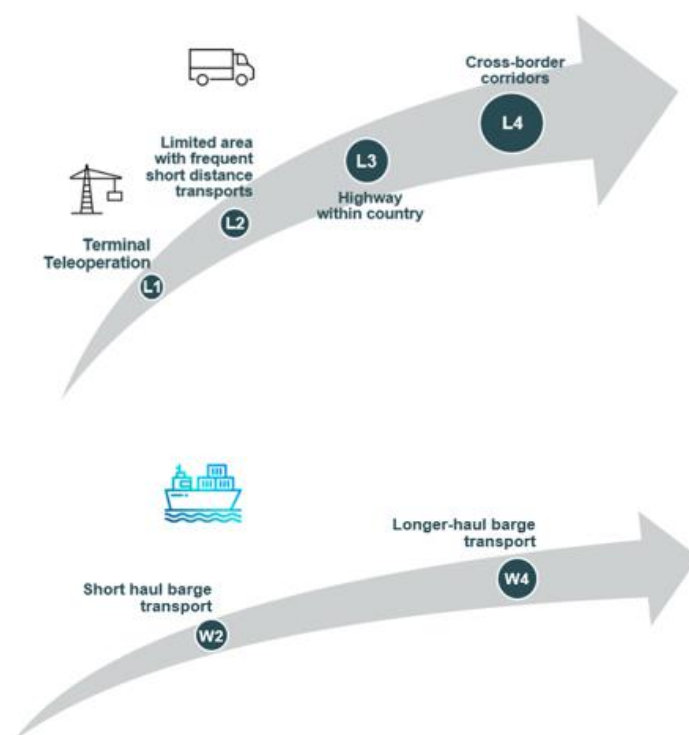
Figure 7. Deployment scenarios for land and waterway transport

3.2 Feasible evolutionary path for teleoperated transport deployments

On the basis of the 6 deployment scenarios defined above, we elaborate on the feasibility, over time, of teleoperated transport Use Cases under each scenario. This section extends and validates the preliminary discussion in D3.2 and discusses the expected evolutionary path or storyline for TO in transport in terms of Use Cases and scale of deployment. This exercise will serve as the basis to analyse relevant business cases involving TO, 5G and 5G-Blueprint's enabling functions. In turn, understanding the business cases will allow us to define more realistic business models.

One relevant aspect to note is the 'role' or type of remote operation being performed by the remote operator from its station. In this regard, the discussion below distinguishes the use of 'direct' versus 'indirect' teleoperation. To try to provide more clarity on these terms, we can define them as follows:

- Direct TO refers to the case where a remote operator is in direct control of a vehicle or crane by taking responsibility of both the dynamic driving task, in which the operator has sustained lateral and longitudinal control, as well as event detection and response. In other words, the remote operator manoeuvres, steers, brakes, accelerates, etc. the vehicle or crane. Notwithstanding this direct control, an automated driving system may provide assistance to some extent (e.g., via adaptive cruise-control or lane keeping).

- Alternatively, indirect TO or indirect control refers to the case where a remote operator only takes care of the strategic (i.e., route-planning) or tactical (i.e., speed selection, lane selection, manoeuvre planning) tasks. An example of indirect control would be a remote operator giving instructions to an automated system on how to bypass an obstacle on the road (e.g., instructing it to switch lanes).

- In the longer-term, a hybrid version alternating both types of remote operation is also possible. Notably, this would be the case in future public road scenarios where a high-level automation truck (i.e., SAE Level 4 automation) can rely on its on-board systems to drive itself on the highway. The remote driver would monitor and take care of the strategic and tactical tasks, and it would intervene via direct control when necessary. Direct control would be needed in two types of occasions: first, when the automated driving system is outside its operational design domain (e.g., in harsh weather conditions or in more complex road environments such as local roads or entering a highway); second, when an unexpected situation occurs (e.g., failure of the automated driving system) and the vehicle needs to be driven to a safe place or to its destination.

Another term for which the reader may find a definition useful is the concept of *platooning*. The discussion below also covers potential Use Cases involving remotely-operated truck platoons. Truck platooning refers to a driving arrangement where two or more trucks travel in close distance from each other (even less than 1 second apart), effectively forming a kind of short train [7]. Following vehicles can tail a leading vehicle automatically, adjusting their speed and position according to the instructions communicated by the leading one. Platooning is made possible by both automated driving technology, including features like automated speed and distance control, as well as wireless vehicle-to-vehicle communication enabling their 'virtual' coupling.

The tables below summarise the outcomes of the discussion in a visual way, while the following sub-sections elaborate on the reasoning and details behind it. Respectively, Tables 2, 3 and Figure 8 present the teleoperated transport Use Cases that are considered technically feasible, from a business and technological perspective, in the short, medium and long run. Nevertheless, even if the technology and regulatory environments would make such Use Cases potentially feasible, actual deployment would be contingent to overcoming a series of business and technical aspects, which we also recap and discuss in the tables and sections below. It must be noted that regulatory and governance challenges are omitted here, since they are analysed more in detail in another task of 5G-Blueprint (i.e., T3.5).

Table 2. Feasible Use Cases in the short run and their challenges

Feasible Use Cases in the Short Run (<3 years)			
	Use Case	**Business challenges**	**Technical challenges**
Scenario L1	Direct TO of cranes, reach stackers, skid steers, forklifts and other yard vehicles	• Unclear ROI of 5G infrastructure: may require co-investment with local actors • Warehouse operations already being highly optimised	• Having a 5G network that covers less dense areas of a port/site or local roads (and areas with bad signal in general)
	Remote operation of passenger cars from unloading area at the dock to and within a terminal site/yard	• Equipping cars with hardware (OBUs, cameras) to enable TO • Granting access by OEMs to third parties to control the car	
Scenario L2	Direct TO of leading truck in 2-truck platoons from port to nearby warehouse	• Availability of (external) trucks on the site to match delivery times for truck platoons • Unclear ROI: May require 5G and TO infrastructure co-investment with local actors if alternative revenue streams for MNOs are limited	• Safety concerns: in public roads, even within the port and nearby local roads where speeds are lower, there is traffic and VRUs; platoons would still interact with road users and cross intersections • Connection blockages along roads (e.g., from large buildings) may require network upgrades
	Direct TO for short frequent "shuttle runs" with trucks in public roads		
Scenario W2	Direct TO of barges for short transports with in a large port environment (e.g. moving containers from one bank to the other)	• Unclear ROI/business case when taking into account the required infrastructure investments	• Connection blockages from passing container ships or buildings around ports may require network upgrades
Scenarios W3/W4	National and international: Direct TO of semi-autonomous barges (with some crew on board for complex manoeuvres or certain tasks)		

Table 3. Feasible Use Cases in the medium-run and their challenges

	Feasible Use Cases in the Medium-run (> 5-10 years)		
	Use Case	**Business challenges**	**Technical challenges**
Scenario L1	Indirect TO of autonomous cranes, reach stackers, yard vehicles	Unclear ROI: May require 5G infrastructure co-investment	Having a 5G network in less dense areas of a port/site or local roads
	Direct TO of cranes and site vehicles		
Scenario L2	Direct TO of leading truck in 2-truck platoons from port to nearby warehouse	• Availability of external trucks on the site; matching delivery times; warehouse operations already being highly optimised • ROI after 5G network upgrades	• Safety concerns in public roads • Complex road types (rather than highways), thus challenging for AD • Connection blockages from buildings may require network densification
	Direct TO for short frequent "shuttle" trips with trucks in public roads		
Scenario L3	Direct TO to support high AD: in complex roads (first- and last-mile) or to help trucks enter a highway	• Upfront 5G and TO centre investments and unclear ROI of 5G network upgrades along roads • Finding alternative UCs for MNOs along roads and with similar QoS	For safety reasons, probably only feasible in combination with level 4 (i.e., high) automation, especially if network upgrades are not pervasive.
	Remote monitoring + direct TO after fallback to help stranded AVs on a highway		
	Direct TO to form and/or lead driverless truck platoons for entry/exit of highways or after fallback	May require road infra. investments (e.g., dedicated lanes to enter highways)	Safety concerns of forming a platoon due to the short distances between highway entries/exits and mixing truck platoons with normal traffic
Scenario L4	Direct TO in complex roads (first- and last-mile) or to enter a highway	• Kickstarting 5G infra. investments to have ultra-low latency coverage • Reaching commercial agreements between multiple MNOs for roaming	• High autonomous vehicles • Seamless session handovers for connectivity & TO across borders
	Monitoring & direct TO after fallback		
	Direct TO to form and/or lead platoons of driverless trucks	It may require road infra. investments (e.g., dedicated lanes to enter highways)	Safety concerns of forming platoons due to short distances between highway entry/exits and mixing platoons with normal traffic
Scenario W2	Frequent short transports with barges in a large port environment	• Business case after 5G investments • MNO commercial agreements for roaming	Connection blockages from passing container ships, buildings around ports or a higher density of connected vessels may require network upgrades
Scenarios W3/W4	Direct TO of crewless barges as complement to AD		
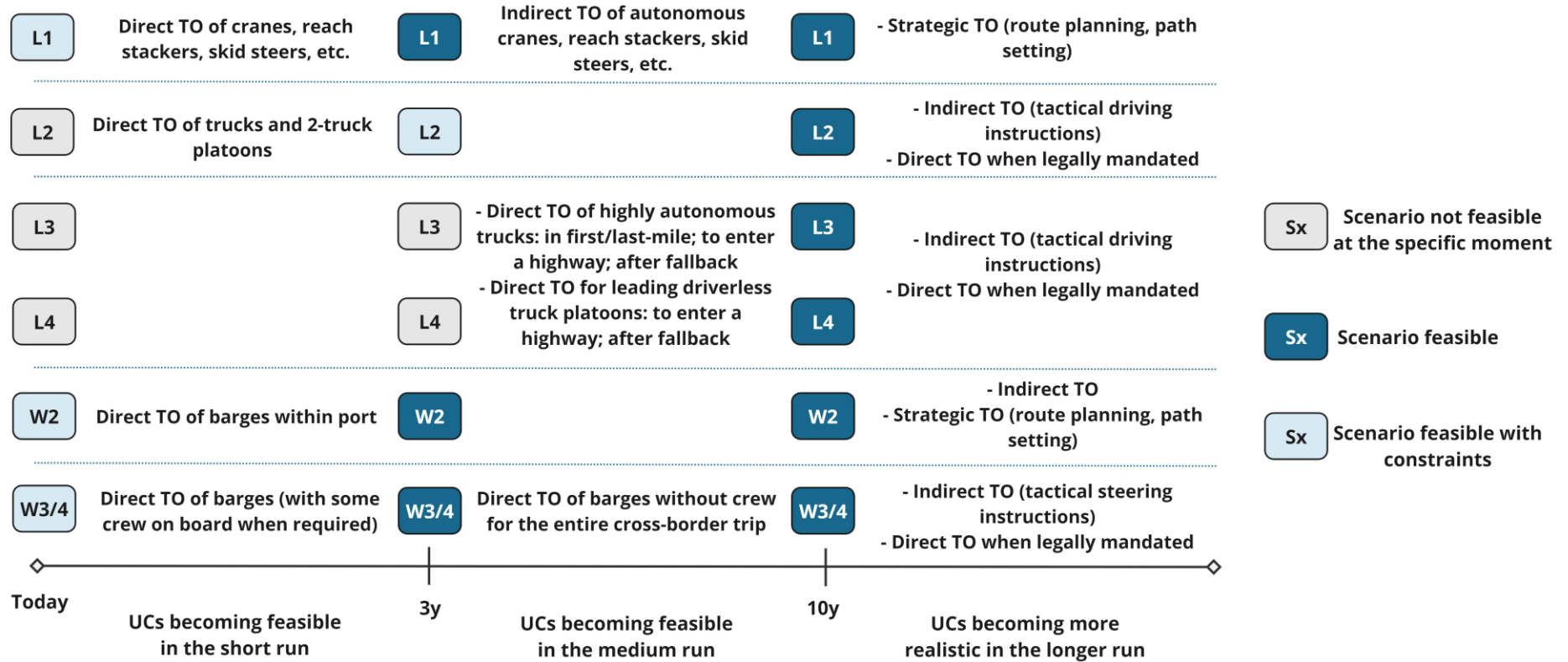
Figure 8. UCs becoming feasible and predominant over time

3.2.1 Land Use Cases/scenarios – Starting deployments

Deployments of teleoperated transport for in-land Use Cases should **start at a small scale (Scenario L1)** before moving to long-haul scenarios, which will require combining TO with high driving automation (level 4).

Scenario L1 is considered the most feasible and sensible scenario where to start the testing and deployment of TO, since it provides a less complex environment in terms of traffic as well as in terms of the number of business partners to collaborate with. A port's terminal, a distribution centre, factory, etc. and the private roads –or even some public but controlled roads– around it can be used as a platform to test if the technology works in a real-life setting that provides a confined environment with lower speeds for remote manoeuvres, while avoiding the safety concerns of remotely operating vehicles in mixed, dense traffic on public roads. While such private sites may include public roads, as is the case in a port, this would still be a more controlled terrain and well governed area, from a traffic perspective.

The reasoning follows as such: once testing and limited deployments have been able to demonstrate that the technology works at the technical level and can provide enough ROI, with smooth operations, both industry and governments would be keener to invest in or allow the scale up of teleoperated transport Use Cases in more complex traffic types, larger and more investment-intensive scenarios, and across countries. Ensuring that the technology is safe and reliable, and the business case positive, would help convince potential users/customers of TO services as well as authorities. Therefore, it is recommended that deployment happens step-by-step over time in order to guarantee market and regulatory acceptance.

Moreover, 5G-Blueprint's Use Cases can already provide safety and economic benefits even in a (relatively) small warehouse/terminal environment. The remote operation of cranes, reach stackers, skid steers or other yard vehicles from a remote station enhances the safety of workers who previously would sit inside a cabin, avoiding the damage caused by occasional, outlier accidents (e.g., collisions or heavy things falling from a crane). Drivers of vehicles are often required to step out the vehicle and stay in a dedicated safety area, but some level of risk still remains. However, safety is not considered to be the biggest motivation for terminals to introduce TO in their operations in the short term, because the remote operation Use Cases considered in scenario L1 would not solve all safety risks; for instance, there will still be manually-driven trucks of customers coming to a terminal to pick up cargo, and, even within the port, there are public roads where there is traffic, including these external drivers, the road behaviour of which cannot be entirely influenced by the port authority.

Becoming an operator from a remote station also increases the worker's comfort: he or she does not need to work in dusty or cold conditions but inside the climate-controlled environment of an office. This may also have a positive impact on efficiency.

Another early Use Case in scenario L1 would be the remote operation of passenger cars that are brought to a port as goods to be stocked and dispatched to the customers of the OEMs. Compared to the Use Cases above, this one is purely motivated by operational efficiency. These cars need to be moved from the dock, after unloading a vessel, to another location within the port, e.g. the terminal of an OEM like Toyota or a company like International Car Operators (ICO) in Zeebrugge. The distance between the location where the vessel docks and their yard varies, since sometimes a vessel cannot dock at the closest location. Within the terminal, a vehicle is also moved around, for instance to bring it to a workshop for repair or to install customer-specific features, or to reposition the car inventory in order to optimise the yard space and have enough gaps at the right places for the arriving cars (a process called

compacting). In addition, the car is transported from the yard or workshop to a location where the cars are loaded on a truck or train to be delivered. From the docking point to the terminal, cars may be driven through a combination of public and private port roads, depending on each site. Today, these movements are done by manual drivers and involve short repetitive moves.

Relatedly, a variation of the Use Case of moving passenger cars within a site would be to use platooning technology to further reduce the need for manual drivers. At the moment, such movements are often done in badges of manually-driven cars that share a destination. A remote operator would control the first car in the platoon. However, this is seen as a Use Case to be explored for a deployment a bit further in the future.

Operational efficiency and the derived economic benefits are thus the **main motivations** for private site owners to adopt TO in the short term, in the context of scenario L1. Such benefits would arise from reducing idle times of workers/equipment and addressing driver shortages. Even in the limited scale scenario of a private site, remote operation can improve usage of equipment: for instance, in a container terminal, a remote operator can swiftly switch to operate a different crane while one is idle; similarly, in a warehouse, a remote operator can switch between yard vehicles while one is idle or needs to be refuelled. For instance, transport companies that now have a distinct employee manually operating each reach stacker do not have a continuous workload; on the contrary, there may be substantial waiting time between tasks. Moreover, the remote driving of passenger cars can provide cost-savings for terminal site owners by reducing idle times and quickening the processing of vehicles: after delivering a car to the destination at the site, drivers need to be driven back to the origin to repeat this process and drive more cars to the storage parking. A bus often brings several drivers back to the initial location of the vehicles. TO can avoid this idle time and also avoid the cost of the bus driver. Removing this idle times also means that they can move more cars per hour, therefore –all else equal– increasing stock turns and allowing both ports and terminals to handle more cargo and ultimately increase their revenues.

Automation also plays a role, in different ways: first, a remote operator can also switch to a different vehicle/crane while the previous one is performing automated tasks, analogously to the previous examples; second, combining TO with automated docking of trucks can increase the feasibility of Use Cases in such private sites, not only from also increasing operational efficiency but also by taking care of an action that would be challenging to perform by a human from a remote position. Remote operation can also be valuable where yard automation remains challenging, for instance for activities like unloading bulk, which are too expensive or complex to automate; additionally, in yard operations there is a lot of variation in tasks, so the potential scale advantages of automating specific tasks is not as present.

The interviewed companies affirmed to often struggle to find workers and drivers for site/terminal operations such as operating skid steers or reach stackers to help unload a vessel, as well as to drive the vehicle inventory from one point of a terminal/site to another. This is especially the case for evening or late evening shifts, where there is also less traffic and therefore less complexity for the driving task. However, in large ports like the Port of Rotterdam, finding terminal workers is less of an issue, since their wages are much higher than for truck drivers and job demand is consequently higher (in an eventual shortage, finding extra workers is seen as feasible if job requirements are eased).

But besides these potential benefits and relative feasibility of implementation, we also need to take into account the following challenges from this first scenario. At the business level, for the Use Case of doing teleoperation in warehouses by remotely driving yard vehicles, one expert highlighted that in certain warehouses, e.g. of leading vehicle manufacturers, operations are already highly optimised, hence the specific benefit of remotely operating tasks

in that specific site would need to be estimated before assuming that teleoperation would actually lead to benefits when taking into account the required investments.

Another aspect is that deploying teleoperation for a large number of vehicles, even within a confined area, may already require densifying telecommunications networks with 5G technology to cover the spots of a site where the signal is less reliable. Such infrastructure investments would be substantial and have an unclear return on investment (ROI); active collaboration in the form of co-investment with other sites or local actors that can also benefit from such improved connectivity may thus be necessary, since the alternative revenue streams for MNOs are limited. However, relevant interviewees from the industry also mentioned that performing certain actions at a small scale of operations with vehicles that operate in a limited space – like reach stackers or forklifts; or like cranes, even in a fixed space – can already be achieved with current infrastructure or with slight improvements with current cellular or fibre technology. The yards where cars are stocked are also usually quite flat, with no big buildings blocking wireless signals. In addition, some site owners, such as OEMs, do see a future need to adopt more Use Cases that use telematics, e.g. for over-the-air updates, which provides another incentive to update networks. Lastly, some sites like Zeebrugge already have their own private 5G network.

Specifically for the Use Case of moving passenger cars, a business-related hurdle is receiving permission for third-party access to control the vehicles. This would be a challenge for companies like ICO, which handles cars from multiple brands. If third parties can tap into on-board diagnostics, they can control the car, hence this is a sensitive aspect for manufacturers, although the reluctance to allow access will depend on each OEM. In general, this would not be an issue for large manufacturers that handle their own vehicles at their own sites, as it is the case for Toyota in their terminal in Zeebrugge. Lastly, in terms of liability, it would be similar to today: responsibility for what happens after the car is unloaded would remain with the site owner that moves the cars.

Another challenge relates to the required investment to equip passenger cars with hardware (e.g., cameras) and software to enable them to be remotely operated. This would represent large investments in on-board technology that currently is only available, if at all, in premium models. OEMs need to be convinced of the business case: whether the benefits justify the investments or, on the contrary, it is more sensible for them to wait for AV technology. In the longer-term, such movements of cars will be done with AV technology, although for regulatory reasons it may require having a human-free zone around the port. It must also be noted that another possibility for performing such movement of cars is using teleoperated loaders, i.e., vehicles that lift a car and drives it (as cargo) to the designated place. This would remove the need for integrating teleoperation technology in each car, although it would require the site to invest in this extra type of vehicles and equipment. However, in this deliverable we focus on the previous approach, which shows a clear incremental change of and impact from the adoption of TO in a context resembling today's operations while also being more uncertain from the business case perspective. Section 4.1 assesses the potential profitability of this Use Case in the context of a Belgian port.

For multi-brand vehicle handlers, the investment in retrofitting cars is not their choice and would not be in their interest to equip the cars with TO technology just for the use of TO in this scenario. If, on the contrary, OEMs equip their cars with TO technology from the start, they can use them for remote operation Use Cases across their large supply chains and markets.

In conclusion, in the short run (i.e., the initial years), deployment can focus on Use Cases within a private site of a distribution centre or a port terminal's own operations: cranes that unload containers from ships, tug masters, skid steers, handling inventories of passenger cars,

etc., in combination with current state-of-the-art automation technology for some actions (semi-autonomous terminal vehicles are already available). These are all potential applications on private premises that can be rolled out in the shorter term. And if these applications are used without any issues for a certain period of time, the practical experience will offer companies the confidence, and policy-makers the certainty, to take the necessary steps to scale up towards public roads.

3.2.2　Land Use Cases/scenarios – Scaling up to public roads

In contrast, for road transport, the feasible timeline for teleoperated transport Use Cases on public roads is generally considered as more challenging in the short term. In addition, in public roads, even within or around the port as in scenario L2, there is a lot of traffic, including VRUs. Even trucking companies familiar with TO technology see it as a far away scenario with an uncertain outcome. For larger road transport scenarios involving high-speed roads (i.e., L3 and L4), TO will need to rely (to a large extent) on automation, but self-driving technology is not expected to be ready in the short or medium term (at least within the current decade).

Therefore, the main deployment challenge envisioned today is the scaling up from Scenario L1 to larger-scale scenarios like L2 (shuttle runs) or even L3 and L4 (i.e., national and international road transport).

At the business level, a main challenge is finding companies that are willing to invest on the required initial investments. Deploying 5G-based teleoperated transport Use Cases entails investing in multiple elements right from the start: chiefly, retrofitting or building TO technology into vehicles, setting up TO control centres, road infrastructure adaptations –possibly–, and telecommunications network infrastructure deployments/upgrades.

At the technical level, a crucial challenge relates to road safety concerns. In public roads, especially in highways, mixed traffic at higher speeds pose a safety concern from the – albeit unlikely – possibility that the 5G connection is interrupted for a small lapse of time. And even within the port and nearby local roads, safety concerns exist because there is still traffic, as well as intersections and interactions of trucks with other road users (even vulnerable road users such as on-site workers in port environments). Not only must remote operation technology be able to handle the driving in such conditions safely, but mobile networks must be able to reliably offer constant coverage with ultra-low latencies.

The direct TO of trucks at scale would require network upgrades along roads (in both local roads and highways) if connectivity is to offer the higher network capacity and stringent requirements through 5G – i.e., extremely low latency and high bandwidth for the uplink. In addition, connection blockages along roads (e.g., from large buildings in the area) may require network upgrades in the form of densifying networks with extra RAN infrastructure (e.g., deploying more antennas). These network investments pose the greatest challenge: not only are they the largest source of costs in terms of up-front capital expenses – a type of cost that not only varies by the number of vehicles that need to be covered by 5G but mostly varies by the distance or size of the areas covered –, but they also hold the most indirect link to the transport Use Cases out of all the listed investment types, in the sense that they relate less linearly or depend less closely from the levels of adoption of TO UCs. Therefore, in contrast to retrofitting vehicles or setting up more remote driving stations, the investment risk of 5G infrastructure can hardly be reduced by introducing TO Use Cases slowly while being more reactive and scaling only when demand becomes clear; even though infrastructure can be densified as adoption scales up, a 5G network that covers the specific requirements of TO needs to be available upfront.

In addition, the business decision behind deploying 5G networks will be done considering the servicing of multiple Use Cases with differing requirements. For MNOs, getting a positive ROI on their network upgrades will not just come from the single business case of TO but depend on non-transport types of Use Cases for connectivity along roads and cross-border areas. However, MNOs still struggle to find such 5G Use Cases that also require large coverage with high QoS. The value proposition of the discussed teleoperated transport Use Cases for each actor that stands to benefit from it will be discussed in section 3.3, along with a discussion on what parties may provide the initial investments.

These challenges alone question the ROI of remote operation in itself and as a result limit the feasibility of larger land-based scenarios in the short term. But even if mobile networks are upgraded to offer connectivity with the required QoS, the service cannot entirely guarantee that there will not be an occasional interruption, even if extremely brief. Therefore, to add an additional layer of safety in those situations, performing remote driving in public highways will probably only be feasible or allowed in combination with level 4 (i.e., high) automation, especially if reliable connectivity is not pervasive throughout a truck's entire journey on the highway. If the connection is lost even for a few milliseconds, on-board automation software in trucks should be able to bring a vehicle to a safe stop until connectivity is restored and the teleoperator can take control again. This is more challenging in a highway environment than in closed roads or less busy areas, because high speeds and the presence of surrounding vehicles increase the chances of collusion.

Driving automation also improves the economics of teleoperated transport Use Cases, because it substantially increases uptime and the related cost efficiency. Therefore, in scenarios L3 and L4, the role of AD becomes crucial. Several of the interviewed experts also questioned whether TO would justify the infrastructure investments in 5G along roads during the transition until AD technology's performance is deemed safe enough for highway environments.

Therefore, a feasible evolution for teleoperated road transport would be scaling up to long haul with direct TO only once high automation technology [i.e. level 4] is available. There are two promising Use Cases in which direct remote control of trucks (direct TO) can be a complement to level 4 autonomous driving (AD) for the long-haul:

- First, one where remote driving is used in more complex areas, either (a) in last-mile areas (e.g., local roads), or (b) to help trucks enter or exit a highway, before they start driving autonomously; and

- Second, one where direct TO is used after sudden fallback to help driverless trucks that are stranded on a highway (either because the AD systems failed or because weather and road conditions suddenly became unmanageable). In the long term, TO may just be a service for back up for such incidental cases.

In both cases, AD is expected to become the default driving mode during the highway part of the trip.

With high automation in highways, where TO is used to monitor and assist driverless trucks only when they face complex traffic situations outside of their operational design domain (e.g., during road works or specific weather conditions), the infrastructure investment challenge lies in the scale of deployment in terms of the number of vehicles. Scaling up to support numerous vehicles on long highway stretches would require the installation of additional cell sites. However, in cases where multiple vehicles require assistance simultaneously, a coordinated platooning approach could be employed: the remote operator would directly control the platoon leader while providing indirect control (path setting) for the other vehicles in the platoon. By sharing the same set of waypoints through short-range connectivity, the requirements to remotely operate all the trucks can be reduced, making platooning a viable solution for scaling teleoperation in long-haul situations.

However, it is expected that even in a future where AD is cleared for highways, more complex roads and traffic types remain a challenge for the technology to tackle safely. This is expected to be the case for local roads, such as those in scenario L2 involving short frequent transports along the same public roads around transport hubs, which involve more connections between modes, interaction with road users, roundabouts, traffic lights, etc. In contrast, this may be an easier design domain for teleoperation: lower speeds reduce the impact of a potential accident due to connectivity failures, while the higher interactions and more unpredictable traffic conditions represent situations that a human driver is accustomed to. While all vehicles should be autonomous to a certain extent, in case connectivity fails, the required level would be lower compared to highway domains. The limited set of routes can also be assessed by authorities and industry actors and, if all safety conditions are met, cleared in advance. Therefore, scenario L2 can become feasible before high automation, for the Use Case of using direct remote operation of trucks or 2-truck platoons. In such a scenario, TO would increase operational and cost efficiency from allowing a remote driver to take over a different vehicle when the present one is idle (e.g., queuing when entering a site), and this way would also increase availability of drivers. An interesting situation to start this deployment with is at night, when roads are less busy and there is less availability of drivers.

In the short term, in absence of advanced AD, a more challenging situation for TO technology would be all first- and last-miles of long-haul trips in general. These also represent local, complex roads, but the routes would be more fluctuating (depending on customer requests) and could happen in any country. Therefore, the possibility of checking and clearing routes in advance is less realistic, and also the feasibility of covering the specific road with 5G RAN infrastructure – in the previous case of scenario L2, the upgrading could be done at the same time as the one done for the private site area, whether done by a private network or coverage on demand. In these situations, which can be considered part of scenarios L3 and L4, except the highway part of the trip, it may be more realistic that experienced manual drivers take care of such local driving. These drivers could 'pick up' and 'drop off' the truck at designated locations nearby a highway, from where a remote driver could take over as in the setting explained above for entering or exiting a highway. This would mean that the driving task would become more local while at the same time enjoying the economic benefits of automation. This Use Case is the one that was described and analysed more in detail in D3.2 [1].

Therefore, in practice, a combination of teleoperation (TO), manual driving, platooning and automation (AD) might be the most technically and financially feasible approach to scale up deployments. TO and AD will complement each other: on the one hand, highly (but not fully) autonomous vehicles would likely require the intervention of teleoperation in challenging situations (e.g., in case of complex traffic conditions, uncommon bad weather, or road works); on the other hand, a high level of automation would provide a safety net by enabling the vehicle to perform the fallback task itself in case of emergency, either due to technical requirements or legislative mandates, allowing the vehicle to be taken over as a safety measure. In addition, AD will improve the economic efficiency of connected driving by further increasing uptime and reducing the need for and the burden on human drivers.

To accelerate the feasibility of road scenario deployments, traffic management and improvements in road infrastructure can also help. For instance, dedicating specific highway corridors to teleoperated trucks can limit the operational design domain. Such corridors would facilitate the remote operation of tasks like getting vehicles on and off the highways or assisting stranded autonomous vehicles.

Finally, another requirement and business-related challenge of the broader L4 scenario is to have seamless session handovers for connectivity when a truck crosses borders. Because a given transport journey can involve multiple countries and each country has several connectivity providers a client can choose from, guaranteeing such seamless handovers would require MNOs to set up multiple commercial agreements with other MNOs for roaming,

establishing the conditions and pricing in advance in order to speed up the process of a vehicle roaming onto a different network when crossing the border.

Regarding the handover for the supervision or control of a vehicle on a cross-border journey between remote operators located in different TO centres, scaling up to scenario L4 within the EU is not expected to pose a substantial additional challenge. Cross-border situations are not likely to represent a substantial extra layer of complexity, both in terms of technical aspects and logistics ones. This is because the transport value chain is already international, cross-border road areas are mostly highways, and TO centres (or TO centre managers) do not need to divide their coverage areas according to country borders, once criminal law and other regulations allow teleoperation to be offered in different EU countries. In contrast, MNOs operate at the national level: even if they are international companies, spectrum licenses are purchased at the Member State level.

In Annex D, we discuss the feasibility of adopting truck platooning in the land-based public road scenarios, as well as the role that truck platooning can play to support teleoperated transport UCs and contribute to their economic feasibility. We present this discussion in the annex because CACC-based platooning is not studied in depth in the business model and business case analyses of the present report, compared to the other UCs.

3.2.3   Waterways Use Cases/scenarios

Compared to road transport, the less complex operational design domain of waterway scenarios, even within the vicinity of a port, allows TO in combination with automation to be more realistic in the short run, and therefore allows to scale up towards broader geographical scenarios sooner. At least for a low scale of operations, waterway scenarios are already feasible today. In fact, remote operation with a captain from a TO centre is a Use Case that is already commercially available today and offered by the consortium partner Seafar.

TO can optimise barge transport by increasing uptime from assigning remote captains to a different vessel during idle times (e.g., loading and unloading). Also, the remote captain can sail for just 8 hours from a remote location, increasing the attractiveness of the job, all else equal.

In addition, the fact that part of the crew can remain on board while still reducing crew size makes it comparatively safer and more economical than TO for road transport. For vessels, direct TO can already also help reduce the required crew on board, by using the idle time that comes with certain tasks more efficiently. There can be a business case from reducing crew on board already for short distances: usually vessels need a small crew of operators, helmsmen or boatmen on board, besides a captain, but with the remote operation of certain tasks including steering, only 1 or 2 helmsmen are required to remain on board (based on current deployments and according to the feedback of our project partners). A longer-term goal is to remotely operate the vessel without the skipper on board and with just one helmsman on board who can interfere when an emergency happens. Nevertheless, Seafar already operates fully unmanned vessels for large parts of a trip.

The reasons why having some technical staff on board is still often necessary include the following: (i) to hand documents to the police and customs (although this could be digitalised in the future); (ii) to perform more complex tasks that cannot be easily automated (e.g., bunkering for barges, although on-shore crew can help do the fuelling); and (iii) because some municipalities mandate it for safety concerns (e.g., those with recreational ports and thus with more traffic from VRUs).

For inland waterway transport, as is the case for the road scenarios, the economic benefits of TO are also expected to be larger for longer journeys than in a port area. However, standard trips with barges in a large port environment for frequent short "sails" (e.g., transporting containers from the left to the right bank) are also seen as a feasible Use Case, although the business case needs to be explored in more detail. This is a Use Case that belongs to scenario W2.

Regarding scenarios W3 and W4, Seafar's TO services for barges already rely on automation for most of the trip along a canal, with the supervision of a captain from their control room in the TO Centre. In the shorter term, a captain on board may take over for the more difficult parts of the trip, for instance around the port.

For longer trips still within national borders (e.g., 8-hour trips), another benefit is less fuel consumption. Captains on board (of vessels with a crew on board) often go as fast as possible to try reach the destination without delays. With a remote spot, they tend to optimise their speed, since they work an 8-hour schedule, and if the vessel has not reached its destination at the end of their shift, they can still go home, and a colleague can take over operation.

In general, thus, waterway TO Use Cases are more readily feasible than road ones. Notwithstanding the above, TO scenarios for waterways also entail challenges related to connectivity aspects. Ports and waterways are challenging environments for any radio network because the coverage provided with land sites along the banks can be blocked if, for instance, a large container ship blocks the signal when passing between an antenna and the teleoperated vessel. In addition, large buildings in ports often stand in the way of current antennas, and a higher density of connected barges (sharing network resources) in the future can also cause network issues. 5G can have multiple active connections to different cells of the MNO to address that, so if the connection from a main cell is lost, the barge immediately connects to another. But this may require densifying with dedicated 5G infrastructure along ports or waterways to provide that redundant coverage. Therefore, the need of network deployment and business case considering the related costs need to be taken into account to evaluate the financial feasibility of large-scale waterway teleoperated transport, since the ROI when taking into account required 5G infrastructure investments remains unclear. However, with the small-scale operations of today, current LTE networks are sufficient to navigate the geographical scope of Seafar's operations.

Wider implementation encounters several other challenges: firstly, the need for more frequent loading and unloading operations, which, especially during nighttime, may increase waiting times if a worker is not available to do the (un)loading; this could be addressed with the introduction of autonomous cranes to enhance the time-efficiency of (un)loading when personnel availability is limited. Secondly, the refuelling process requires dedicated personnel in certain locations; presently, Seafar often has personnel available on-site for this task. Thirdly, existing legislation poses an additional barrier as TO service providers are required to apply for exemptions for each specific route and vessel.

Finally, another crucial obstacle is the establishment of commercial agreements between MNOs for seamless roaming. Presently, Seafar tackles this issue by employing multi-SIM solutions through contracting multiple network providers and having multiple SIM cards (from onboard of their vessels, which continuously search for available wireless networks that offer a suitable QoS. When operating across a limited number of countries, e.g., through Belgium and the Netherlands, the multi-SIM solution is seen as a feasible way to guarantee having robust connectivity, either from having a national SIM at all times to avoid roaming, or from having multiple 'home' operators and thus being able to select the one that has the best roaming agreement (based on the QoS their partner provides in a specific area). Fortunately, the potential impact of temporary connectivity losses on waterways is lower than in road

environments due to less dense and slower traffic with fewer Vulnerable Road Users (VRUs).

3.2.4   Longer term

In the first stage of implementation, combining teleoperation (TO) with automation on long routes is expected to present a more evident business case, offering enhanced safety and efficiency until automation reaches a level where the role of TO can be further reduced.

The role of TO will therefore transition from more direct interventions in the short and medium term, such as driving trucks for frequent shuttle transports or for entering a highway or remotely steering vessels, to a more indirect and even strategic role. Examples of more passive roles will be seen earlier in waterways scenarios and in scenario L1, because on-board automation capabilities will be more ready for cranes, yard vehicles or barges in these less complex scenarios. Such indirect actions would entail offering tactical instructions to a highly autonomous vehicle (e.g., "switch to the right lane") or, even more passively, strategic instructions like travel and route planning.

In the long run, the feasibility of TO and TO-based platooning in highways and waterways will significantly improve with a high level of automation, wherein the role of direct remote operation and TO-based platooning would be a support one to autonomous driving, reinforcing automation for intricate manoeuvres or in challenging conditions. For example, during road construction or adverse weather conditions, TO would be employed to intervene if necessary, while the vehicles operate autonomously for the majority of the journey.

However, as automation progresses further and more tasks become automated, such as achieving Level 5 full self-driving capability, the role of TO will gradually become less central, as it will become less and less necessary to support AD in complex design domains. Under the premise of high automation on highways, TO will primarily serve to monitor and assist driverless trucks during highly uncommonly complex traffic situations that fall outside their designated operational design domain.

Nevertheless, legislative mandates may still require TO as support to Autonomous Vehicles (AVs) in fallback scenarios or for specific edge cases, complex manoeuvres, or certain road types in the first or last miles. It is expected that, at least, an indirect role of TO (i.e., monitoring and being ready to take-over when necessary) is mandated once AD is allowed on public roads.

3.2.5   Passenger transport Use Cases

The role of passenger transport Use Cases is also relevant for our current work, even if not directly tackled by the 5G-Blueprint project. Passenger transport teleoperation Use Cases would use (at least part of) the same infrastructure and technology used in our described Use Cases, thus offering an alternative source of demand and revenue to cover the investments that represent a challenge to kickstart teleoperated transport Use Cases. These types of initiatives/Use Cases with cars or buses could this be a market force that accelerates the further investments in deploying teleoperation technology.

Examples of teleoperation Use Cases for passenger transport include the following:

- Touristic bus rides between two cross-border municipalities, based on 5G connectivity in inter-urban roads. This is described in Sari et al. [8].
- Driving private cars for either (a) return trips when a driver becomes unable to drive,

e.g. because he or she has drunk, or (b) blind or disabled people.

- Valet parking.
- Supporting driverless vehicles, e.g. for risky/complex manoeuvres or to drive in complex road situations.
- On-demand ride-hailing services, where a remote operator brings a vehicle to the customer's location, and then the customer drives the car manually to his/her destination, from where a remote vehicle operator takes over again and relocates the car to a depot or the next user.
- Car sharing services.
- Car rental services.

For ride hailing, car rental and car sharing services, the benefit of TO relies on the relocation of vehicles. Doing this remotely means it can be done quicker in periods of high demand, which in turn increases utilization rates. In addition, it adds flexibility: it can extend the reach of operations by allowing users to start a journey where it is unlikely that another user would drop off the vehicle. Relocation can be done for geographical re-balancing (i.e., moving vehicles across areas to better match the demand in each location), as well as to drive a vehicle to a depot for maintenance and cleaning, to a pick-up point, to a charging station, etc. Such relocation is more time- and cost-efficient if done by a remote operator than an employee that needs to travel until the car's location and then back. For ride-hailing urban services, rebalancing across neighbourhoods also reduces waiting times for end users.

To some extent, the main cost elements behind TO – equipping vehicles with TO technology, deploying 5G network and TO centre infrastructure, etc. – could be shared across passenger and goods transport Use Cases. For instance, part of the infrastructure of TO centres.

For the specific Use Case of moving passenger cars within a port, the teleoperation of cars also after they are treated as cargo, would provide an incentive for OEMs to build TO technology and functionality into their cars. These costs are quite prohibitive and question the business case of remotely moving cars from the docking point to a logistics site in case no additional (future) TO functionalities can be materialised (see section 5.1 for a discussion on this topic).

Regarding 5G infrastructure costs, this claim is apparently less certain, as many of the most advertised passenger Use Cases are envisioned to be deployed in urban areas. But some Use Cases mentioned above, particularly touristic bus rides in cross-border areas, supporting or relocating cars for car rental services, could potentially reuse the same 5G networks along inter-urban roads. Not only could the investments be shared among different parties, but MNOs would also see a clearer business case of investing in deploying 5G networks along roads, and therefore be more incentivised to take care of the upfront capital outlays.

Another question is whether goods and passenger transport Use Cases overlap in terms of timing. Most passenger Use Cases target dense urban areas or dense, mixed traffic roads. These are considered more challenging environments than our scenarios within logistics hubs or around port terminals, thus one would expect that passenger transport Use Cases align more in terms of timing with our medium-term scenarios. Notwithstanding this, there are several companies, such as Vay or Imperium Drive, that already advertise the commercial deployment of teleoperated ride-hailing services at scale in the near future.

3.2.6 Realistic deployment scenarios - Recap

To summarize the feasible deployment path outlined in the previous tables and sections, the initial implementation of teleoperation (TO) in land-based scenarios should commence in areas where vehicles can operate at low speeds, thereby mitigating safety concerns. This

entails employing TO for short distances on private sites or controlled port areas and potentially in less complex and less congested open road sections near sites or warehouses. In such settings, TO can be beneficially utilised to remotely control cranes for unloading containers from ships and for controlling reach stackers, tug masters, and other site vehicles to move containers around a site –in some cases in conjunction with automation for certain vehicles and cranes or for specific tasks like docking. These initial Use Cases would already provide operational efficiency gains by reducing idle times, addressing labour shortages, and to some extent, enhance safety for workers. At this early stage, regulatory authorities should closely monitor developments, gain a comprehensive understanding of necessary actions and associated timing for regulations, and potentially encourage further R&D efforts by facilitating collaboration among relevant parties and supporting testing initiatives. As the technology matures and gains experience, the potential for scaling up TO deployment to public roads increases, paving the way for broader adoption and greater benefits.

This conclusion is in line with the recommendations of D3.3: based on the results of their techno-economic analysis, D3.3 recommended starting the deployment of TO services in a geographically limited area, including short trips on public roads, and only scale up deployment to also cover major national and even international transport routes when significant TO adoption –in terms of the number of connected vehicles– has been reached.

However, scaling up to scenarios on highways would require higher levels of driving automation for safety and financial reasons; hence, teleoperated transport Use Cases in scenarios L3 and L4 are only expected to become technically and financially feasible in the medium to long run.

In contrast, TO Use Cases in waterway transport scenarios, even for the long haul, are already technically feasible today, with implementation of remote captain services happening at a low scale in Belgium and the Netherlands. But even here, teleoperated transport will only be feasible in practice under certain constraints. In general, realistic business models will have to help overcome such constraints and help facilitate deployment.

In the farther future, the role of TO will become a more indirect and even strategic one, e.g. offering tactical driving instructions or path setting to highly autonomous vehicles. This transition is expected to happen first in waterways scenarios and in scenario L1, because of the lower domain complexity of these scenarios and the readiness of automation capabilities for cranes, yard vehicles and barges.

3.3 Value proposition and the problem of kickstarting investments

Enabling teleoperation (TO) requires investing in multiple elements (5G network infrastructure deployments, setting up TO control centres, equipping vehicles with CAD technology, etc.). Deploying TO solutions exhibits a mutual dependency among multiple stakeholders: it represents a significant risk to bear the costs of undertaking any initial investments without knowing if complementary elements will be deployed. To incentivise investments, it would be helpful to have an entity that acts as an *orchestrator* and/or *kickstarter*. An orchestrator is an entity that helps establish long-lasting relationships among different partners within the ecosystem and encourages them to share their knowledge and resources. A kickstarter could even take the lead in getting this ecosystem up and running by (partially) investing in TO and 5G infrastructure itself.

Table 4 below addresses the following question "Who could act as kickstarter in different deployment areas?". By kickstarter we mean a party that while not necessarily being directly involved in the provision of TO services nor being a main transport service customer, it (partially) invests in TO and 5G infrastructure. An investment kickstarter would help reduce the risk that these required elements would not be available. We discuss the pros and cons of hypothetically assigning the role of providing initial investments to deploy teleoperated transport to each distinct stakeholder type. Such pros and cons reflect their point of view and preferences of each stakeholder as well as what would be sensible and realistic.

Similarly, Table 5 below addresses the question of "Who could act as ecosystem orchestrator?" by also discussing the pros and cons from the perspective of each stakeholder type. By orchestrator we mean a party that facilitates the creation of a business ecosystem in a specific deployment area, i.e. a trusted entity that takes up the responsibility to help establish long-lasting connections among different partners and encourages them to work together and share their knowledge and resources. Since the studied UCs rely on innovations that merge business roles that traditionally belong to the transport, smart driving/automotive technology, smart mobility services and telecommunications sectors, helping partners find each other may be beneficial in certain areas to deploy teleoperated transport. Such orchestration would reduce the uncertainty that (i) TO is deployed and gains adoption and that (ii) there will be a long-lasting use of TO in an area, which will be important for firms to be able to recover their initial investments.

For those actors that are (potentially) technically capable to perform main roles in the value network, the value propositions of teleoperated transport need to be clarified in order to incentivize these companies to adopt such roles and the business models defined later; they must see a financial interest in adopting and investing in TO. This is especially the case for MNOs and road transport companies, which, respectively, are expected to play the central roles of deploying 5G network infrastructure and contracting (or even offering) the TO service to include TO in their daily operations.

To convince (road) logistics companies to adopt the technology, it is important to understand their operations, where they spend more hours and money today, and tailor the value proposition to the efficiency and economic gains that TO can offer. It is unlikely that they will be fascinated by the technology itself (i.e., by its innovativeness or even the broader societal benefits that it can offer, unless the economic benefit accompanies them). For MNOs, it is important to understand the alternative Use Cases through which they can monetize the investments in upgrading 5G infrastructure, besides the ways in which they can directly charge for the connectivity service provided for TO (which is discussed within the descriptions of business models).

Road vs waterways. For water- and land-based scenarios alike, the source of economic value of TO is quite clear: crew/driver shortage is one of the biggest challenges in the industry, while the work-life balance of working from an office is seen as an attractive feature for captains and truck drivers alike. Therefore, teleoperating barges makes the role of captains more attractive and helps fill in job shortages as it does for trucking.

Companies like Seafar are not the vessel owner, but provide a TO service – including retrofit equipment, their control system, etc. – which in the eyes of the customer can be offered as a "captain-as-a-service". This service is already offered today, and as mentioned before, in combination with automation it can not only enable the remote operation of some tasks but also reduce onboard crew requirements. Vessel owners, however, need convincing, i.e. be shown that there is a business case from lowering captain and crew costs. On the road, however, one cannot reduce the crew (either there is a driver or the truck becomes driverless),

so the safety and economic implications are different. Regarding safety concerns, in the short term, starting a driver-as-a-service is therefore only seen as realistic in confined areas on the road. To scale up geographically to scenarios L3 or L4, which involve the transport of goods by truck on highways, a high automation level is expected to be required. Moreover, the monetary value of a captain of an inland vessel is greater than that of a truck driver, since vessels contain multiple (in fact, dozens) of containers. This makes the "captain as a service" offering from Seafar much more valuable than the "driver as a service" on a per-vehicle basis.

Table 6 below presents the main value proposition that TO can offer to distinct types of stakeholders from the 5G and transport value chains, to reinforce the discussion of which parties would be better positioned to contribute to kickstart investments in the systems and infrastructure required to deploy teleoperated transport. Therefore, we discuss it together with the outcomes of the related discussion on the favouring and disadvantageous conditions that affect each actor in their potential decision on whether they would be willing to kickstart the investments in infrastructure and equipment required to deploy teleoperated transport Use Cases.

The findings in this section came in the largest part from assembling the relevant input received during the validation interviews and workshops with project partners and the project's advisory board.

Table 4. Pros and cons for each stakeholder to act as an **investment kickstarter** in different deployment areas.

Entity type	Pros	Cons
National or regional governments	• Within the traditional role of the government to support the adoption of Use Cases that would yield outcomes in line with policy goals • Availability of funds • They can support testing and grant exemptions for specific transport routes	• Hard to convince them to invest; they would rather let the market play • Slow pace and organisational complexity. Governments are very large and bureaucratic organisations; alignment between departments alone requires large investments in time. Each department/ministry has its bounded responsibility and domain; in larger scenarios, convincing multiple departments for investment and/or approval may be necessary. • Coordinating across national governments can be time consuming and challenging (relevant in cross-border scenarios) • In initial stages, there is virtually no societal interest; it's mostly economic benefits accruing to the logistic sector.
Supranational (EU) bodies	• Funding for R&I programmes that promise to bring societal benefits is part of their mission • Availability of funds	• Road/driving regulation and policy are largely seen as a matter of national regulation and policy • In small-scale scenarios, they would need to clearly envision the expected societal benefits of TO, which may require to scale deployments to the wider scenarios in terms of geographical coverage
Local governments	• Less bureaucratic; easier to align among departments and their policies • More interest (or less conflict) in promoting specific economic benefits affecting a (relatively) small pool of companies or a single sector	• More limited funds and power to affect policy at sufficient scale
Port authorities	• They have authority over the site (the private ground parts they own), so their decisions can be implemented quickly (need not wait for policy)	• Willingness/capacity to invest in Use Cases that do not directly benefit the port as a whole. Port authorities are not the main party benefiting from teleoperation; rather,

	• Long-term interest in increasing the efficiency of logistics operations in the area.	terminals or companies operating within the port • In large ports, shortage of terminal workers (e.g., crane operators) is less of a bottleneck; wages are higher and so is demand for the jobs. • Belief that market players with specific knowledge should take care of TO and 5G services, at least in the long-term
Industrial site owners and port terminals	• Some warehouses (like MSP Onions) have their own buffer area. • The terminal itself can be the (single) entity directly benefiting from the TO of certain location-bound vehicles (cranes, reach stackers, forklifts, etc.) • Can pass the benefits to their customers in terms of higher value (e.g. time to unload) and increase margins	• Deep-sea terminals work with largely automated cranes, so there is no real need for teleoperation. • For their limited operations with vehicles that stay on the site (e.g. cranes), some terminals do not see the need for 5G (a.o. because they suffer less from low coverage spots) • In large ports, shortage of terminal workers (e.g., crane operators) is less of a bottleneck • Willingness/capacity to invest.
Shippers	• Shippers benefit from the TO Use Cases: they save costs on a per-container shipped basis, as customers of the transport and container handling services. • International players often have more available funds than local or specialised transport companies • They would speed up deployment of the technology in terminals and by transport companies. • In smaller scenarios, they are seen as the stakeholder that benefits more directly and the most (economically)	• They may not be directly concerned in implementing the transport of their goods (they would rather delegate it to the transport company)
Transport companies	• They derive advantage from TO, and can directly internalise the economic benefits of it, adding a margin before passing the cost or time reductions to customers. • Are the most threatened if a competitor adopts TO first	• Currently do not show eager interest to start investing in the technology • Global players may not have enough vested interest in a specific local area; while local players may not have a business case in themselves (or be convinced of it)

	and builds a competitive advantage from it	• Large infrastructure/deployment investments may be out of reach for a single company, especially local/regional ones
Truck OEMs	• They can generate a competitive advantage with respect to competitors • It's easier to integrate TO technology in vehicles at the production line stage than retrofitting it afterwards. • Their vehicles would be safer: TO can provide a safety fallback for normal operations. • They could use the connectivity along roads to enable other extra features in their cars • TO can provide them ancillary revenue	• Limited benefits envisioned, relative to the required investments and changes in the way they operate • The role in and benefit from the TO service is seen as a more indirect and limited one, so they have a more passive/risk-averse approach
Start-up, dedicated TO service provider	• Direct business case: they would enable their own, direct business from providing the TO service	• Limited scale of operations; they would require a larger scale to have a large enough risk/return on investment
MNOs	• Upgrading 5G networks is their core business • Can have an extra Use Case for their networks (to monetise the investment in 5G licenses): TO offers the opportunity to unlock new B2B revenue streams from 5G	• The TO UC may be too niche to make it attractive to them. • TO alone may not provide enough return for the connectivity service. And finding other UCs along highways, waterways, and cross-border areas is challenging.
Vessel owners	• Can indirectly benefit from quicker and cheaper deliveries of goods	• Would not have control over the cost reductions (it would be up to the transport company or shipper to pass the savings to the service price)
Traffic manager / road operator	• Interest in influencing the scaling up TO Use Cases to a national transport scenario (L3), in order to ensure it is deployed in a controlled and safe way and where road and traffic characteristics make it most sensible.	• Unlikely to be willing to take care of small-scale problems in selected areas (e.g. scenarios L1 & L2)

Table 5. Pros and cons from the perspective of main stakeholders on their incentives to act as **ecosystem orchestrator**

Entity	Pros	Cons	Related BMs in [1] (& scenarios)
Public authorities and agencies (regional or national)	• They can incentivise adoption by setting up public-private partnerships of local industrial companies and help establish connections with regional startups. • Public authorities can help reduce uncertainty by coordinating and (partially) funding projects (subsidies, tax incentives, procurement, etc.) • Governments can take up a key role (legal framework, type approval and standardisation of technical requirements, etc.) • Integration of the process into policy • Alignment with what happens in other countries	• They lack the domain expertise of industrial actors • View that it should be up to the market	• In **BM5⁶ (scenario L4)**, traffic managers/road authorities in each country deployed TO centres within their traffic control centres, and lease the space to the TO service provider
Supranational (EU) bodies	• Facilitates coordination and standardisation across countries and Member States	• Deployments should start at the local level, according to the pace set by the legislation of each member state.	

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⁶ The six preliminary business models in [1], referred to in this column as BM1-6, are summarised at the start of section 4 of this report.

Port authorities and industrial site owners	• They are a point of contact for actors that operate in and around the site. They can identify what stakeholders are best placed to deploy TO in their area. • They are a trusted partner to the companies in the site and the business partners in the area.	• They lack the domain expertise of companies more specialised in transport.	- In **BM1 (scenario L2)**, the port authority contributed to finance a private 5G network and to establish a JV that offered the TO service. - In **BM2 (scenario L2)**, the port's role was more limited, but still offering infrastructure and orchestrating.
Logistics players (e.g., freight forwarders, transport companies)	• Companies operating at a large scale (e.g. freight forwarders) can 'divide the pie' of costs and revenues among the regional logistics companies that make use of TO. • Local companies share a commercial interest to enable the technology in the region, thus may be interested to invest in infrastructure collaboratively.	• For local transport companies, viewing and orchestrating the sector 'top-down' is not their current way of doing business; and may not have the resources • Large companies and shippers/forwarders: willingness to be involved directly in a local ecosystem	- In **BM2 (scenario L2)**, it was assumed that a JV of local transport companies would take up the roles of TO centre management and TO service provision.
International TO service providers	• A clear business case may only be available to an actor that pools demand across countries and UCs. • Customers may enjoy getting E2E TO services from a single source that takes care of all elements (e.g., employee training, contracting 5G services, retrofitting vehicles, etc.)	• It may result in more market power and less economic competition	- In **BM6 (scenario L4)**, the orchestrator and main investment party is a large international digital platform.
MNOs	• They can co-invest in upgrading networks	• They lack the domain expertise of companies more specialised in transport. • Transport Use Cases are not their current focus	- In **BM4 (sc L3)**, network deployment is based on network sharing. - In **BMs 5 & 6 (scenario L4)**, a neutral host may deploy 5G infrastructure.

Table 6. **Value proposition expected** from teleoperated transport by stakeholder type

Entity type	Value proposition required (What (extra) incentives need to be offered? What makes TO interesting to them? What is missing? What other challenges need to be considered?)
National or regional governments	• Evidence of the societal benefit of implementing the technology • Robust evidence of the safety of the technology (minimal risk from allowing it) • Scale of deployment: in the long term, if TO is effectively combined with AD on highways to create extra road capacity without building more asphalt and enhance traffic safety, then there is a large societal interest.
Supranational (EU) bodies	• Evidence of the societal benefit of implementing the technology • Enough scale of deployment
Local governments	• More interest (or less conflict) in promoting specific economic benefits affecting a (relatively) small pool of companies or a single sector • Robust evidence of the safety of the technology (minimal risk from allowing it)
Port authorities	• Evidence of improved productivity for the port as a whole or for many of the companies operating in it • Being able to label itself as an innovative port, to attract more traffic compared to competitors • Efficiency of operations: higher uptime at night, weekends, etc.
Industrial site owners and port terminals	• Clarifying the business case and the economic opportunity for the longer term, both at the long haul level as well as for shunting operations in yards, where operations are already largely efficient. • They can increase safety and their operational efficiency through TO (see discussion above). • Including automated docking in the TO service for trucks can further increase efficiency in distribution centres with limited manoeuvring space. • Comfort and safety of personnel (terminals and logistics players) • Efficiency of operations: higher uptime at night, weekends, etc. • Cost efficiency from wages

Shippers	• The business case needs to be clarified • Simplify the business model from their perspective, with a clear role and revenue source
Transport companies	• Clarifying the business case for a traditional transport company at different geographical scales of operation • Efficiency of operations: higher uptime at night, weekends, etc. • Overcoming shortage of drivers: for the short-haul, especially for night shifts, as well as for the long-haul • Cost efficiency from wages, fuel efficiency, etc. • Comfort and safety of personnel: Attracting and retaining drivers/captains would be easier, due to the value of the flexibility of working from an office. • Economies of scale • Digitalisation of processes and data. Data from other parties to simplify and digitize processes. E2E digital transportation would create more efficient flows. TO means a digital trail, can enable digitalization • Clarify liability implications • Transport companies' clients want to pay for on-time deliveries. To deliver on that value, the main issue they face as transport companies in the BeNeLux is having an employee ready to dispatch quickly. TO can help by allowing a remote driver to always be available in terms of location (since all trucks are controlled from the same office), and being able to supervise multiple trucks at the same time
Truck OEMs	• Being able to distinctly market the offer of TO as an extra feature or additional service for their branded vehicles • Clear business model with a limited role and risk, and clear revenue source • Roadmap of TO that helps with the transition toward or approval of AVs • The ability to offer TO as a service (in the business models where the OEM is also a TO service provider) • Be able to scale it up to passenger transport Use Cases (since many OEMs are also car manufacturers). Such UCs may include bus rides, valet parking, etc. (see D3.2) • Business case of addressing market demand for more automated and safer trucks by allowing external 3rd party systems • Sharing data gathered by some apps relevant for logistics customers (e.g. to show efficiency increase

	of trucks) -> help gradually move to transport as a service offerings and offering extra value to customers
Start-up, dedicated TO service provider	• Easy plug-and-play if infrastructure is available
MNOs	• Suitable cost and revenue sharing models and liability sharing arrangements (e.g., to deploy and/or monetize network infrastructure) • Having a business case to sell the data they collect? • Positive extra business case of offering 5G for corridors, to earn back return on frequency licenses investment
Vessel owners	• The most important added value is that TO reduces the OPEX from captain wages. • Business model that shows a secure way to earn return from the potential investment

One **key takeaway** of the tables above is that each stakeholder, to a greater or lesser extent, stands to gain from the deployment of teleoperated transport Use Cases, but at the same time have reasons to be reluctant to take the initiative in kickstarting the risky investments by itself. As is often the case for technologies that rely on several heterogeneous and costly elements to function –here, TO hardware and software, 5G connectivity, or even site and road infrastructure, including smart traffic lights or cameras–, we encounter a chicken-egg investment problem where it is not evident how investments can start and may require some level of distributing the responsibilities.

To expand the brief examination in the table above, we will now elaborate on the incentives and priorities by the parties that are, by nature, best positioned to lead initial investments. Moreover, we discuss why such involvement would be justified in different scenarios.

In Scenario L1, a substantial part of the initial investments in rolling out equipment and infrastructure could come from the infrastructure owners like port terminals. They own the costly infrastructure and can increase the value offering of that infrastructure to its customers through teleoperation and extra services like automated docking technology. This can be achieved through higher efficiency, increased safety, and reduced personnel vacancies and costs.

- Personnel costs can be reduced by sharing remote operators who remotely operate less frequently used equipment across multiple port terminals. For example, reach stackers for full containers or giant forklifts that can lift two empty containers at once require specific operators who are not continuously working. This also helps cover some personnel shortages.

- Terminals can also increase safety with TO, specifically via the skid steer Use Case. Today, it is challenging for a terminal to operate with certain hazardous materials as they are required by law to rotate operators every two months. Additionally, scooping up non-hazardous bulk cargo in the ship's hold for the large mobile crane to lift is a dangerous activity. These are tasks that can be addressed through TO and are likely not easily automatable due to the complexity of the work.

- Regarding higher efficiency, there are potential benefits for various types of infrastructure.

  o For a port terminal, temporarily employing additional operators from a third party can be applied to manage peak workloads. For example, when unloading an extra-large container ship, port terminals can rely on teleoperation to move containers from the dock to the container stack as quickly as possible. This way they can add value to their customers (shipping companies). On large terminals, automated guided vehicles (AVGs) can be used for this purpose. However, this is not so easy for smaller terminals where the "seaside" simply merges with the "landside," requiring AVGs to drive in mixed traffic and follow more varied routes.

  o Automated truck docking can also lead to higher efficiency in distribution centres where limited manoeuvring space is available for trucks to dock at the scarce loading bays. Using these loading bays more efficiently by remotely taking over a vehicle and autonomously docking faster than a truck driver would offer an added value to the owner of that site.

Based on the premise that **infrastructure owners** are the best positioned party to undertake investments in small-scale scenarios like ports/private sites, since they can directly benefit from TO due to (a) higher efficiency from using their infrastructure, (b) higher safety and (c) reduced personnel costs, an analogy could be made for a road transport scenario within a country (or a small region like the BeNeLux), where infrastructure owners (i.e., road authorities

or governments) also benefit from TO due to (a) higher traffic efficiency and (b) safety (both societal/mandate goals), but in terms of (c) costs, they may not only not benefit but may actually need to do further investments in road infrastructure (e.g., adapting signs or lanes for TO trucks). However, a transport company that owns trucks, which is the infrastructure user, although it may not care enough about the (a) and (b) benefits from TO, they directly benefit from (c) cost reductions from personnel wages and also driver shortages. Therefore, co-investment could make sense here, for instance some kind of PPP. While a government may be reluctant to take initiative in investments and let the market dynamics play, market interest in scaling up to the road is less clear.

The discussion in the previous two paragraphs can be summarised in the table below:

Table 7. Stakeholders benefiting from TO in the different scenarios; potential investment kickstarters

Scenario	Type of entity	Efficiency benefits	Safety benefits	Other economic benefits
L1: port/distribution centre site	Infrastructure owners	+ (operational) efficiency	+ safety	+ cost reduction, labour shortages
L3/L4: road within one country (or contiguous small ones)	Infrastructure owners	+ (traffic) efficiency	+ safety	- cost reduction
	Infrastructure users			+ cost reduction, driver shortages

Governments believe that financial incentives for deployment should come from market dynamics, since the technology offers not only traffic safety but also economic benefits that will be captured by private entities. This is especially the case in those short-term scenarios that are most limited geographically, where the potential benefits of increasing safety in public roads will be much less relevant, and the predominant gains are monetary from reducing costs and from filling in job vacancies. Nevertheless, such industrial benefits can also have positive repercussions on the wider economy, from the impact on the health and competitiveness of the local industry. Therefore, TO could find sustainable funding from authorities for certain aspects where there can be expected to be a market failure reflected in under provision of logistics services. Public funding would be justified from the existence of these positive externalities from TO. Examples of such long-term focused public funding could include:

- Investing in the deployment or upgrading 5G infrastructure in less dense areas and along roads, in line with the intention to improve connectivity in certain rural areas or to promote the adoption of safety-enhancing V2X Use Cases.

- Investing in the deployment of TO centres to aid traffic management and to incentivize the use of TO as fallback to automation (e.g., to remove a vehicle stranded from the side of the road without much wait). This can be accompanied by legislative mandates that aim at encouraging the adoption of highly autonomous driving in a cautious manner.

- Investing in the testing of teleoperation and enabling Use Cases (such as automated docking) in small-scale areas where the size of the deployment would not guarantee a positive ROI for private parties but where the testing can be done in a controlled way and can pave the way towards larger deployments.

It is also relevant to note that road authorities and road operators could become customers of

TO services themselves. For instance, they currently use heavy vehicles to perform road works and to provide signalisation for such works. And the manual drivers of these vehicles are occasionally involved in traffic accidents as well (see, e.g., [9]).

For **MNOs**, a challenge would indeed be that the TO connectivity market is not big enough for MNOs. As mentioned before, 5G network investments are large and subject to the risk of not being recovered or not yielding a sufficient return on investment. Therefore, these investment challenges can act as a barrier to the deployment of TO in practice.

In smaller scenarios where private networks or coverage-on-demand were considered the most feasible business models (i.e., scenarios L1 and L2), MNOs and other network infrastructure/service providers see themselves taking their traditional approach to investing, in which they react to demand: when a customer requests higher network capacity at a site and the revenue prospects are optimistic, the MNO builds it. However, while normally MNOs make the investments upfront, they see teleoperated transport as a far away and uncertain business case for them, with an unclear ROI for the sizeable and high-risk investments it requires.

Moreover, deployments of 5G infrastructure along highways or canals are not their first choice when they look at possibilities to densify their networks in underserved areas; first they would look at cities or rural areas, where there are more potential customers. There are more consumers in big cities and the connectivity UCs in highways are not seen as attractive, at the moment. Providing the QoS of TO is also more costly.

Nevertheless, there may be a positive business case and an attractive role for them in teleoperated Use Cases, with the right business models. For instance, the consulted experts mentioned that MNOs would likely be open to partner with a big investor, such as a government or logistics company, to share the burden of the required investments.

Another way to clarify the business case to MNOs is by indirectly by convincing the direct beneficiaries of TO (transport companies/logistics players) in order to increase the demand for teleoperation services. If the potential cost-efficiency gains are large enough, these parties benefiting directly from TO would be willing to pay premiums for enhanced connectivity, provided that they adopt business models with satisfactory revenue and responsibility sharing agreements. The business models need to analyse the associated costs and expected revenue flows, and clarify and communicate the potential value proposition of 5G-Blueprint's Use Cases and scenarios from the connectivity provision perspective.

Regarding **logistics service providers**, one challenge is that they are not yet convinced about the business case. The need to clarify in a quantitative manner what they stand to gain from teleoperation was mentioned several times during our interviews. One direct potential benefit from TO that they did consider more evident was the impact on driver shortages, which is a current pain point: they struggle to find captains for inland ships/barges, drivers for long-haul trucking, terminal workers, etc. Some logistics service providers are already trying to be innovative to overcome this challenge by starting their own driver schools. They could do something similar for remote operation. The consulted experts agree that TO would make the jobs more attractive and stable, and indirectly, by offering a better work-life balance, help filling vacancies to meet their future job demands, especially for the night shifts.

Another aspect that was discussed with experts from the **logistics industry** was the impact of TO on safety. In general, TO can enhance safety for road and waterway transport as well as for people working in terminal operations or distribution hubs. For the latter, the fact that the employee working with heavy goods can be located far from a dangerous spot can limit work injuries. For waterways, TO also increases safety thanks to the higher information that

the captain has access to from cameras, sensors, AI tools, etc. This can lead to safer driving and reduced stress levels, which in turn can reduce human error. The potential effect on long-haul truck driving from more regulated driving shifts and a less stressful job from a remote office is also something that is seen positively. In addition, TO is also seen as a technology that can add value in those cases where automation falls short (e.g., dense traffic, uncommon tasks where human judgement is still valuable, etc.). On the other hand, the idea of remote driving also arose some concerns in terms of safety. It is important to note that currently, if an accident happens on the road, a manual driver can check if someone is hurt and can provide first aid to other road users immediately, without having to wait for an ambulance to arrive.

In general, another factor that must be considered is the sense of urgency to adopt teleoperated transport, because such urgency would motivate a certain stakeholder to be the initial investor (or kickstarter). In this sense, logistics players feel the most pressing need to adopt teleoperation to overcome the current problem of job vacancies, but would also feel it in the near future in order to react to a competitor suddenly adopting remote operation and reducing the costs of its own transport or handling services.

Port authorities may also play a role as an investment kickstarter or orchestrator for early deployments in or around ports, such as in scenarios L1, L2 or W2. Port authorities are a point of contact for many actors that operate in and around the port. They can identify what stakeholders are best placed to deploy TO in their area, and in certain situations may orchestrate and even kickstart deployments. The role of the port authority, besides managing their site, issuing concessions to companies that operate within it, etc. is to be a community builder and try to increase the size of the business done by the port at large. In addition, from its interest in increasing the efficiency of operations within its site, a port authority can act as a trusted partner to the different port stakeholders, finance infrastructure investments in its site, or offer existing network or real estate infrastructure that can be used for TO use cases.

Similarly, **large industrial companies**, a large company like ArcelorMittal, is a, or for, their partners, including logistics companies and freight forwarders.

Lastly, **truck manufacturers** may also have a role to play to enable the deployment of teleoperated transport. It was also argued that investments in incorporating the TO technology in vehicles should come from manufacturers, for the following reasons: first, it is costly to retrofit vehicles with TO technology; second, they can more easily incorporate the expertise into the process of assembling the vehicles; and last, if they invest in TO tech, they can also benefit from creating a new market and positioning themselves as sales leaders.

To recap, starting deployments of teleoperated transport presents a ***chicken-egg investment problem*** where it is not evident which entities will be responsible or willing to undertake the necessary investments. A similar challenge would be present when scaling up beyond scenario L1, where additional, larger investments will be needed (e.g. in 5G infrastructure along roads and canals). While many stakeholders would benefit from teleoperated transport, they remain reluctant to take up the initial investments or orchestrate the new business ecosystem. The business models in the following section will have to take into account the present discussion in order to come up with models that are more realistic to implement, by considering how costs and revenues may be shared among the different parties that can derive value from the studied Use Cases.

4   REFINED AND VALIDATED BUSINESS MODELS

Deliverable D3.2 [2] described 6 business models (BMs), two for each of the three deployment scenarios that had been defined at that stage.

For the scenario equivalent to L2, where TO services would be offered within a port or industrial area with a high frequency of transport flows and from the site to local distribution centres, the following two models were discussed:

- BM1, which relied on a more locally orchestrated deployment, with a private 5G network financed by a port authority. In addition, the port would also help finance the deployment of a TO centre, in collaboration with local logistics companies. These logistics companies would form a joint venture to offer the TO service within the area.

- BM2, which relied on attracting deployment of 5G and TO services by providers with a broader (inter)national focus. With coverage on-demand, an MNO upgrades the capacity of its public network in the port or industrial site. The TO service is done by an independent service provider. Compared to the previous model, here the port/industrial site owner plays more the role of orchestrating rather than financing.

The two business models for the scenario covering a major road and/or water transport axes within a country, equivalent to L3 for the road and L4 for waterway transport with semi-autonomous barges, were the following:

- In BM3, port authorities and TO service providers lease customised network slices as-a-service (NSaaS) from MNOs, who in turn acquire virtual network resources via a slice broker. TO service provision is provided by a specialised service provider that offers an integrated service and deploys its own TO centre.

- In BM4, 5G network deployment is based on network sharing; MNOs densify their networks along waterways by relying on active network sharing to substantially reduce costs by jointly investing in masts, antennas and other RAN elements. Regarding the TO service, the provider would be a large transport company with a wide geographical presence and substantial volume of transports. This company would retrain their current captains (or, by extension, drivers) to be licensed to remotely operate vehicles.

For the scenario equivalent to L4, consisting of goods transport via roads across national borders, we assumed a deployment of TO as a support to highly autonomous trucks in complex local roads and adverse climatic conditions. These models focused on commercial and organisational arrangements that were considered to be realistic only in a wider scale of operations.

- In BM5, a vehicle manufacturer integrates the role of TO service provider, offering it as an added value service. In this model, the TO centre would be co-located within the premises of a traffic manager, who would lease space for the TO stations. The OEM may even own its own fleet of trucks, implying that the business model of logistics service providers would change to resemble that of a broker.

- In BM6, the TO service provider is a large international match-making platform that owns TO centres across the EU. It would not, however, own the vehicles. The customers of the platform (e.g., transportation companies) would pay a subscription to access the service, complemented with additional optional fees for a priority allocation of a teleoperator in periods of high demand (i.e., premium fees to reduce waiting times).

The following tables provide a simple recap of the of the 6 preliminary business models, comparing them across the four main variables we considered, namely who would take, in

each case, the roles of (i) deploying 5G networks, (ii) providing the connectivity service, (iii) providing the TO service, and (iv) deploying the remote control centre.

Table 8. Summary of preliminary business models to validate.

BM #	Scenario	5G network deployment	5G connectivity service provision	TO service	TO centre deployment
BM1	L2	Private network by port/site owner	Dedicated (micro) operator	JV of logistics companies	JV with financing by site owner
BM2	L2	Coverage on-demand	MNO	Specialised SP	SP with orchestrating by site owner
BM3	L3	Network slices as-a-service via slice broker	Different MNOs	Dedicated TO SP (incl. regional companies)	
BM4	L3	Network sharing among MNOs	MNOs/ specialised transport B2B MVNO	Large transport company	
BM5	L4	Neutral host	M(V)NO	Vehicle OEM	Traffic manager/authority
BM6	L4	Neutral host	M(V)NO	Large international match-making platform (e.g., mobility app)	

The structured validation interviews sought to explore whether these models are considered feasible and sensible, based on the state-of-the-art of the technology and the current level of knowledge at this stage of the project. Such feasibility was explored at the technical, financial and operational level. Interviewees were also encouraged to explain what factors would improve the feasibility of the preliminary business models and to suggest any ideas for other possible business models. In addition, we asked for each stakeholder's preference among the different options. Lastly, we endeavoured on the possible challenges to realise each of the following model and the potential implications of each option and the Use Cases in the different scenarios.

Sections 4.1 to 4.4 below present the outcomes of the validation interviews and present a series of validated business model options for the different deployment scenarios defined in section 3.1. The discussions avoid redundancy with the lengthy descriptions presented in our preliminary analysis in [1]. Therefore, they focus on the new input and findings instead of presenting again the entire original discussion and descriptions of preliminary business models. Notwithstanding this, the summary tables provide a comprehensive, albeit brief, view of all the feasible business models for each scenario.

Before presenting the business models for the respective scenarios, we summarise in the lines below some general aspects that are common across the scenarios, and that have been validated from the previous analysis in [1]. These refer to pricing arrangements, which we describe briefly here in order to avoid redundancy in the following sections.

The TO service provider monetizes the service by either receiving a fee from the end customers of the TO service (i.e., transport companies, site owners, etc.), or by internalising the cost benefits of teleoperation. This will depend on the business model and which type of entity takes up the role of TO service provider. For example, in the case a transport company

becomes the TO service provider, the most likely payment scheme would be incorporating the TO service in the traditional transport service or contract. In those business models where an external entity, such as a dedicated start-up or joint venture, provides the end-to-end TO service, the most realistic payment schemes would be (i) spot pricing, or 'pay-per-use' for each trip, if the service is requested on-demand for less predictable or recurrent cases, or (ii) a recurring subscription, with possible fee layers based on the volume of operations (e.g., in terms of number of trips or hours).

TO technology providers may license their technology to a different entity that takes care of training employees, deploying and managing TO centres, contracting connectivity services, and providing the TO service.

The TO service provider or vehicle owner would pay connectivity providers for their 5G service via a recurrent subscription. This subscription may have a fixed fee or be two-tiered, with the first tier being volume-based and the second incorporating a premium for guaranteed bandwidth or priority in certain instances.

Regarding the deployment of 5G network infrastructure, the business models differ in the degree to which the upfront investments are shared among different parties.

Saakel et al. [4] and 5G-ROUTES [5] discuss business models to monetize 5G V2X deployments and services. In the 5G CARMEN project, co-financing by the European Commission is considered a potential key element to make 5G V2X deployments possible, especially where the density of V2X subscribers is low [4]. In non-urban areas with low density of inhabitants, revenues to 5G services would rely on these V2X customers, as we assume to be the case for TO services in industrial areas. In contrast, in densely populated areas with more than 50,000 inhabitants, 5G subscribers of non-V2X UCs that would share the same 5G infrastructure become an important source of revenue. These studies also found that the monetisation of the 5G network infrastructure deployments is highly dependent on the availability of alternative services enabled by connectivity, such as in-vehicle infotainment.

Similarly, we consider the option of co-financing, in the form of the role to 'kickstart' investments, in several business models, and assume that finding alternative revenue sources that share the same 5G infrastructure in the defined timelines remains challenging and uncertain.

4.1 Scenario L1: Terminal teleoperation

Scenario L1 – 'Terminal Teleoperation' involves teleoperation Use Cases on private premises like port terminals or in-land distribution centres. It involves the remote operation of vehicles or equipment that are strictly used in private sites, such as RTG cranes, terminal tractors or skid steers.

Private grounds offer a compelling starting point for the testing of teleoperation Use Cases. This entails evaluating the technology's efficacy and its potential to augment productivity, all while mitigating part of the safety concerns from deploying the technology in more complex public areas. Implementing a proof of concept in private locations is thus seen as a sensible initial step. Once the viability is proven, the scope can be broadened, for example by including operations like 'shuttle runs'.

In this scenario L1, site owners at port sites stand to gain in the form of safety enhancements and expedited ship (un)loading processes. This is especially interesting since container shipping companies value swift unloading times for their vessels. An expeditious handling of ship operations translates to reduced costs for both port infrastructure and shippers' inventory

management. By economizing on the time required for ship (un)loading, ports can optimize their infrastructure utilization, accommodating a greater volume of port calls per berth. This, in turn, translates into cost savings and efficiency improvements. Additionally, for shippers, an accelerated unloading process cuts inventory holding costs. In addition, improvements in port efficiency can bolster a region's trade competitiveness, further underscoring the far-reaching implications of streamlined (un)loading operations.

Scenario L1 was considered feasible in the short term in the discussion of section 3.2. According to interviewees, there exist different areas in Belgium and the Netherlands where short-haul teleoperation could be implemented within confined perimeters, involving Use Cases from the operation of cranes to the transportation of cargo from buffer parking zones to terminals through segregated traffic routes. Illustratively, such locations exist in the Port of Antwerp-Bruges (in Antwerp and Zeebrugge), in the North Sea Port (in Terneuzen and Vlissingen), in Moerdijk, etc.

In fact, remote operation Use Cases area already being implemented in the BeNeLux, although at a small scale. For instance, within its terminal in the North Sea Port, Kloosterboer (Lineage) has already made significant investments to implement teleoperation of RTG cranes, reach stackers, and forklifts. It is noteworthy that the port authority itself was not directly implicated in this endeavour.

The case of Kloosterboer is an illustrative instance of business model where a terminal undertakes the deployment of teleoperation itself and for its exclusive use. Therefore, within this context, it appears viable for terminals to adopt TO solely for their internal operations. In such environments, time is a critical resource, with only a limited window available for each container-handling operation. The primary merit of TO lies in enabling the execution of a higher volume of tasks within the same time frame through avoiding idle times. Specifically, remote operators could supervise and, when necessary, control numerous cranes, skid steers and autonomous directed (AD) tug masters. For tug masters, TO might be employed primarily for the purpose of coupling and decoupling trailers.

In this business model, the responsibility for investment in the TO infrastructure and equipment/vehicles would be assumed directly by the terminal. In the case of Kloosterboer's terminal, they adopted the use of TO for cranes in tandem with autonomous Terberg terminal tractors on restricted roadways. Because of the small scale, investments in 5G infrastructure were not needed. Altogether, it resulted in a simplified business model, since they did not need to partner with the port owner nor enter into a JV; collaboration was confined to Terberg and the autonomous driving software (AD SW) layer provider.

This business model, together with an initial deployment at a small scale, without the need to upgrade wireless networks, was also identified as a promising one for other companies. For instance, a transport company like Roosens sees business opportunities in training manual drivers to become remote operators.

It is important to emphasize that the fact that TO is adopted for internal operations does not imply that its use is limited to a single location. For instance, consider the case of Verbrugge, which operates two terminals in Vlissingen and one in Terneuzen; usually, the containers that arrive are handled – picked up by terminal tractors and filled or discharged – in their own warehouses in the same terminal. Similarly, a transport company like Roosens has a small fleet of reach stackers stationed at two separate sites. A single company adopting TO for its own operations could allocate the remote operators according to the operational needs of each of their terminals.

This approach would enhance the benefits of TO by allocating an available remote operator to idle vehicles or cranes across diverse sites. An alternative approach, to leverage further the benefits of remote operation, would be that the different companies in the same region join forces in a joint venture to collectively invest in providing teleoperation for their own internal operations. In contrast to the examples above, in larger ports like the Port of Antwerp-Bruges or the Port of Rotterdam, where there are huge warehouses, multiple companies may share a site.

Another potential initial setting where to deploy teleoperation and automated docking Use Cases are private industrial sites such as those from Toyota. Remote operation could be used to support two different types of transport services. First, for common internal handling operations that occur within every warehouse and yard facility. Second, for shunting, i.e. moving goods or trailers for short distances, e.g. from a parking area to the warehouse or from the arrival site to the dock and then to the yard. In the first case, the business model option in which the site owner deploys TO itself for its own operations would make sense in a site like Toyota's, since the automaker generally owns the specific equipment/vehicles, such as forklifts, reach-stackers, etc. In the second case, a specialised company could provide the TO service; using the same example of Toyota's site, such shunting 'transports' are operated by an external logistics provider, but using Toyota's Yard Management System.

Yet another Use Case identified in this scenario L1 involves the remote operation of passenger cars from unloading area at the dock to and within a terminal site/yard. The business model options align with those previously discussed:

- Having a proprietary TO centre. The terminal owner can have its own remote centre within their premises. This allows them to deliver the TO service for their internal operations. In this model, the terminal maintains control over the entire TO process.

- Shared remote centre. Alternatively, there is the prospect of inter-terminal collaboration. Terminals can jointly invest in the creation of a remote centre even though the TO service is provided separately by each terminal and used to their own, respective operations. In practice, this implies that remote drivers associated with the said terminal exclusively access and manage cars contracted to undergo movement by that terminal.

- Shared private network. Similarly, different terminals can partner among them and with the port authority to establish a dedicated private 5G network that ensures comprehensive coverage throughout the entire port area.

- Relying on current 4G networks for small scale deployments. Alternatively, smaller-scale implementations might depend on the existing 4G network infrastructure to support their teleoperation Use Cases.

Notwithstanding the discussion above, there are a series of business-related challenges to deploy the mentioned business models in this scenario L1:

- **Connectivity needs**. Using current 4G networks was considered sufficient to deploy teleoperation in small sites with a relatively small number of vehicles or equipment. Upgrading wireless networks to deploy 5G infrastructure and technology would pose a significant challenge, but may be necessary if there are many (types of) vehicles moving around a site. Beside scale, the need for denser connectivity would depend on each site. For instance, in the port of Antwerp one can often find towering walls of containers that can block the signal from a given antenna. In contrast, in the example site of Kloosterboer, the current coverage near the water was sufficient.

- **Access to technology.** Companies that lease the cranes from an external entity, instead of owning them, as is the case in Verbrugge terminals, may not be allowed

by the owner to retrofit them with TO technology.

- **Diverse regulatory landscape**. Different terminals have different driving regulations, and common remote operators would need to be aware of and trained for it. For instance, one terminal of Verbrugge has similar rules to those in public roads with the exception that the terminal traffic has priority (e.g., a terminal tractor has right of way even when coming from the left).

Based on the discussion above, we can map the following discrete business model options for each type of variable.

Table 9. Summary of validated business model options for Scenario L1.

	Business model options for scenario L1: Small scale deployment at private sites			
	Option 1	**Option 2**	**Option 3**	**Option 4**
Concept	An owner/operator of a private site, such as port terminals or distribution centres, invests in providing teleoperation at a small scale for its internal operations (maybe across sites)	A private site owner/operator, such as a port terminal or a distribution centre, invests in enabling TO at a small scale for the operations in its site, relying on a third party for the remote operation service	Multiple private sites in the same area invest in providing teleoperation for their own internal operations, with a private network	Multiple private sites in the same area invest in providing teleoperation for their own internal operations, with coverage on demand
5G network deployment	Mostly relying on current LTE and possibly fibre upgrades		Private network covering the entire port or a few terminals (coordinated investment by the involved entities, see cost sharing agreements below)	Coverage on demand requested by each site owner/operator; although they can join forces for the request to the MNO
5G connectivity service provision	Current connectivity provider (MNO)		MNO deploying the private network or Dedicated (micro) operator	Current connectivity provider (MNO), at a premium fee
TO centre deployment	The site owner or operator (e.g., the terminal) takes care of the investment of setting up a remote control 'office' in their own premises.		The site owners or operators partner in a JV to set up a remote control 'office' in their area; terminals may rent office space from a port authority at preferential rates	
TO service	The site owner or operator also takes care of the TO operations and the responsibility, possibly subcontracting the training of their current employees.	The site owner relies on an external logistics partner to provide the remote operations and thus also to be responsible for the liability and employee training.	The site owners or operators partner in a JV to offer TO as a service to all the partner companies; charging will be done per usage (e.g., based on the time used) although in practice each remote operator may be assigned to a specific site and only exceptionally, during spikes of demand, assist another site; employee training taken care by the JV.	
Investment in TO tech for vehicles	The site owner also invests in cranes, skid steers, tug masters, etc., whether by buying or	The site owner invests in the TO tech for the vehicles and equipment it operates; the retrofitting of third-	Each site owner invests in its own cranes, skid steers, tug masters, etc., whether by buying or leasing them, and contract the retrofitting of TO technology	

	leasing them, and contract the retrofitting of TO technology	party vehicles operating at the site would be done by the third party.		
Relevant cost and revenue sharing arrangements	Site operators internalise costs and revenues although they may share the remote operator across multiple sites of their own	If the logistics partner providing the TO service also uses it for its own tasks at the site, a discount (part of its cost-efficiency gains) on the service price can be agreed upon until the investment in the TO centre by the site owner is paid back.	Terminals split the upfront costs of the PN; the port authority may contribute a small share, together with regional governments. MNOs are unlikely to cover a big part of the initial investments for such a risky Use Case.	The MNO may take care of a larger part of the upfront CAPEX to upgrade networks, and establish a contractual obligation from the JV to pay a premium connectivity subscription for TO for a certain minimum number of years.
Additional investments	Setting up of cameras for the EF of container ID recognition (i.e., to monitor the location of containers and the arrival of trucks at the site, to check the damage on a container, etc.). Deployment by the EF provider at the request of either: (i) site owners or terminal operators, or (ii) a TO service provider, probably for a setup fee before entering into a subscription to the service itself.			
Role of an orchestrator	A port authority can support deployment by applying for exemptions to allow driverless or remote driving in the port for research and testing purposes.			
Main value proposition	Addressing job shortages and increased cost efficiency (to site owners/operators)	Addressing job shortages and increased cost efficiency; simpler deployment: no need to build the teleoperation competences in-house	Addressing job shortages and cost efficiency (to site owners/operators); competitiveness of the local industry (regional governments); appearing as innovative port and leveraging the PN for other Use Cases (port authority)	Addressing job shortages and cost efficiency (to site owners/operators); competitiveness of the local industry (regional governments); appearing as innovative port (port authority).

Regarding additional revenue sharing arrangements, a potential method of revenue distribution and collaboration include data sharing among logistics companies, ports, original equipment manufacturers, and MNOs. The data collected by connected vehicles holds value, potentially leading to its commercialization. Furthermore, part of the revenue may need to be dedicated to compensate insurance companies, via increased premiums, due to higher perceived risks of remote operation. Lastly In the case of remote transport of passenger cars as cargo, companies like ICO in ZeeBrugge could employ a kind of discriminatory pricing approach between vehicle brands to differentiate between OEMs that have enabled TO capabilities for their cars and those who have not. A percentage of the benefits derived from quicker handling of vehicles, facilitated by TO, could be shared with the TO-enabled brands. This might even be presented as a premium charge to incentivize the adoption of TO technology. However, this incentive-driven approach would likely require collaboration across multiple ports rather than a single one.

Business model options 1 and 2 are expected to be the most immediately feasible at the operational level, since they entail no additional dependencies on other partners: the terminal operator would invest in deploying its own equipment and TO centre for its internal operations. The lower scale and range of operations is expected to allow TO UCs to be adopted without the need to invest substantially in the densification of wireless networks. In the case that 5G network infrastructure needs to be deployed at the specific site, the business models involving a joint venture of site owners would be more feasible at the financial level from the sharing of costs and the possibility to enjoy economies of scale from efficiently allocating remote operators to more vehicles and reusing infrastructure.

4.2 Scenarios L2 & W2: Short-distance Shuttle Runs

Scenario L2 involves a geographically limited area with numerous short-distance transports of containers between ports or industrial zones and nearby distribution centres or warehouses. Feasible Use Cases include direct teleoperation of trucks and small truck platoons for such shuttle trips on local public roads. However, safety concerns arise due to dense traffic in public roads and the presence of vulnerable road users.

Similarly, scenario W2 involves the remote operation of vessels for the very short-haul, more specifically to transport goods in and around large port environments. For instance, short trips involving the moving containers from one bank to the other. To avoid redundancy, the present discussion will focus on road transport, but the business model options in Table 10 can be considered to be valid for Scenario W2 as well; hence, like in the preliminary business model discussion, we limit the business model discussion for this 'second' scenario in terms of geographical scope to this section. The business model options behind scenarios L2 and W2 can be considered analogous except for the specific characteristics inherent to the respective transport modes.

In both land and waterway scenarios, potential network blockages may require substantial upgrades for reliable connectivity. This technical challenge presents in turn a business challenge, since the ROI of such investments remains uncertain. Remote operation in this larger area will require a guarantee that every corner is covered, something that 4G networks are currently struggling to offer; terminal owners still have some blind spots in their sites.

Using TO in short frequent transports can provide an opportunity to increase the timely availability of containers at their destination. Unloading a ship as soon as possible is a concern of both port terminals and transport companies. For instance, transport companies like Roosens use their own hubs to store containers because there is not much place in the busy large ports of Belgium and the Netherlands; if the container stays longer than 24h in the port

awaiting to be transported, the transport company must pay. A quicker dispatch of containers would be achieved by increasing the availability of trucks for such transports: currently, local transport companies, with fleets of a few dozen trucks, often struggle to have a manual driver available at a specific point in time, especially for night shifts, but remote transport would allow each driver to supervise more than one vehicle during the same journey, by taking over a different truck when another is idle. In addition, truck platooning would fraction driver needs by the size of the platoon (which is expected to be realistic for small groups of 2 or 3 trucks).

Interesting locations for L2 would be within the Port of Antwerp and from the port to an outside location of a client a few kilometres away. Another example would be regular short transports between Kloosterboer and the locations of McCain and MSP Onions around Vlissingen.

Assuming that actual deployments of L2 scale up from an initial deployment in scenario L1 and thus incorporate both L1 and L2 –i.e., combining teleoperation of (semi-autonomous) cranes, reach stackers and terminal tractors as well as trucks for short transports–, the benefits of TO Use Cases would accrue to the entire logistics supply chain within the area: the port would gain safety and shorter (un)loading times for vessels, container shipping companies would also benefit from having their ships ready earlier, terminals would process containers, transport companies would be quicker to dispatch containers and reduce the costs of storing them, and warehouse owners would receive their cargo sooner and also process it more efficiently if they also adopt TO in their sites.

However, as discussed in section 3.3, it is unclear which party or parties would take care of the responsibility of kickstarting investments to scale up to this scenario. To incentivise a transport company to adopt teleoperation, or to incentivise a TO service provider to come deploy a service in a certain small area, we need to show a sustainable business logic behind the Use Cases in scenario L2 and feasible business models for all the parties involved.

Scaling up towards scenario L2 presents a series of technical and business challenges:

- One challenge to scaling up towards scenario L2 is the fact that the trucks would drive through potentially dense public roads, with higher speeds, substantial mixed traffic and more presence of vulnerable road users.

- Compared to Scenario L1, where the adoption of TO for internal operations within terminals is considered feasible, Scenario L2 entails more complex business dynamics, involving multiple stakeholders and destinations. This complexity suggests that a third-party service provider (SP) could be a more apt solution. Therefore, in this scenario, terminals would be hesitant to undertake the role of a teleoperation service provider for operations extending beyond their internal scope. In addition, the wider adoption of TO may diminish the incentive for terminals to differentiate themselves as pioneers in innovation.

- Moreover, the inclusion of various parties and destinations amplifies the intricacies of managing risks and insurance. A more formal and structured arrangement, like a JV, would be better suited to deal with this complexity than multilateral agreements.

- Lastly, another challenge surfaces when potential parties have differing focal points, such as varying transport modes. When a terminal's focus remains on its own operations, as in the example of the previous scenario, there is less of a need for an external SP.

The table below presents, in a summarised way, the discrete business model options of scenario L2. A more elaborate discussion of each type of option and variable is presented afterwards, mainly differentiating between connectivity and teleoperation aspects.

It is important to note that the individual business model options for each variable (i.e. the rows in the tables with the business models) are theoretically independent; options 1-3 are suggested combinations that would result in feasible business models, but other combinations are theoretically possible. For instance, a combination of an in-house TO centre deployment (e.g., by a JV of transport companies or site owners) and a 5G coverage-on-demand model was the business model with the lowest costs across the examples of the business case analysis in section 5.2.

Table 10. Summary of validated business model options for Scenario L2.

	Business model options for scenario L2: short-distance transports around logistics hubs		
	Option 1	**Option 2**	**Option 3**
Concept	Private network with co-investment from port and TO platform from logistics partners	Private network with co-investment from city and TO platform from local transport firms.	Public MNO network coverage on-demand and independent TO provider
5G network deployment	Private network from MNO or other supplier, with co-investment from a port	Private network from MNO or other supplier, with co-investment from a city	Coverage on demand
5G connectivity service provision	MNO or 'micro-operator'	MNO or 'micro-operator'	MNO
TO centre deployment	JV of logistics supply chain actors (e.g., origin and destination site owners)	JV of local road transport or shipping companies	Specialised service provider (e.g., TO start-up)
TO service	JV of logistics supply chain actors; cost-efficiency gains can be passed to customers as lower transport prices	JV that uses remote drivers employed by each transport company (occasionally shared for individual peaks of demand)	Specialised TO service provider charging at a usage or service basis
Investment in TO tech for vehicles	In the beginning, retrofitting contracted by the TO service provider (due to the small amount of trucks that will be used in a given pioneering area). In the future, when homologation is possible, the same party would buy enabled trucks from OEMs.		
Relevant cost and revenue sharing arrangements	Profit sharing according to shares in the JV	Sharing according to shares; procedure to credit for the teleoperation time used, and settle such credits, among the JV partners	Share of future profits or price premium if the MNO covers part of the network upgrade costs (also possible in options 1 and 2)
Additional investments	Investing in cameras and systems to enable auto docking and container ID recognition		
Role of an orchestrator	The local authority (option 1) or port (option 2) can set up the public-private partnerships for investing in the 5G network; they can also help establish connections between local industrial companies and regional startups looking to offer TO services (option 3).		
Main value proposition	More tailored connectivity QoS from a PN. Quicker deployment if the parties of the JV see the business case of TO in their area. The port benefits from quicker turnover of containers.	More tailored connectivity QoS from a PN. Quicker deployment if the parties of the JV see the business case of TO in their area.	CoD offers a more flexible implementation, and less complexity from handovers. A dedicated TO SP can use teleoperators more efficiently from a larger pool of vehicles to monitor; it is easier to scale up

4.2.1 Connectivity business model aspects for scenario L2

Regarding the connectivity side, the preliminary business models suggested the following two options: (1) a private network (PN) with a dedicated (micro) operator, and (2) coverage on-demand (COD) by a national public network MNO. Expert consultations validated that both business model options for 5G network deployment were potentially feasible, from a 'blueprint' perspective. And both models can theoretically provide the required QoS for teleoperated transport. Nevertheless, expert feedback allowed us to improve our understanding about the suitability of each model for different settings.

Coverage-on-demand (COD), where an MNO adds capacity on request, would be quicker to implement, in practice, than convincing a port or a city and building a private network. In addition, in a first stage where the business case of TO is still seen as somewhat uncertain, a simpler implementation like COD is seen as more feasible. Furthermore, at the financial level, COD is generally cheaper to deploy.

Even though both PNs and COD are feasible at the technical level, the surveyed MNOs would prefer the COD option over building a real PN, for the following reasons. First, private networks add complexity at the technical level, and handovers between public and private networks would also be a source of additional complexity. Second, managing and maintaining a PN requires knowledge; and it is not clear on whom the responsibility of providing such maintenance would fall (e.g., in case of outages), since an MNO would not be obliged to do so, although some MNOs offer this as a service. Third, if PNs are not upgraded at the same pace as public networks, this can create islands (i.e., isolated areas) of old generation networks. Lastly, even though the actual model of deployment will depend on the customer's demands, MNOs argue that it should be left to them to figure out what type of deployment would be ideal in each area.

Private networks make sense in areas that are more confined but where there is a large scale of operations. Furthermore, from a site owner, and thus a client's, perspective, private networks are the most logical approach, since they offer the most tailored solution to the port/terminal situation. Any SLAs will be negotiated directly between the port/site owner and the MNO, so they would be clear and tailored to the QoS required by the Use Cases at the site. In addition, the financial feasibility of a PN will depend on the scale of the area and the customer: from an MNO perspective, a larger site/customer provides less risk in terms of default, as it will provide a larger ROI for the customer.

However, terminals and site owners are seen as unlikely to invest in their own private 5G network. An alternative for the deployment of a private network would involve co-investment with a municipal authority, for certain ports near urban areas. Local authorities may have an interest in enabling logistics UCs that improve the economic competitiveness of the area, and they are often involved in research projects that test innovative technologies.

Another alternative is that the port authority co-invests in a network for the entire port; in that case, the costs can be split across the terminals, and the masts can be reused if their coverage is larger than a single terminal. The first preliminary business model (BM1) contemplated the possibility of a port authority acting as the kickstarter of investments in order to support initial deployments of teleoperated transport in its area. However, the willingness of a port to play this role will depend on the type of port and, more specifically, on the following characteristics:

- Focus of the port. NSP would likely not lead the investments in TO. Especially for things on the road, since they are more focused on nautical than trucking aspects.

- Size of the site owner. Some ports with more financial capacity will invest, also if they experience more traffic jams. In Antwerp, we not only have a port but a big chemical hub, which is the largest in the EU, with large container traffic (more than 20,000 ships seagoing ships per year). There are over one thousand companies in the Port, which stretches many kilometres north of Antwerp, and includes some public roads. In the Port area, more than 160 thousand people are employed. There are not only terminals but also industrial companies, so there are many opportunities for MNOs in terms of traffic and B2B Use Cases. MNOs have already invested in B2B 5G in the port. A private network does not make as much sense in Antwerp. MNOs provide upgrades to the public network on their own, the operations and terminals companies are more engaged in negotiating the upgrades than the port as of today.
- Other characteristics of the site. In Zeebrugge, it is more complex but more compact, compared to Antwerp. The port had invested in a private 5G network with Citymesh for their short-term needs, giving some concessions for slices, because they have common Use Cases using 5G and because they couldn't get fibre to certain locations. Logistics UCs were not the reason to use 5G, however. They chose Citymesh because at that time it had access to 5G frequency bands for which national MNOs didn't. In Antwerp, the port authority is unlikely to provide port-wide coverage if it's not a port-wide interest: we have many UCs, and many companies that can use connectivity for innovation, so it is delicate to decide to invest in/prioritise a single UC. The Port does make its own investments in private networks, although for fibre (they don't share that fibre with other actors in the port); but a 5G PN may be too costly. UCs of the port itself include surveillance with cameras for security reasons.
- Current coverage issues. In Zeebrugge, there is less density of traffic, since it is a smaller port. In Antwerp, there is no big demand by terminals and companies to improve the network. But 5G may be useful in some terminals that are km long and may have trouble getting signal everywhere. For vehicles, 5G to avoid the buildings blocking the signal.
- Who invests/owns the vehicles/equipment and thus directly benefits from TO. The investment or leasing in cranes is often done by the terminal itself (in NSP, ...). NSP: Nevertheless, potential co-investment is always part of the commercial discussion when investing in things that can bring more efficiency in logistics processes and more traffic in terms of goods being handled, which indirectly benefits the port since it results in more income for the port. Lineage installed optic fibre cables for the cranes in its own terminal; it required extra investment, but they needed the fibre installation anyway.
- Philosophy and business culture/strategy of the port. The Port of Antwerp-Brugges, for instance, does not see itself as a service provider, but rather wants to let the market play. Although they want to be a driver of innovation, they would not deploy TO by themselves but in consortium with SPs, although they could play the role of ecosystem orchestrator. The Port of Rotterdam prefers not to engage or interfere in building networks in the port (for UCs of the companies in it). However, they can facilitate the ecosystem, and they may have port-wide needs for 5G for other UCs.

In terms of cost and revenue sharing agreements, one option involves an agreement between the MNO and the client (e.g., a port). MNOs, in general, are not willing to subsidise the networks they build, but may potentially take up part of the upfront investments in exchange for a share of the future revenues. Another option involves multiple players based on a port that invest together, including large companies in the port together with the terminal or port authority. An agreement to share future revenues can be offered to incentivize large companies with larger funds to contribute to kickstart investments. These companies may not

see an immediate need for 5G but may have a future interest in it. To overcome their risk aversion, a preferential claim or premium on top of their contribution share may be offered; in other words, that these investors' investments are paid back first (e.g., through future dividends), or that their percentage of profits/revenues is more than proportional to the initial quantity invested.

Lastly, it is important to note that the business model for deployment of 5G infrastructure in a port needs to be evaluated case by case.

4.2.2 Transport operations business model aspects for scenario L2

The business model where local transport companies embark on a joint venture (JV) is seen as better suited for this scenario compared to L1 because most of the time there are (just) a few companies operating the short, frequent transports from one logistics hub to other hubs or warehouses nearby. An option is that the JV is formed by two companies from the logistics supply chain, for instance the warehouse owners from origin and destination of the short shuttle transport. A practical example in the context of the project would be a joint venture between Kloosterboer and MSP onions, which are current partners in trade as well as in R&D projects like the 'Living Lab Autonomous Transport Zeeland'. The JV could also be participated by a third associate, in this case a transport company operating in the area such as Transport Roosens.

Joining forces in a JV is also seen as a feasible way to help make the business case positive by sharing resources. The incentives for local transport companies to adopt TO are cutting personnel costs for local drives and overcoming a shortage of drivers. This could be done not by replacing current drivers but by making operations more efficient, since some vehicles are quite idle most of the day. And to avoid that remote operators also have idle times, they could monitor the trucks of different transport companies in the JV.

Forming a JV to adopt teleoperated transport would require transport companies to build a strong cooperation with companies that are current competitors, and agree, from the start, upon the division of return and the initial investment costs, and the distribution of liability, which may be tricky if the vehicles remain under each transport company. One option is that remote drivers are employed by each transport company as well and that most of the time they remotely operate vehicles from their own company; in peaks of workload, if a remote operator from another company is available, he/she may provide remote operation at the request of the different company. In that case, the JV would need to have a simple procedure in place to charge or credit the recipient company for the teleoperation time used, and settle such credits periodically if there is an imbalance in terms of resources used among the partners. If the vehicles and drivers belonged to each company, then the OPEX from wages and usage of vehicles would fall under each logistics company rather than the JV, which, according to one of the interviewed experts, would make things easier regarding contracting insurance.

For eventual requests by other companies, the JV could charge for the TO service on a usage or service basis. In the future, if such requests become more frequent, this can be a way for the JV to grow and scale up operations, or even start employing its own remote drivers and eventually become a more independent TO service provider.

In contrast, the business model of having an independent, specialised TO service provider is seen as an easier model to implement and to scale up to larger deployment scenarios. It is also seen as more likely to become the standard model in the long term. By this we mean a company that specialises in offering TO services and focuses on multiple markets, i.e. at the international level or at least in multiple sites, and that would likely be independent to

established logistics players (e.g., a startup that is not created by existing transport companies or other logistics supply chain actors). However, an example of an entrepreneurial company that identifies a market opportunity and takes the risk of kickstarting investments –like Seafar, which provides remote operation for waterway transport with barges– is still not present for road transport.

A shared concern between the business model options is that the business case needs to be clarified; both the size of the investment and the potential return, compared to current operations based on manual driving, are not yet clear.

4.3 Scenarios L3 & L4: Highway within and across borders

Scenario L3 consists of teleoperated transport of containers with trucks over a major transport axis (e.g., along a highway) within national borders. Main bottlenecks to scale up from scenario L2 to larger scenarios included the safety of remote driving in high-speed roads and covering these segments of the road network with pervasive 5G connectivity. In previous sections we argued that, for safety reasons, we assume that remote operation of trucks in highways will only become feasible in combination with level 4 (i.e., high) driving automation. Regarding network investments, they are considered to carry a substantial financial risk, especially considering that MNOs are not convinced about alternative lucrative UCs along roads. Lastly, it is still uncertain who will be responsible for kickstarting the investments but also to deliver the TO service.

Scenario L4 extends the range of the previous one, and consists of road transport across borders. We focus on the teleoperated and autonomous transport with driverless trucks over highway corridors across multiple countries. However, in practice, for the first and last miles, the driving may be done manually or with remote operation. TO and connectivity service providers need to ensure a seamless handover of connectivity and remote control/monitoring sessions; in a cross-country trip, a vehicle will need to be constantly connected to a 5G network and to a TO centre. Therefore, this scenario entails the highest complexity for the challenge of guaranteeing continuity of service, but it also offers the largest geographical reach and potential economic benefits. An extra challenge for implementation is that regulations need to permit remote or autonomous driving in all the EU member states through which the truck would drive for a specific trip. Consequently, the Use Cases in this scenario were only considered feasible in the longer run.

While in terms of deployment and Use Cases it was sensible to discuss scenarios L3 and L4 separately, in the case of the business models there is no need to do so. First, because while some business model options would be more realistic in a cross-border scenario than in one within borders, there is no clear, fit-for-all delimitation; for instance, it would depend on variables such as the size of the country, the timing of adoption, etc. To give an example, waiting for a specialised TO service provider was considered less realistic in the short term and smaller-scale deployments, but a deployment within a certain country may be larger in scale and happen later in time than an international deployment such as one falling under the framework of 5G-Blueprint. Second, it would be redundant and time-consuming for the reader to offer two separate discussions where a majority of the content is similar. Therefore, we group both scenarios for the present business model and business case discussions, highlighting the differences in a cross-border setting where relevant.

In addition, when considering technical and business challenges, session handovers for cross-border trips are only seen as a concerning challenge at the network or wireless connectivity

level. Cross-border situations are not likely to represent a substantial extra layer of complexity from the perspective of remote driving, both in terms of technical aspects and logistics ones. This is because the transport value chain is already international, cross-border road areas are mostly highways, and TO centres (or TO centre managers) do not need to divide their coverage areas according to country borders, once regulations allow teleoperation to be offered in different EU countries.

The cross-border element is not seen to constitute a great challenge at the transport level, especially for container transport. Matters such as transport and customs documentation, for instance concerning hazardous goods, will require more digitalisation, although this is an industry trend that is expected to happen in parallel and, in fact, earlier than the technological advances behind teleoperated transport. Besides paperwork, other manual links currently remain at border points, such as inspections of the cargo, in which the truck driver can assist the police if required. A more thorough analysis of how current driver roles may be transformed in a driverless scenario will be conducted in 5G-Blueprint's D3.5; in the present analysis, we make the simple assumption that the remote operator can communicate with the police and grant access to the vehicle or the cargo when necessary, similar to what we assume for fuelling at gas stations. Regarding the teleoperation service, scaling up to international transport within the EU is also not expected to pose substantial additional challenges in terms of remote session handovers between TO centres for a specific vehicle on a cross-border journey. The TO centre may not be located in the same country than the vehicle or the network to which the vehicle is connected at a certain point in time. Therefore, the handover between TO centres for the control or supervision of the same vehicle does not need to happen at the border.

In contrast, MNOs operate at the national level; even if they are international companies, their spectrum licenses are purchased in each Member State. Therefore, when a vehicle crosses the border the connectivity service provider needs to handover the session to a different network, and this needs to happen seamlessly, avoiding the danger of even the slightest interruption. Handovers also happens inside the same country, for example when a vehicle switches from a private to a public network. While the technical complexity of such a handover is similar to a cross-border one, the difference is at the commercial and governance levels[7]. At the international level, the complexity of roaming agreements between multiple MNOs is what proves to be a considerable challenge to scale up to cross-border scenarios. This will be discussed in more detail in the following section.

Besides the technical and business challenges discussed here and in section 3.2, other important issues specific to cross-border settings relate to legislative obstacles. One such obstacle would arise if TO is not allowed in one or more of the Member States that are part of a vehicle's trip. Ideally, authorities would adopt an EU-wide standardised approach, but in practice some countries may move at a faster pace. Public road driving regulations depend to a large extent on state legislation, as is the case for rules to allow technology trials (i.e., provide exemptions) on public roads. In the present discussion, we assume an international scenario L4 where TO is allowed across the EU. In practice, however, conflicting legislations in different

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[7] Among other factors, because (a) the public network MNO shares the area where the PN is located, (b) the fact that the PN operator will not need to roam in the public network once a vehicle leaves its area, and (c) that the agreement is just a bilateral one with a party that may not be a direct competitor.

countries will require variations in the assumed deployment setting such as involving manual drivers for parts of the trip[8].

Logistics will not be a top priority and will need to compete with more regular traffic. Each country will have different priorities: e.g. safety vs economic benefit.

Another outcome of the validation interviews was the validation of our assumption that scaling up safely to highway scenarios would necessitate a combination of teleoperation with highly autonomous driving. The reliability of TO would increase when coupled with AD, while TO could support driverless vehicles when autonomous system fails and the vehicle is stranded on the highway. Additionally, direct TO could be used for the more complex first- or last-mile roads or to help vehicles enter or exit a highway. From an economic standpoint, it is most sensible that the highway part of the trip relies largely on autonomous driving.

The business model options for scenarios L3 and L4, as well as their discussion, are split between connectivity and teleoperation aspects. By teleoperation we refer to those aspects more directly related to the remote driving actions (i.e., the investment in remote centres and the provision of remote driving and transport services). This split is made because the respective business model options are seen as independent decisions, and any combination of 5G and transport-related business model options is possible in a given setting. Moreover, it was also argued that the teleoperation customer would not care about how the connectivity service is delivered –i.e., whether there is an MNO or an MVNO, a neutral host behind the ownership of the network, etc.– as long as they can buy a SIM card that provides the required quality of service at an affordable price; similarly, connectivity providers do not want to interfere on how their data is being used (given that they are aware of the requirements of the Use Case).

4.3.1 Connectivity business model aspects for scenarios L3 & L4

With regard to wireless communication aspects, the experts in our validation interviews agreed with the identification of our preliminary 5G business models for infrastructure deployment as the most feasible options. Specifically, these entailed 5G network deployment via (i) a neutral host, (ii) network sharing, and (iii) single MNO deployments. Nevertheless, it was stressed that the suitability of each business model will depend largely on the density of the area, among other variables. For instance, a neutral host would make more sense in less dense areas, where MNOs would not see a business case to invest individually. An example of a 'neutral host' is a firm that owns a portfolio of RAN assets and provides infrastructure access to M(V)NOs, who act as tenants of this shared infrastructure.

It was also suggested to remove the business model options related to network slicing (i.e., using a slice broker and offering slices as a service) from the list of 'business model options' for deploying 5G networks and offering 5G connectivity. While slicing technology is certainly relevant in practice and will be used in some settings to deliver the QoS required by teleoperation Use Cases, slicing is seen as a technical implementation issue at the core network level, hence an internal decision from MNOs, who would choose the appropriate technology in a given area according to what is more sensible to deliver the required QoS. Furthermore, governments can influence slicing by stipulating priorities for specific Use Cases. In conclusion, it is not seen as a mutually exclusive decision in relation to the three business model options listed in the previous paragraph.

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[8] Note that this would not entail changing the essence in the assumed deployment types: a manual driver could pick up a truck at a certain 'hub' either to drive it (or be the safety driver) on the highway or on the local roads of the country or area where vehicles are not legally allowed to travel without a driver on board.

Having defined the options for the deployment of 5G network infrastructure (upgrades), the next logical step is defining the feasible options for the investment in such deployments. The wide array of potential practical arrangements can be classified in the following three broad options:

- The party that deploys the infrastructure is the same one that finances the upfront investments. Based on the 5G infrastructure deployment models discussed above, this would imply that either (i) a telecommunications infrastructure company that acts as a 'neutral host', (ii) a partnership of two or more MNOs in the form of network sharing agreements, or (iii) a single MNO finances the entire costs of upgrading and densifying public networks. In that case, this party would seek to recover the investment through the pricing of the connectivity service (e.g., charging premium rates by high-QoS Use Cases like TO) and/or finding alternative revenue streams to generate economies of scale from additional 5G-based Use Cases in the same area where coverage is enhanced. While theoretical applications include in-vehicle infotainment services (such as video streaming or augmented reality), remote diagnostics for electric cars (e.g., checking battery status), and C-ITS services, finding new revenue streams that justify the network upgrades required for TO along highways is considered a challenging task.

- The network owner/operator and other stakeholders co-invest in the deployment of 5G infrastructure. In smaller-scale scenarios, these other stakeholders were the port or site owners, who contributed to finance a private network, or authorities that sought to support the early adoption of innovative Use Cases via R&I projects. In highway scenarios, one of the business model options is that national or regional authorities contribute to finance 5G network upgrades along highways, for instance via public procurement. As discussed in section 3.3, authorities are more likely to contribute to deployments if the outcomes of adopting teleoperated transport are clearly aligned with policy goals. In this line, the involvement of regional or national authorities can be considered as a feasible option for deployments within their region in broader road scenarios, which promise to yield societal benefits in terms of safety road safety and driver well-being and shortages. In a similar manner to their financing of research programs, supranational bodies may help subsidise investments in more bottleneck areas like around cross-border points. A further possibility in the preliminary business model BM5 was that OEMs would take responsibility for investments in telecommunications infrastructure, but our validation interviews led us to conclude that this is not a realistic option.

- Alternatively, an investment kickstarter may be the same customers of the connectivity service, i.e. the TO service providers, who use the connectivity to enable a lucrative commercial service like teleoperation. A TO service provider would be able negotiate at the continental level with several MNOs and authorities to partner for TO deployments, but it would be challenged by the compound amount of such upfront expenditures.

For any of these parties that participate in upfront investments but do not directly derive financial benefits from teleoperation, a channel to recover part of the investments and reduce the risk thereof is a prospective profit or revenue-sharing agreement with the TO service provider. An example would be a dividend-sharing model that reflects the asymmetry in the upfront capital expenditures of initial network investments, while another would be the commitment of a preferential claim of future profits until the initial investment is paid back.

Regarding the connectivity service provision business models, we distinguish between the type of service provider and the pricing agreement for the service. Concerning the former, the validation discussions confirmed the following three options as the most realistic ones:

- An MNO provides the connectivity service directly to the users, with the motivation

to enlarge its subscriber base. The MNO would charge the user of the SIM card (i.e., the TO service provider) via a kind of subscription, which could take form in one of the following options:

- An MVNO provides the services to the user. MVNOs use a national MNO's network infrastructure; they would buy wholesale network resources from the MNO and resale them in a tailored package for teleoperated transport Use Case requirements. B2B applications such as teleoperated transport Use Cases offer an opportunity for virtual operators to specialise with service packages that are more adapted to the specific needs of this market. MVNOs like Transatel or Cubic Telecom are current examples of connectivity providers to the automotive industry. Potentially, MVNOs could buy resources from and have agreements with multiple MNOs (combining virtual SIM cards, to put it in an illustrative manner), so to offer a 5G service solution that delivers connectivity from the best available network at any point in time, by automatically choosing the network with the best coverage at a given location.

- Industry players can provide the connectivity service by becoming MVNOs themselves. The MNOs would sell access to their infrastructure to the industry company, who would use the MNO's wholesale connectivity to provide a more tailored connectivity service on top of it. The stakeholder taking up this business model could be the TO service provider itself. This option is more likely in the cases in which this service provider is a specialised company or a truck manufacturer, compared to the cases where a transport company adopts this service. For a startup specialising in remote operation services, building this expertise from its inception would represent less of an organisational challenge. For a vehicle OEM, the presence of alternative uses for wireless connectivity (e.g., V2X, remote updates for their vehicles), as well their company size and financial resources, would make the adoption of this role a feasible option. Some automotive companies such as Hyundai in South Korea have been reported to explore the offering of connected car services like V2X for their vehicles as an aftersales recurring service.

Regarding the pricing agreement for the wireless connectivity service, we distinguish the following three options:

- A "flat" subscription for the service, with a pre-agreed rate and a certain guarantee in terms of bandwidth and latency.

- A base rate with a usage-based premium once a certain volume of data consumption is reached.

- A 3-layer subscription where, on top of the base and extra usage rates, there is another premium for priority over the network resources. This premium would entail charging for the guarantee of a certain level of bandwidth and/or latency for a certain customer in exceptional occasions where the capacity of the network is challenged due to high user density. The MNO would give priority over its network resources to the customer (or set of customers using the same virtual slice), implying that these users would not have to compete with others for the shared resources. This would be equivalent to having a virtual slice. While currently challenging due to net neutrality rules, network slicing may be the enabling technology to implement this type of price-discrimination model. Other users located in the same area (i.e., users of a 'public' slice) would receive best-effort QoS. Safety concerns may result in a legal requirement of including this priority option when connectivity services are contracted for remote driving in public roads.

Another crucial part in the overall business model revolves around how to charge the end customer for the 5G connectivity 'part' of the teleoperation service:

- The most likely approach is that the TO service provider is the party that contracts the subscription for the 5G connectivity and prices the connectivity use within their

TO package, providing a more convenient end-to-end solution to trucking companies. This is especially expected to be the case when the TO service provider retrofits vehicles with TO-enabling technology. The usage- or priority-based premiums could be passed along to the TO customer separately.

- An alternative option, in a future scenario where manufacturers incorporate the required technology in their vehicles, and the OEM is also the MVNO, is that the OEM charges the vehicle owner (e.g., the transport company) directly for the connectivity use. To increase convenience for their customers, the value proposition of OEMs could expand the traditional vehicle sales with the offering of a recurrent subscription where 5G-services such as teleoperation or remote system upgrades can be added.

The figure **summarises** the discussion above by portraying the different business model elements and options from the 5G connectivity side, also showing their logic within this bounded value chain. A more specific discussion of roaming agreements is provided below.
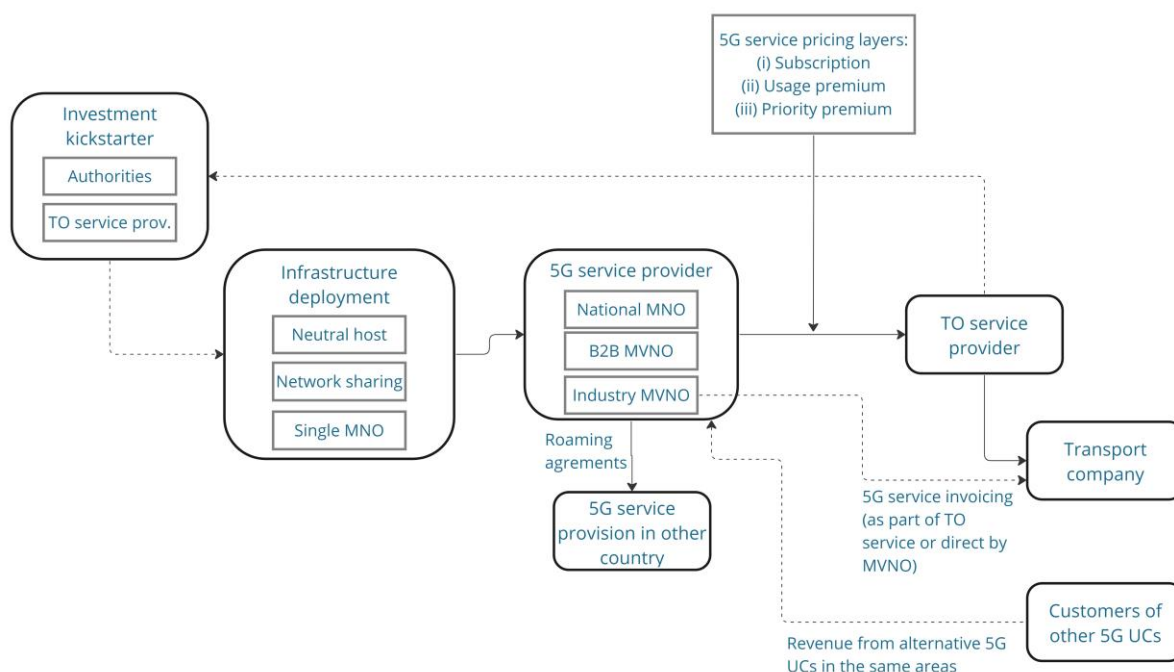
Figure 9. Validated **business model options for 5G aspects** in Scenarios L3 and L4

Roaming agreements in scenario L4

Roaming is not just about crossing a border but about enabling users to stay connected regardless of their location. In this deliverable, we focus on international roaming agreements. National roaming also exists and can be used to share coverage in scarcely populated areas within the same country. Even though a different, dedicated task of 5G-Blueprint (T5.3) deals more in depth with roaming agreements and issues, we discuss the topic here from a business perspective.

It is the responsibility of a home MNO to arrange international roaming where desired/required by its subscriber. The choice of a network for roaming depends on factors such as network quality, coverage, available services and cost. One challenge behind cross-border continuous coverage includes the difficulty to determine the quality of a roaming network, which can vary per location and over time. In addition, there are numerous quality parameters to consider, for

instance bandwidth and availability. Another challenge is that providing the roaming service requires negotiating complex service level agreements (SLAs), configuring network interconnections and meeting the needs of a diverse user base, all while maintaining quality standards and complying with regulations.

Handover between networks when a vehicle crosses the border presents a challenge at the commercial level. When a user is roaming, the visited network invoices the home or original MNO with which the user has a service contract. According to the interviewed experts, this invoicing between MNOs would not represent an issue and could be done in a similar manner as it is done today; already today, traffic is not always balanced and for transport Use Cases it is not expected to be worse. In addition, the magnitude of data usage when roaming can be tailored at the retail level based on the business offer.

The problem lies in the fact that that multiple standard contracts would need to be in place. Today, the number of players with which a given MNO needs to negotiate is limited, and MNOs have a choice of which MNOs to partner with for international roaming. Being bound to one operator is preferred and more feasible than having multiple fallback operators to which the home network is able to handover. However, for teleoperated transport, complex agreements would be needed to guarantee that a vehicle can seamlessly receive a 5G connectivity that provides high reliability, ultra-low latency and high-throughput for the uplink across multiple countries. From the MNO's side, the routes and destinations would be difficult to predict. In addition, each national MNO may have different coverage in different areas. Therefore, for a given home MNO, guaranteeing this QoS when its subscriber is roaming in multiple countries would entail entering into pre-defined agreements with many national public networks.

Such roaming agreements consist of a long list of preliminaries, before an MNO can guarantee that a device can cross a border with the same QoS. In the absence of an agreement with a trusted MNO, before handing over to a different network, some requirements are checked automatically: if the first "requirement" is met, then the second requirement of the list is checked, etc. But all these "negotiations" add latency. In addition, the second and following 'jumps' (e.g., when a Dutch vehicle that has driven to Belgium now crosses the border to France, and subsequently to Spain) are out of control of the home MNO, and it may thus also be the case that the visited MNO providing roaming is not the preference of the home MNO. A more efficient solution would be having a pre-defined agreements that avoid this "negotiation" process. With this type of agreement in place, the home MNO would know that a vehicle can cross from country A to B and receive the guaranteed QoS connectivity.

However, negotiating this type agreements containing these preliminary conditions is challenging when a large amount of MNOs are involved. One key issue to be agreed upon is whether the liability would be handed over as well. In addition, it is complex to know the specific situation of each border crossing (e.g., between Germany and the Netherlands there exist already above three dozens of cross-border roads).

This discussion makes it important to highlight the difference between geographical distance and network distance, i.e. how many 'jumps' between networks are needed to reach a vehicle. If the network distance is not larger than 2 MNOs, which is often the case in a range of few hundred kilometres, there is no need to have a long chain of governance agreements. However, to cover a wide EU region like a TEN-T corridor, several bilateral agreements between MNOs would be needed.

Lastly, discussing technical aspects on how to guarantee acceptable latency levels with handovers is beyond the scope of this task, but we present some considerations that will influence the assumptions behind the present analysis on business models. First, the

theoretical possibility of having a transatlantic network that 'glues' multiple public networks to behave as a single one is not seen as a feasible solution in the foreseeable future, since this merging would add latency at each step, likely far beyond the <25ms required for TO.

Another option is carrying two or more SIM cards in a vehicle. While this dual or multiple SIM solution is not the preferred approach, in the short term it can be a more realistic alternative to seamless handover for those markets where the commercial agreements between MNOs are not ready. However, the scalability of such an approach is limited, since travelling anywhere around the EU would necessitate having a large number of connectivity service contracts. Multiple SIM solutions are also used by waterway transport TO service providers like Seafar within a country, allowing their barges to automatically change to a provider that offers better coverage in a specific area without the extra latency that can arise in cross-border handovers.

D5.3 discusses the following four roaming models that can be scalable to a pan-European level, along with their trade-offs.

- Model 1 relies on RAN network sharing along an entire highway corridor. There is a trade-off between the advantages of network sharing, which include faster and broader deployment of 5G networks while reducing costs, and the potential drawbacks, such as reduced incentives for investment and diminished market competition. In a network sharing model, there is no need to change roaming partner within the country borders. Since the radio network is shared and therefore equal for all participating national operators, changing roaming partner will result in reusing the same RAN, i.e. without any difference in quality nor coverage. MNOs do not compete on quality because they offer their domestic service based on the same radio network. A handover is only needed when the service is expanded to an area where the shared corridor is not active. One more disadvantage becomes apparent when considering a border crossing between two visiting networks. In a shared network solution, guaranteeing quality could even be more complex than with non-shared models. Consortium participants need to agree on a way to share the commonly used spectrum and on SLA clauses to resolve any potential performance issues by the shared network.

- Model 2 consists of the issuing of exclusive licenses to operate a corridor to a single MNO in each country. Roaming is then viable solely through the designated licensed roaming partner. If in a country only a single network exists as corridor, there is no need to change roaming partner within the coverage area of the national corridor. Only once reaching a country border or when exiting the corridor, a change of network needs to take place, but the selection of the new network becomes almost trivial: only one of the domestic networks is able to offer tele-operated driving services. However, in the event of technical failure there is no alternative network available to guarantee service continuation. In addition, competition is limited, since this model would lead to a situation that resembles a monopoly. The bidding process to acquire the single license could also drive up costs and make it difficult for smaller operators to compete

- Model 3 - Competing corridor-based model: within this model each roaming partner builds its individual corridor, leading to the emergence of multiple corridors competing to offer the TO services. MNOs could differentiate in terms of quality and coverage area. In that setting, an MNO may wish to use the corridor of roaming partner A during the first part of the journey and of roaming partner B for the next part, in which case handovers would be needed at the locations where the networks intersect, including national borders. Consequently, roaming subscribers may be able to enjoy the combined coverage of corridors. Clear agreements will need to be in place to guarantee continuous service delivery in a predefined geographical area

abroad. In addition, MNOs would need overlapping coverage with neighbouring networks that can support high bandwidth demand.

- Model 4 – Business as Usual. Several MNOs offer nationwide coverage in each country; hence, there is no need for distinct corridors, given the availability of seamless handover functionality across the entire coverage area of the MNOs. Each MNO builds capacity and is free to establish agreements for roaming SLAs. In this model, the challenge of ensuring uninterrupted service delivery throughout the entire route is even more pronounced: without corridors, it is impossible to know in advance which network a subscriber will use. This makes it difficult to negotiate attractive roaming rates, as the MNO cannot guarantee that their customers will be using the best network available. In order to secure favourable roaming rates through negotiation, it becomes imperative to possess a controllable solution for influencing network selection.

4.3.2 Transport operations business model aspects for scenarios L3 & L4

Regarding the TO side, the validation interviews discussed the feasibility of each of the preliminary business models, while also introducing some nuance and extending the analysis by suggesting additional options and considering their suitability in different contexts and time frames.

Business model options for the deployment of TO centres and the TO service provision

One straightforward arrangement is that an external and innovative company whose mission if offering TO as a service sees a market opportunity in deploying a remote operation service that covers a country's major transport axis or a larger international area. The concept of a specialized service provider, akin to Seafar's offerings for inland waterways, is also theoretically feasible. However, in contrast to scenario W2, the existence of such an entrepreneurial service provider is not present for goods transport on the road, as the business case remains unclear in the eyes of the industry. A wait-and-see approach by interested parties, i.e. waiting for such a provider to emerge and the service to be available in the market, is not seen as a very realistic strategy to kickstart deployments, albeit it is a sensible business model in the long term, once the market becomes more mature. On the contrary, a more proactive business model is considered a more sensible approach to reduce the uncertainty of having timely initial deployments in a specific area like Belgium or the Netherlands. This proactivity may arise from parties that take up main business model roles or by a cooperation of interested parties in a region that share efforts for investment and deployment.

A proactive approach can be seen in the business model option where a large transport company invests in having remote centres and drivers for its own trucks. In this business model, the transport company would take care of the investment in training their employees and renewing their fleets of trucks. This is seen as the first logical point to implement teleoperated transport in scenarios L3 and L4. First, because in that setting the transport company retains its operations and current business model, and just adapts certain technical aspects; traditionally, trucking companies take care of the entire transport. Second, because they would benefit more directly from TO, and then they can pass the benefits to their customers in terms of quicker and/or cheaper transport – overcoming future labour shortages is seen as a main added value of teleoperated transport in the future: currently, transport companies in the BeNeLux have a higher demand for jobs than the truck drivers they can find, and the improving economic conditions from the EU countries where many truck drivers come

from (e.g., Poland and Romania) points to even more vacancies in the longer term. Third, having their own drivers also simplifies matters concerning liability arrangements. Another reason is that teleoperating transport at a large scale would disrupt their own core business, and therefore lagging behind competitors in adopting it would constitute a competitive disadvantage and thus a threat to their market position.

Under this business model, the transport company could generate ancillary revenues by providing TO services to other transport companies when they have excess capacity.

However, it is challenging to find large transport companies that are interested to adopt the technology; to convince them to invest would require proving that the technology works safely and that the business case is clear. Another question is whether transport companies would be willing to offer the teleoperation service to trucks of competitors. Nevertheless, if that were not to be the case, the presence of a competitive advantage would motivate the industry to catch up and adopt TO as well.

In addition, the aforementioned business model of a JV of local transport companies that employ their own drivers to provide the TO service is also considered to be a feasible approach for the present scenario L3. Smaller transport companies may join forces to face the large investments, which are considered too large for a single company to undertake by itself. In a later point in time, such an entity could scale up to offer the TO service to external companies in a larger, international scenario like L4, thereby transitioning to the first business model described in this subsection. This would represent an organic approach to scale up from previous scenarios where we identified different Use Cases that have an earlier feasible implementation. In addition, it would offer a business opportunity in the form of a growth prospect for the logistics players in regions that take the risk to innovate to adopt teleoperated transport Use Cases.

Another preliminary business model option involved truck manufacturers (OEM) offering the teleoperation service for their own brand of trucks. At least for passenger vehicles, OEMs are increasingly shifting their focus to provide more than just vehicles, to mobility as a service (MaaS). For instance, some OEMs have launched MaaS apps in the past years, including for shared cars and for extra features offered in the car (e.g., BMW), or in partnership with competitors or with tier 1 suppliers (e.g., Daimler and Bosch for remote valet parking). In spite of this, the experts we interviewed considered this model as a less feasible one compared to the previous options discussed; rather, it is seen as unlikely that an OEM takes the role of direct provider of TO services for initial implementations. First, due to the inherent risks of high-speed remote driving from potential network issues. The brand reputation of OEMs largely comes from the reliability of their vehicles. Second, the expertise required for running transportation services differs from OEMs' current focus. Third, the incentive from a competitive advantage with respect to other brands is not as evident as the direct benefits that logistics players would obtain from teleoperation. An exception would be highly innovation-driven OEMs, such as start-ups that have focused on testing autonomous vehicle prototypes from their inception. Fourth, because OEMs operate in the worldwide market, therefore they may not be interested in investing in kickstarting deployments of teleoperated transport Use Cases in specific regions or routes, which would require building an understanding of the distinct characteristics and regulations of these areas/regions. Finally, and specifically for the transport of their new cars until a retailer's location, it is more realistic that OEMs like Toyota continue to rely on third-parties. The main reasons are that, currently, (i) trucks share capacity to carry cars of different brands and that (ii) OEMs pay for 'one way' until the delivery of their cars; afterwards, the transport company will find a request to transport another cargo with the same truck.

Nevertheless, OEMs may see such deployments as a stepping stone and testing environment towards building a global product, as is the case with the R&D of autonomous vehicles (e.g., consider the case of Mercedes, which offers vehicles with bounded autonomous driving capabilities on certain German highways, because Germany has transposed UNECE guidelines into national law and the vehicles have been homologated). This would make it more likely for OEMs to pursue the approach of equipping their vehicles with the necessary technology directly in the production line. This would be more efficient than retrofitting each vehicle with TO technology, as well as easier for the customer of the trucks. For this, OEMs can enter into close partnerships with existing TO technology providers, which could help overcome the manufacturers' reluctance to opening their gateways for external partners to access the vehicles' systems and plug and play their technology. However, a concern of incorporating the technology in all vehicles is the question of whether approval for the vehicle would remain.

Yet another preliminary model in D3.2 consisted in a large international digital platform that owns their own TO centres and provides the TO service, while matching demand and offer for transport between, on one side, shippers and end customers – as owners and customers of the cargo, respectively – and, on the other side, transport companies or even individual truck owners. Compared to the model of a specialised service provider, this type of platform would be a more disruptive one: instead of being contracted by the transport company for a specific route, it could play part of the traditional role of freight forwarders by assigning carriers and negotiating rates with them, dealing with insurance and documentation for customs clearance, providing real-time tracking and monitoring of shipments or consolidating small shipments. The most conspicuous entity to adopt this business model would be an Uber-type start-up. Alternatively, a large global retailer like Amazon could adopt this model with the ambition to integrate and control even more the logistics chain while leveraging on the remote centre infrastructure to share its use with other innovations such as home deliveries with drones. A downside of this model is that, while theoretically possible, it is only seen as feasible in the long term.

Lastly, a variation of this match-making platform business model would be a combination of some of the identified options in this section. More specifically, we could envision an arrangement wherein an OEM owns the platform in partnership with an existing mobility platform type of company that has experience in the development and hosting of such digital applications. In turn, the remote operations could be provided by specialized service providers that sign up in the platform as suppliers. The overarching platform would orchestrate the matchmaking between shipper or transport companies and the TO service provider. The OEM could market this platform as an added value for its vehicles, and its brand reputation could help garner trust among the logistics industry.

4.3.3   Business model aspects related to Enabling Functions

As described in the introductory chapter, the 5G-Blueprint project will also research and test a series of 'enabling functions' (EFs) that aim to support and facilitate teleoperated transport Use Cases by providing and processing additional data. EFs aim to increase the safety and efficiency of teleoperated road transport. They either increase safety from enhanced situational awareness or offer more predictable and optimized trips. All EFs ultimately provide input to the remote operator through a dashboard located in one of the screens of the remote station. This dashboard represents EF1 and in the present analysis it is assumed to be incorporated in the TO centre's technology and functionality.

The EFs can be understood as information services that are provided to the TO service provider, but that can be used and sold for other purposes as well. In fact, these services are currently offered for other passenger and goods transport UCs, with their respective existing business models. The marketability of these EFs is thus independent of teleoperated transport, but TO can provide an extra source of revenue that can increase the feasibility of their business case. In addition, TO can lead to or require different business models.

The data for these EFs may come from different sources such as vehicle telemetry and sensor data or roadside infrastructure. While 5G-Blueprint covers the eight EFs below, the present analysis will focus on the following ones:

- EF2: Vulnerable road user (VRU) interaction. This EF provides warnings about the presence of VRUs in the anticipated path of the teleoperated vehicle. Therefore, it helps overcome one of the drawbacks of TO compared to manual operation or driving, namely the loss of sensory perception and a reduced interaction with other road users (e.g., eye contact with other drivers).

- EF3: Timeslot reservations at intersections. Intelligent traffic light controllers allow the reservation of green-light time slots at intersections, guaranteeing that an entire platoon of trucks can cross an intersection at once.

- EF6: Container ID recognition. This EF provides a message with the ID of the relevant container. It may be used, for instance, to detect the entry of containers in ports or to detect containers with dangerous goods.

- EF7: Expected time of arrival (ETA) sharing. Lastly, this function provides updates during the trip on the ETA of the teleoperated truck, taking into account real traffic and potential obstacles.

The reason to focus on the aforementioned EFs is that these are the ones that can be expected to be able to be commercialised as a distinct service by an external entity rather than incorporated as part of a vehicle's or a TO centre's systems, as well as the most likely ones to entail a list of operational and/or financial arrangements.

It is important to note that we place the analysis of these EFs within scenarios L3 and L4 even though these services will play a significant role in smaller scenarios as well. For instance, container ID recognition and VRU warnings can enhance efficiency and safety in logistics sites, while time slot reservations and ETA sharing can optimise delivery planning and the driving already for the shuttle runs of scenario L2. However, the business model aspects we discuss below are relevant to the commercial delivery of the EFs in each case; hence, providing separate discussions would be redundant. Therefore, the present analysis can be considered to cover a cross-border road transport scenario that spans the entire trip from the reception of cargo at a port to its delivery in either a nearby warehouse, another logistics hub in the same country, or a location in a different EU Member State.

This section provides a structured discussion in which we consider business model aspects related to the selected EFs according to the following variables: (i) what assets would need to be invested in in order to adopt each EF, (ii) which parties are likely to invest in or contract the deployment of the previously-defined assets, (iii) who would be the direct customer of each of these elements, (iv) what are the likely pricing strategies for the commercialisation of the EF's service, and (v) what other relevant aspects (most notably, additional cost sources) have the potential to influence or impede the business case of deploying each EF.

EF2: VRU interaction/warnings

This information service is likely to be provided by a smart mobility service provider (e.g., Locatienet or Be-Mobile) that acts as an external provider to the TO service provider, who receives the warnings in the dashboard. It is likely that EF2 is offered as part of a package of mobility services that rely on similar types of data; first, because the business case of investing in the required assets to just provide VRU warnings seems limited, and second, because these assets can be leveraged to generate or process data for different applications. Smart mobility service providers already gather and process the kind of road and user data that is required to deliver the EF of VRU warnings.

Table 11. Business model analysis for Enabling Function 2: **VRU warnings service**

Relevant assets (to invest in)	Investment/contracting party of the relevant asset	Customer (who pays for it)	Sales strategy of the EF2 service	Other aspects that make or break the business case
Handsets (VRU phones with the app installed)	VRU (drivers/riders on the road + employees at the port/logistics site)	VRU or site owner + TO SP	Ideally, the EF2 info is sold via a subscription (e.g., monthly), rather than per warning, and in a single package with other EFs, rather than as a standalone service. Which party contracts the service will depend on its kind of adoption: (i) The TO SP can pay for it, if EF2 is mostly used for TO or if it's offered in a bundle with other EFs (ii) Terminal/port: the company using the EF for safety reasons (e.g., a port authority or a terminal operator); and then it can request a third party offering TO in the area to use the platform. (iii) Transport companies directly, although their WTP for this kind of services is low (based on current experience with route planner apps), because they have their own systems (even though often not based on real-time data).	It is crucial that VRUs install the app, but the WTP from road (end) users to pay for the app is low. To incentivise their adoption of the app, the mobility app provider can cross-subsidise them with other UCs, or compensate them for their user data. Another UC that can use EF2 in a port environment is the track and trace of employees, to know where people are, which could be helpful in case a calamity happens. OBUs are already required for TO/C-ITS functions, so it is not expected to be an added challenge for the EF service.
HW for dashboard in TO station (EF1)	TO service provider (integral part of the TO Use Case)			
Exchange platform (cloud, network edge) to enable/host the mobility app and the data being exchanged.	It will probably be deployed with COTS solutions by the EF's SP (e.g., Locatienet or Be-Mobile), who also provides maintenance. It is an essential expenditure behind the service.			
OBU in vehicles (to share info in platform)	Retrofitters or OEMs	TO SP or vehicle owner		
Telecommunications infrastructure. While the higher connection stability of 5G networks is advantageous when the service is offered at a large scale (i.e., with many sensors and devices), the EF by itself would not require an infrastructure upgrade compared to the teleoperation Use Case, and low latency it is not critical to this EF.				

EF3 & EF7: Timeslot reservations at intersections & ETA sharing

The time reservation and ETA sharing information will likely also be offered by external mobility data service providers. These providers gather and process data from vehicles and real-time traffic to estimate the time of arrival of a truck or truck platoon both at its destination and at a given intersection. On the basis of this information, they can issue the traffic light reservations to the traffic manager at the request of the remote driver through the EF service provider's app. Therefore it makes sense to study the combination of EF2 and EF3, because by taking into account both functions one can consider separate ETAs for different traffic lights or intersections. Ultimately, the road authority decides whether to give a green light and whether an entire platoon can cross together. It is unclear whether there will be a central platform in between like in Mobilidata, where the customer is the road operator.

The experts we interviewed did not envision the single service of ETA sharing being set up as a separate business case; there is little value that the EF can provide as a stand-alone service. Rather, it makes more business sense when combined either with EF3 or as part of a product package with other mobility information such as a kind of navigation app. The dashboard at the remote station's screen will incorporate different types of driving- and traffic-related information; hence, in a sense it could be understood as an extension of a mobility data application such as Be- Mobile's Truckmeister or Android Auto.

Table 12. Business model analysis for EFs 3 & 7: **Traffic light reservations & ETA sharing**

Relevant assets (to invest in)	Investment/ contracting party	Customer (who pays for it)	Sales strategy of the EFs services	What relevant aspects (e.g. costs) make or break the business case
HW for dashboard in TO station (EF1)	TO service provider (integral part of the TO Use Case)		The mobility data platform would sell the service with the following revenue scheme: (i) A fixed upfront charge for the set up. (ii) A subscription fee, based on the area covered, the number of TOVs, etc. (depending on customer requirements) The most likely customer of this subscription would be the TO service provider.	The dashboard should be interoperable, combining information input streams from different companies and EFs. It is unclear who would be legally liable in case an accident happens after wrong data is provided; in some occasions it may fall under the EF provider, who is responsible for combining, checking the quality of, and interpreting all the data.
Traffic info platform (server set up and hosting costs)	The EFs service provider, who also maintains it. It is an essential cost behind the service	(i) TO SP, most likely, via the EF service provision (ii) Truck companies (*) (iii) Cities (*)		

* Directly selling to truck companies is more difficult, unless it is legally required for safety reasons such as requiring the TOV to avoid certain roads, school areas, inner cities, etc. In that case, there may also be a business case of selling the EFs services to a city. It may also be required that the platoon passes a green light at once, but this requirement may come from the TO service provider itself.

EF6: Container ID recognition

Container ID recognition systems scan the license plates of trucks and the codes of containers to record their location and arrival times, and to identify dangerous goods. This is especially relevant at logistics hubs like ports, where myriads of containers are daily picked up by cranes, stored, re-located and subsequently transported by trucks, trains or barges. These systems rely on cameras that would be located mainly at the site but may also be located at different points where a truck stops during the route (e.g., setting up fixed cameras in portals or using drones to check damage from above). The TO service provider and/or the site owner can then be granted access to the livestreams and ID scans from these systems.

Container ID recognition can take the shape of an information service provided by a specialised company like Sentors, which sells the camera and ID recognition systems and provide video recordings.

Video records serve as proof, in case of a dispute over damaged cargo, of whether the damage was already present at the point in the logistics chain where the recording was made. This is already useful today, because drivers, who are responsible to check for damages, cannot easily check the roof of the container. But it will also be useful in a future when a manual driver is not present, to provide some assurance over the monitoring of damage and a fair allocation of liability. A transport company may contract this service to substitute the driver's responsibility to check for damages while remaining liable for these checks. Alternatively, the TO service provider can contract the service and include a liability assumption clause in its agreement with the transport company.

This system can also provide the container's cargo information needed for CMR documents (e.g., who is responsible for a certain container), which is needed by a transport company when fetching a container. In a future with TO, the digitisation of these processes where manual drivers currently play a role is key. This EF will help in this digitisation, a trend that is already happening in the EU with e-CMR.

In addition, EF6 can provide cost efficiency by helping automate the process of locating and sorting containers; currently, reach stackers are continuously looking for a specific container that may be at the bottom of a stack. Optimizing this process will require a complete registration, planning and real-time tracking of all containers, which can be efficiently supported by ID/plate recognition but will also require having a terminal or yard management system that has a complete view over the site and the containers within it. Currently, not many terminals, especially inland ones, have this complete overview. In addition, having such a system would also help terminals in predicting delivery times, the notification of which would add value to their customers.

Automating the registration of containers through ID recognition systems will also add efficiency in the context of teleoperated transport from the removal of the current task of crane operators to register their actions at the same time they operate the crane. Additionally, this can be distracting to crane operators.

Lastly, 5G also has a role to play in this EF by helping enable the edge processing of video streams from cameras on logistics sites. This would reduce the required amount of computing power in a distant server and provide cost-efficiency by reducing the need to install fibre to reach this central server. Edge processing would also reduce the need to build processing power (CPUs) in cranes and reach stackers; transferring and centralising this computation to the edge cloud would be more cost-efficient without adding substantial latency nor the aforementioned need for fibre upgrades. Therefore, it would result, all else equal, in hardware and infrastructure maintenance cost savings.

Table 13. Business model analysis for EF6: **Container ID recognition**.

Relevant assets (to invest in)	Investment/contracting party	Customer (who pays/gets value)	Sales strategy of the EFs services	What relevant aspects (e.g. costs) make or break the business case
Cameras & modems	Deployment by the EF provider at the request of a site owner (for scenario L1) and/or a TO SP (for public road scenarios).	(i) Site owners, terminal operators and other third-parties providing logistics operations/services at a site.	The Container ID recognition service would likely be sold together with the other functionalities mentioned above (video proofs, CMR information, etc.), probably including (i) a fee for the setup and HW costs, and (ii) a subscription for the service.	There is already a use in the port for this kind of systems, for other types of operations. Its adoption can be expected to grow in the near future with trends towards automation. The incremental investments for TO Use Cases can be assumed to be limited to surveillance infrastructure to control the state of a container along a driverless truck's trip.
Software (ID recognition and video processing systems)	ID recognition service (EF) provider, as part of the internal capex to deploy the service.	(ii) TO service providers		
Edge cloud processing infrastructure (e.g., an MNOs edge cloud server, etc.)	MNO at the request of a site owner or a TO service provider (e.g., via a private network or coverage on demand), with possible co-investment from the client or kickstarter party (see business models in scenarios L1 and L2).	(i) & (ii) above; (iii) Providers and clients of other UCs relying on 5G	It could be sold to site owners, terminal operators, transport companies, or to the TO SP directly.	Edge processing and 5G will also be needed for the remote driving itself and potentially for other UCs within logistics hubs.

Summary: Enabling Function business model considerations

The figure below summarizes the discussion on business models for EFs by putting together the business model considerations of each EF service.

The EF service providers can be considered tier 1 suppliers of the TO solution; they sell their information services to TO service providers, but their data is also relevant for other Use Cases and stakeholders. Therefore, their services are also sold to other types of customers, and their business case does not depend on teleoperated transport alone.

We consider that the services of EFs 2 and 3, i.e., timeslot reservations at intersections and ETA sharing, will be part of the same commercial offer and therefore invoiced as a single service in the eyes of the TO service provider.

Nevertheless, it is possible that a single traffic information service provider also includes EF2 in its service. A company like Be-Mobile could provide these 3 EFs as part of the same service package. The actual information service providers and their business models may differ per country; at least in the shorter run, considering the market as it is today, it seems unlikely that the TO service provider would rely on a single, pan-European provider.

Integration also makes business sense given the similar nature of the main assets that the data providers need to invest in to enable the EF services; namely, their data platforms that rely on (edge) cloud infrastructure
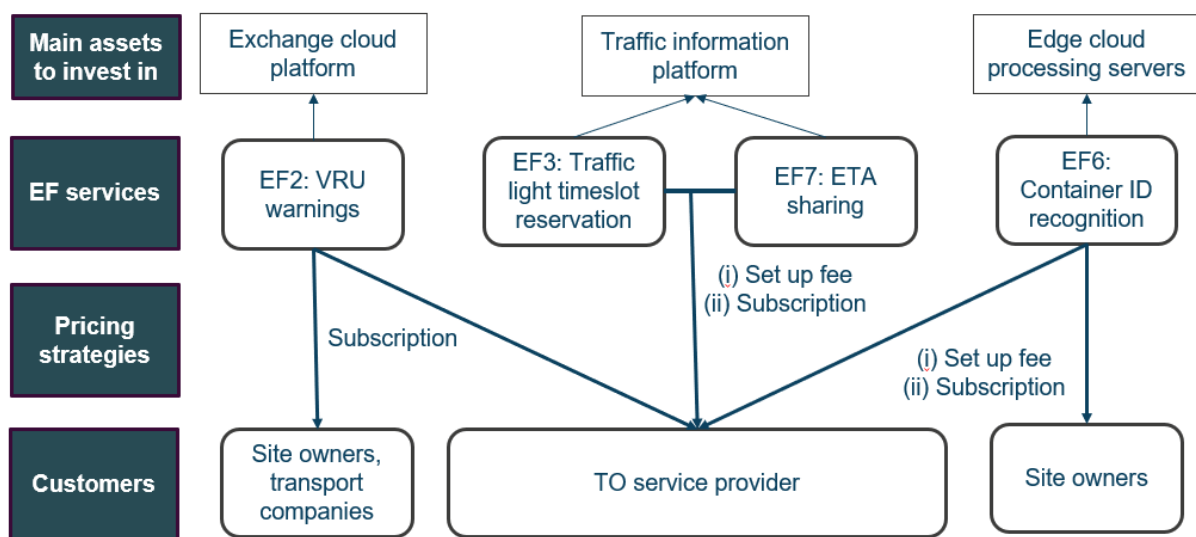
Figure 10. Summary of business model aspects for enabling functions.

4.3.4 Recap of business models for scenarios L3 & L4

In the same line of the analyses in previous scenarios, below we provide a table that summarises the discussion about the business model options for each of the themes we considered. Once again, it is important to note that the discrete business model options (i.e., the "options" columns) are suggested combinations of the different variables (i.e., the rows) the that would result in feasible business models, but other combinations are theoretically possible.

The variables related to specific connectivity and teleoperation aspects, however, are split in two different tables, because the respective business model options are seen as much more

independent decisions, and any combination of 5G and transport-related business model options is possible in a given setting.

Table 14. Validated business model options for **5G Connectivity aspects in Scenarios L3 & L4.**

	Connectivity business model options for scenarios L3 & L4: transports along a highway within and across national borders		
	Option 1	**Option 2**	**Option 3**
5G network deployment	Neutral host who pools resources and offers (rents) them to MNOs (tenants) to create their own connectivity services	(Active) Network sharing by two or more national MNOs	Single MNO deployment
Main value proposition	Lower costs per operator and investment by a third party that can have multiple tenants; the involvement of this independent party may be more attractive by other investment kickstarters to chip in, thereby speeding up deployments	Lower costs per operator, thus faster deployment, but more controlled by any given combination of MNOs (thus more market power that can be problematic if a single national MNO is left out of the agreement)	Least operational complexity: an MNO can upgrade their networks and expand the coverage of its 5G network at the request of a customer
Relevant cost and revenue sharing arrangements	Cost and revenue sharing agreements can be made in any case, in the event that an extra party contributes to finance the initial investments.		
5G connectivity service provision	TO service provider integrates the role of MVNO, buying wholesale network resources from an MNO	B2B MVNO	Same MNO
Main value proposition	The TO service provider can control the specific connectivity QoS for its UC requirements. If an OEM is the TO service provider, it can use the connectivity to provide additional ancillary services for its vehicles.	A B2B MVNO that specialises in offering connectivity services for transport Use Cases will market its offer as one that is more tailored to deliver the specific needs (incl. after sales) of the TO customer	Transport companies can rely on their existing trusted parties; the same owner of the network is the one providing the 5G service, thereby avoiding intermediaries, being in more control of the coverage in each area and roaming agreements
Relevant cost and revenue sharing arrangements	Three-way SLAs to establish the distribution of liability and the process for compensation in case of damage caused by a network issue.		Simpler and more direct SLA with TO service providers for the limitations of responsibility in case of network issues and the distribution of the liability

Table 15. Validated business model options for **Remote operation service aspects in Scenarios L3 & L4**.

	Remote operation and transport service business model options for scenarios L3 & L4: transports along a highway within and across national borders		
	Option 1	**Option 2**	**Option 3**
TO service and revenue model	Specialised TO service provider that provides the service and the fleet manager role. It may incorporate the automated docking action.

Service priced via subscription (possibly with flat and volume-based rates) with connectivity included. | Large transport company or JV of local transport companies (the former is more feasible in scenario L4 and the latter in L3).

It can provide the service to other transport companies when they have excess capacity. The TO service for external transport companies relies on spot pricing (price per trip, on-demand if excess capacity). | Large digital platform (possibly owned by an OEM, if not by the digital mobility app itself).

Spot pricing (per TO trip) or match-making fee (for external TO providers). |
| **TO centre deployment** | | | The platform owner (not its host or operator, if different) will likely invest in setting up the TO centres |
| **Additional investments** | Initially, the TO service provider would train truck drivers and retrofit trucks with TO technology. In the long term, with higher adoption, OEMs would incorporate TO technology in their vehicles. | Initially, the transport company would invest in training their employees and retrofitting their fleets of trucks with TO technology. In the long term, with higher adoption, OEMs would incorporate TO technology in their vehicles. | The OEM would incorporate TO technology in the vehicles from the assembly stage. |
| **Relevant cost and revenue sharing arrangements** | - Agreement with TO technology provider to contract the retrofitting of the fleets of customers;

- This SP performs the fleet manager role and deploys its own employees at warehouses for (un)loading; it also collaborates with gas stations.

- Potential revenue sharing agreements to incentivise site owners to take care of upfront investments and operating costs of installing cameras and other elements necessary for TO and automated docking.

- SLA with transport companies for liability of cargo and vehicles | - If smaller transport companies join forces to face the large investments, they can split extra revenues according to JV shares and establish a procedure to credit the teleoperation time used by each partner.

- The JV or transport company performs the fleet manager role and deploy their own employees at warehouses for (un)loading; they also collaborate with gas stations.

- Potential revenue sharing agreements to incentivise site owners to take care of upfront investments and operating costs of installing cameras and other elements necessary for TO. | - The platform collaborates with terminals and warehouses to ensure they employ people to perform tasks that drivers currently take care of, besides driving, e.g. (un)loading

- Possible revenue or data sharing agreements with road authorities to co-locate TO centres in their traffic management centres

- SLA with transport companies for liability of cargo and vehicles |

Main value proposition	A specialised provider can more easily gain the expertise to deal with the technology and to provide the service in different locations, as well as to build the necessary partnerships at scale with other key actors (gas stations, regulators for exemptions, etc.). Transport companies can have an end-to-end solution without worrying about initial investments, contracting the 5G service, training employees, etc.	The transport company retains its operations and current business model (traditionally, trucking companies take care of the entire transport). No need to wait for external actors to adopt the service, offering a quicker implementation to tackle own needs from cost-efficiency and labour shortages. Having their own drivers avoids extra liability arrangements Under this business model, the transport company could generate ancillary revenues by providing the TO service to competitors that have not adopted teleoperation technology.	Ability to scale up fast and meet the demands for teleoperated transport if demand for adoption rises fast. Transport companies avoid any fixed costs; the TO service can be booked on-demand only when necessary.
Additional operational arrangements	The TO service provider would reach agreements with gas stations to guarantee that the driverless truck can be fuelled on the road. The TO would also contract, incorporate in the dashboard and price in the TO service, the subscriptions to EF information services for VRU warnings, ETA sharing, container ID recognition and time slot reservations.		

4.4 Revenue sharing and operational arrangements

Because the adoption of teleoperated transport Use Cases will require a series of operational arrangements, liability agreements and investments in technology and infrastructure, it will also call for the sharing of costs and revenues across the stakeholders in the overall value network. Some elements may be included in the price of the TO service, such as a transfer of liability, the 5G connectivity itself or a platform's match-making fee. Others, in contrast, will entail distributing the cost-efficiency benefits derived from TO and its enabling functions throughout the value network in order to incentivise external parties to contribute in the required investments in the new systems and infrastructure.

Another source of new operational arrangements will be the need to adapt logistics sites, fuel stations, etc. to be ready to adopt teleoperation. This would require a combination of factors representing either upfront investments or operating costs, for instance having workers for the (un)loading of driverless trucks.

For the very first and last mile, the TO service provider or the transport companies would need to collaborate with terminals and warehouse owners to avoid the gaps that removing the manual drivers would cause, in terms of the additional tasks that drivers currently take care of, besides driving. During the trip, new forms of collaboration will need to be established with fuel stations and customs to guarantee a smooth driverless journey. Several of these responsibilities will be taken up by the newly defined value network role of a 'fleet manager' that interacts with all these other actors in the value chain. This role may be either incorporated 'in-house' or subcontracted by the TO service provider.

In line with the learnings from 5G-Blueprint's 'Task 3.5: Roadmap for deployment and governance', we assume that current tasks that require the physical presence of an operator of a vehicle (e.g., monitoring vehicle health, (de)coupling the trailer, fuelling or charging, monitoring cargo safety, (un)loading, providing documentation, etc.) will be either automated or taken up by an existing role, because creating a new role would imply the largest change to the current logistic processes. However, for the following tasks it is more likely that a fleet manager would be needed from the challenge to automate it or assign it to existing roles:

- **Fuelling/charging.** The most sensible and economic option will depend on the scenario and the scale of deployment. In scenarios L1 and L2, we make the conservative assumption that the new role of fleet manager will be responsible for the fuelling/charging task – e.g., compared to assuming the automation of the fuelling/charging task –, and thus we include the cost of employing additional staff in our business case tool. For larger deployments, such as major highway corridors, it makes more sense to invest in equipping stations with automated fuelling/charging infrastructure, or contract dedicated staff that communicates with the remote operator to fuel or charge the unmanned vehicle. These stations would be owned and operated by third parties; hence, we assume that part of the economic gains from the teleoperation service would be transferred to these stations to pay for the fuelling/charging service. In the water-based scenario, fuelling (or bunkering) requires either a bunkering barge to be moved alongside the vessel with the assistance of tugboats, or pipeline infrastructure which allows fuelling from the pier. In contrast to the land-based scenarios, this poses less of a challenge as current processes already require the involvement of a specialized on-shore crew.

- **Coupling/decoupling of trailers.** We assume that an employee will still need to perform this task or assist in doing so; therefore, we count the incremental cost of

employing dedicated staff in the business case tool. This cost may be an internal one: in scenarios L1 and L2, warehouse crew could also take on this task. In the assumed context, the warehouse crew and the transport company are part of the same entity, which is typically the case for shuttle runs. For example in Vlissingen, the warehouse owner MSP Onions is also responsible for the transport to the terminal. However, for larger scenarios, we assume that the fleet manager will be responsible for this task and the one contracting the required staff that performs this task.

- **Loading/Unloading**. For land-based scenarios, we assume again that a fleet manager will employ dedicated staff to take care of the (un)loading tasks that are currently done by manual drivers. In waterways transport, the (un)loading of containers usually involves the supervision of the skipper. In a teleoperation context, the remote skipper will still be able to supervise the loading, the hatches, monitor the stability of the vessel, etc. using video feeds, provided that vessels are equipped with cameras and sensors.

As an example of goods transport by truck over longer distances, we can consider the international transportation of automotive spare parts and chassis destined for after-sales use. In this case, the large variety in the types of goods makes it difficult to predict the volumes that will need to be delivered in future points in time. In addition, (un)loading of said varied cargo requires experienced and skilled staff, hindering the ease of automating this task. Therefore, the presence of employees that manually (un)load trucks is still deemed as necessary in a future with teleoperated transport of automotive spare parts by truck.

Currently, some large trucking companies already have their own employees at port terminals, in which case adopting teleoperation would not require a substantial change in their current modus operandi, as these workers could remain responsible for securing cargo in trucks, the transport company retaining the liability for it. It is implied that in the business model where the transport company offers the TO service, this cost would remain internal. Alternatively, such costs and responsibilities could be distributed among different parties, but the initiative of transport companies would be key since they would reap most of the benefits from adopting teleoperation in long-distance transport.

Toyota Motor Europe contracts external logistics service providers such as freight forwarders to plan and perform the road transport of their cargo, and pay for it on the basis of rates that are defined in yearly agreements. The metrics that Toyota uses to pay for the transport of goods depends on the type of the goods but involve the following: euro/km, euro/kg, euro/container, etc. The contracts are written with a focus on "time-bound" KPIs. The providers own and maintain the trucks and have their own fleet dispatch service that interacts with Toyota's systems for an efficient scheduling (e.g. to predict drop-off times and the pick-up of the subsequent outbound load by drivers). In this setting, the closest teleoperation business model in a highway scenario would be one in which the current logistics service provider adopts teleoperation, whether in-house or subcontracting the service, to provide the transport of the spare parts and chassis. In the example that the forwarder is to deploy teleoperation, the customer (Toyota in our example) will expect a transfer of part of the benefits in terms of reduced rates in their yearly agreements.

Other relevant investments that are subject to result in revenue-sharing agreements include the installation of cameras and CCTV at the sites, as well as other enabling assets considered in the section about enabling functions.

Lastly, another source of operational and revenue-sharing agreements is the transmission of TO-enabling vehicle, road or traffic data by multiple parties. While some of these data transactions will be mandated by regulation, and others will be incentivised by a reciprocal

sharing of in-vehicle or traffic data from different vehicles or roads, other transactions may be motivated by financial incentives. Direct or indirect financial compensation may be provided as part of the price in a connectivity subscription (e.g., for the dynamic maps of QoS and coverage that MNOs may provide to TO service providers) or as part of a (reduced) insurance premiums (e.g., for aggregated data on TO driving patterns and performance), while other data may be sold as part of a mobility service of an EF that the remote driver receives through its dashboard, such as a the ETA estimation at an intersection equipped with intelligent traffic lights and the reservation of a time slot for the truck or truck platoon. The analysis of relevant data transactions for teleoperated transport was studied in more detail in D3.2. The importance of data sharing as an important source of ancillary revenue and distribution of benefits was highlighted during the expert consultations of the validation exercise.

Yet another possible revenue sharing arrangement to consider involves road authorities. In section 3.3, we mentioned (road) authorities as candidates to contribute to 'kickstart' deployments in TO Use Cases by providing investment support, e.g. by co-financing infrastructure investments. (Road) authorities should seek to monetize these investments in a way that is directly linked to adoption of teleoperated transport and that, consequently, ensures a return on their investment while not posing a financial burden on the logistics or TO companies if these struggle to find customer demand in the initial stages of adoption – in comparison, for instance, to a loan with fixed, timed repayments. One such mechanism would be charging variable tolls (in other words, usage fees) per distance travelled by the connected trucks on the 'enabled' highways. By enabled highways we mean those in the area where the authority has contributed to finance infrastructure investments such as TO centres or 5G networks. Road authorities could charge TO service providers or vehicle owners through road distance-related charging (i.e., highway tolls or vignettes), or through a connectivity subscription as a function of network usage.

In conclusion, establishing upfront revenue sharing agreements would ease the upfront capital requirements by a single company and incentivise other parties to engage in the necessary investments and adoption of new processes. This way, such arrangements could ease the transition to public highway scenarios.

4.5 Scenario W3/W4

Scenario W3 & W4 scenario consists of the inland waterway transport of goods through rivers and canals via teleoperated barges. This scenario includes waterways where a significant volume of transport flows is present, for example a canal between two ports in the same country or across borders (for example, a river that crosses several EU countries). The vessel may be completely unmanned or retain a limited amount of crew on-board.

Although they represent longer-range scenarios, potentially including long-haul trips across countries, some Use Cases are already feasible in the short run. In section 3.2, we identified the direct TO of semi-autonomous barges as a feasible UC in the short term. Vessels may retain part of the crew on board for complex manoeuvres or certain tasks, albeit maybe for only the necessary parts of the trip. Seafar is already offering a commercial service for this UC with its captain-as-a-service model. In the longer term, vessels are expected to rely on automation for longer parts of the trip and require less workers on-board during their journey.

To avoid redundancy, in this section we only focus on the differences with the equivalent road transport scenarios (i.e., scenarios L3 & L4). While traffic conditions in waterways are simpler compared to public roads, which limit the challenges at the technical level from a safety

perspective, the nature of the connectivity challenges is shared between the land and road scenarios. Assuming a substantial adoption of remotely-operated vessels, we also assume that covering the latency, bandwidth and reliability requirements, as well as overcoming the potential coverage issues from buildings or container ships blocking wireless signals, will make the deployment of 5G base stations along waterways and around ports necessary.

The 5G business model aspects defined in the previous section for long-haul road transport, i.e. those related to the deployment of 5G infrastructure and the provision of 5G services, are also valid for waterways transport. Therefore, we refer the reader to Table 14 for a recap of 5G business model options. The lines and table below focus on the business model aspects related to the provision of the TO service.

A validated business model option for the provision of TO services for vessels is one in which a specialized service provider offers an integrated service, deploying and managing its own TO centre, training and employing its own remote captains, retrofitting TO technology in the vessels. However, this TO service provider would not hold ownership of the vessels nor the cargo. The owner of the vessel or the cargo would be the end customer of the TO SP, either directly or indirectly through a forwarder, for instance, and would contract the TO service for the navigation of the vessel from origin to destination.

This is seen as the most feasible option in the short run according to our consultations, although it must be noted that this is a similar business model to Seafar's current model in Belgium and the Netherlands.

Whether the TO service provider contracts the 5G connectivity service will depend on the customer type. In the case of a recurrent customer that is an owner of a small fleet of vessels, the TO SP can take care of arranging the contracting a 5G subscription as part of its integrated service. However, in the case of large fleet owners, it may be the owner itself that arranges the contracting of the 5G connectivity subscription; it may be cheaper for them, since they would probably also put it to other uses.

The personnel that is required to be on board, e.g., helmsmen, may still be employed by the shipowner. However, with the introduction of highly-automated barges, which will reduce the presence of manual workers, the TO service provider may also take the responsibility to coordinate personnel for other tasks than navigation. This may be done either by employing these professionals or by subcontracting the service to an external fleet manager. Along a vessel's journey through an inland canal, for instance, the presence of an on-site worker may be needed at specific locations along the journey (e.g., in municipalities that have stricter regulations regarding crewless vessels, in areas where manoeuvres are more complex, or in spots where network availability is more limited). The TO service provider would be responsible for arranging the manual operation once the vessel reaches these areas.

Table 16. Validated business model options for **Scenarios W3 & W4**.

	Option 1	Option 2
TO service and revenue model	Specialised TO service provider that provides the service. It may incorporate the fleet manager role or subcontract it. For customers that are small vessel owners, it can rely on spot pricing, according to the trip's length.	A (local) logistics company can invest to take the role of TO service provider and fleet manager, with its own captains and employees.
TO centre deployment	For recurrent owners or forwarders with larger volumes of predictable operations, a volume-based subscription can be used.	The logistics company may invest in setting up its own TO centre. However, to support with the investments and help scale operations, they may join forces with trusted partners from the logistics chain, e.g. a forwarder.
Additional investments	Initially, the TO service provider would retrofit the TO technology into the vessels. In the long term, large vessel owners can be expected to invest in incorporating the technology in their fleets. In Option 2, the logistics company is less likely to build the expertise to control the retrofitting of the technology; it would either subcontract the service or only offer the service to already-equipped fleets.	
Relevant cost and profit sharing arrangements	- Collaborating with external fleet managers, when relevant, and possibly site owners, to ensure that an employee is ready to perform required manual tasks where necessary - Potential cost sharing agreements, or price discounts, to incentivise vessel owners to take care of upfront investments and operating costs of installing cameras and other elements necessary for TO.	- Agreement with TO technology provider to contract the retrofitting of the fleets on behalf of fleet owners, when relevant - Potential cost sharing agreements, or price discounts, to incentivise vessel owners to take care of upfront investments and operating costs of installing cameras and other elements necessary for TO. - Possible co-financing and profit sharing arrangements with forwarders in the case that they contribute to set up and manage TO centres.
Main value proposition	A specialised provider (e.g., a risk finance-supported startup) can more easily build the in-house expertise to deal with the technology and to provide an integrated service. It can also leverage the fact that TO is its core business and expertise, as well as a flexible organisational and asset structure to scale up faster to different countries and build up early market share.	Logistics companies have expertise that they can leverage from the managing of the transport service and for the navigation of vessels. They can leverage partnerships with existing customers, who would also be the prospective customers of the TO service. Under this model, important upfront costs from the installation of TO technology in barges and the setting up of TO centres would be (partly) externalised.

5 BUSINESS CASE ANALYSIS

The overarching objective of this section is to help clarify the business case of 5G-based teleoperated transport Use Cases. In turn, this will help improve the descriptions of business models presented before by allowing to allocate costs to each business model or estimate revenues for the different main parties of the value chain in each business model.

During our expert interviews and workshops, logistics companies and telco operators alike stressed the need to clarify the business case of adopting teleoperated transport Use Cases. Without a clearer understanding of the associated investments, it will be difficult to convince these key stakeholders, or any potential investment kickstarters, to see the practical value of the technology and consider the adoption of the identified business models in a timely manner, even if they have been validated as feasible theoretically.

Regarding the cost-benefit analysis, this section builds on and extends the work carried out in the previous reports of 5G-Blueprint's business and governance work package. D3.1 [2] provided a tool to assess the operational business case of using direct remote control of trucks in a safe 'local' road environment. D3.2 [1] provided a preliminary quantitative assessment of the potential benefits of the teleoperated transport Use Case of using TO to assist driverless trucks that drive autonomously on highways but cannot handle unexpected road and weather conditions. D3.1 and D3.2 focused on costs at the operational level, without including network infrastructure upgrades. D3.3 [3] provided a thorough techno-economic analysis to assess the technical and economic feasibility of using 5G connectivity technology to provide teleoperated transport with different types of vehicles and across five different deployment scenarios. It examined the costs and benefits of deploying a 5G network, a teleoperation centre, and equipping vehicles (such as barges, cranes, and trucks) with teleoperation technology. **This section will complement these two sets of previous work by assessing the impact of adopting teleoperation UCs on current costs and allocating such costs to the different business models**.

To increase the robustness and representativeness of our analysis, besides the inclusion of different scenarios and Use Cases, we will also consider different settings in terms of the availability of 5G networks and of alternative 5G-based UCs to allocate any upgrade costs among them and TO services. To this end, we will consider conservative assumptions in which dedicated deployments put more financial stress on the TO business case as well as situations with more cost-splitting among UCs – which can be expected to be a realistic case in many settings, especially in larger geographical scenarios where deployments are expected later in time. With the aforementioned objectives in mind, we have developed **a business case tool adapted to each of the deployment scenarios[9]**. This tool allows any interested user to explore if there is a positive business case of deploying TO Use Cases in the setting that they have in mind, in terms of deployment scenarios, Use Case types (i.e., types of vehicles to be remotely operated), size of the area to be covered, business model options (e.g., whether the TO centre is managed by an 'outsourced' independent service provider[10] or 'inhouse' by the TO beneficiary itself), and the specific scale, costs and characteristics of the transport operations in a given site and country. While this tool relies on a simplified cost model, this model incorporates all the main cost elements identified and calculated in the methodology section. In addition, the tool provides a simple and flexible way to calculate the business case

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[9] This tool has been provided as open access and can be found in Zenodo under the following link: https://zenodo.org/records/13141691

[10] Understanding by it the type of entity described in section 4: a specialised service provider that offers TO across different markets, i.e. at the international level, and may be independent to established logistics players.

of teleoperated transport, therefore providing a user-friendly tool that can be understood as a blueprint that applies to hypothetical investments throughout the EU.

For illustrative purposes, we have put such tool in practice by estimating the business case of deploying TO in a series of various (hypothetical) contexts: for each scenario, we applied our cost model to specific geographical settings that are relevant to 5G-Blueprint. However, the outcomes in terms of cost quantifications have to be treated carefully, as the business case of any potential deployment depends on many variables that are context-dependent. In fact, many of the underlying operational variables have to be entered manually in the model by the user.

Regarding the interpretation of the tool's output, it must be noted that the model yields the incremental costs from adopting, all else equal, the different teleoperated transport UCs. Therefore, a negative value means a cost reduction compared to today's manual operations. Since this cost reduction represents a financial gain from the point of view of the logistics company or the site owner, negative values are portrayed in green. Likewise, a positive value is portrayed in red because it shows an increase in expenses compared to current manual operations.

A thorough explanation of the assumptions, cost elements and calculations is presented in the Methodology section, more specifically, in section 2.2. Annex C also presents a list of values for a series of inputs used in the model's calculations.

A key shortcoming of this study is that we only applied the tool to road transport UCs. This decision was made for two reasons, namely availability of data and practical relevance. Regarding the former, a lack of available data on several cost elements (i.e., the impact on maintenance, needs for manual support, effect on crew reduction, reliable TO/V ratios to employ, etc.) would have required to extend the already large list of assumptions, which in turn would reduce the reliability of the estimations. Regarding the latter, waterway goods transport is not considered to be as much of a hurdle compared to road transport, with commercial services already existing, and there are many aspects that would be redundant to explain thoroughly, as many cost elements are shared – or their logic is equivalent – between road and waterway transport in our business case tool. In addition, automation for barges is already available, and in fact, Seafar's TO services already involve automation, with up to 70 or even 80% of the trip along a canal being done autonomously by the vessel, with the supervision of a captain in the TO Centre. With a captain on-board, TO can take over when the captain rests, which already increases uptime. A user can still use the tool with caution by providing its own input, as some estimated values that need to be pre-defined, such as the annual depreciation from the retrofitting costs for barges, are included in the model.

5.1 Business case / cost-benefit analysis of scenario L1 BMs

In this section, we apply the business case tool to illustrative deployments of short range teleoperated transport Use Cases in the limited setting of a port terminal, exploring situations in which 5G private networks are available as well as those in which network upgrades are required. More specifically, we will consider the remote operation of passenger cars, skid steers, cranes, reach stackers and terminal tractors, focusing on the geographical context of the project while also trying to generalise our findings.

Already in scenario L1, TO can provide benefits from more efficient and faster handling and operations, as well as avoiding potential labour shortages, but the business case is not yet clear. In general, the business impact depends on the scale of operations, which will determine

the actual cost savings from more efficient operations as well as the required size of the investments in 5G and TO infrastructure and other elements.

General cost-savings sources chiefly include the reduction of idle times from driving vehicles and operating equipment. Additional expenses come from the following: tasks that require having an operator in the field (fleet manager role), equipping vehicles with TO technology, investing in a remote-control centre, and investing in telecommunications network upgrades.

For cranes or skid steers, there is a potential business case within the terminal itself, from the higher cost efficiency and from solving employee shortages: it is very hard to find employees for these tasks, especially for night shifts.

But we start our quantitative analysis below by applying the business case tool to the specific Use Case of using remote operation to transport passenger cars individually from one point of the port to another. We use the practical example of Zeebrugge and derive our assumptions from the expert input that we gathered during our business model validation interviews.

ZeeBrugge, part of the Port of Antwerp-Bruges, is the port with the largest roll-on/roll-off handling (i.e., cargo that is driven from and on board of vessels) of cars in the world.

In Zeebrugge, companies like International Car Operators (ICO) and Toyota Motor Europe (TME) manage port terminals and handle large numbers of passenger cars. ICO's core business is loading and discharging cars from vessels and trains. ICO has a big site in ZeeBrugge: there is up to 7km distance within their sites. On average, car movements from point A to B (e.g., one parking block to another) usually cover just up to 500m or 1km. They do not own the cars they move and move cars of many brands. Currently, their yard optimisation system already optimises the transports and distances (i.e., which cars to drive where and when) and the compacting of cars at the parking location.

Toyota, one of the largest car manufacturers in the world, handles the transport of its own cars at several locations throughout Europe, where it receives vehicles from their factories in Japan. In TME's storage yard of Zeebrugge, for instance, they have space for over 20 thousand cars; when a new badge of car cargo is brought by a vessel, it may carry over 3 thousand cars. In total, TME has around 500 jockeys moving cars in the EU, counting those employed by TME and by 3rd-parties. From vessel to storage yard, in some other places in the EU it can include public roads. The distances vary: some can be 1km, some just 300m.

Today, TME moves an average of around 1,500 cars per day from one side of the port to the other. At ZeeBrugge, ICO does the same type of operations but at an even larger scale.

The cost-savings sources of this Use Case for terminal site owners mainly arise from the manual driving of the cars and the associated inefficiencies. Currently, cars are driven manually by the terminal's employees, who after delivering a car to its destination at the site, need to be driven back to the origin (e.g., where the vessel docked) to repeat this process and drive more cars to the storage parking. A bus brings several drivers (usually, 6 at a time) back to the initial location of the vehicles. TO can avoid this idle time and also avoid the cost of the bus driver.

For reference, below we include a map of Zeebrugge's site. Toyota's terminal is the one numbered 30 on the map, while ICO's terminals are 38, 39 and 40.
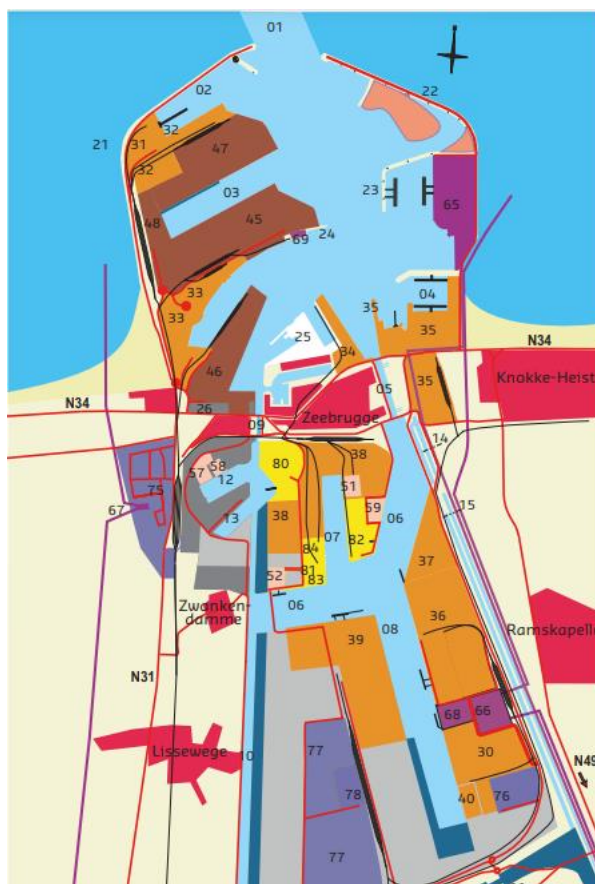
Figure 11. Plan of Zeebrugge. Source: Vlaamse Dienst voor Arbeidsbemiddeling en Beroepsopleiding (VDAB)

A remaining challenge is to optimise remote driver availability and reducing vehicle idle time (thus driver or operator waiting times); therefore, with TO, waiting times will not be reduced completely, as that would require having idle remote operators that are guaranteed to be available at a certain point in time when the vehicle or equipment becomes idle.

In Zeebrugge, there is already a private 5G network, therefore we assume that no 5G network upgrades are needed. We also start with the assumption that the TO centre management will be done inhouse by the terminal itself, according to 'Option 1' among the L1 business models. This represents a feasible short-term business model of a single terminal investing in TO for its own operations. Below, we provide the outputs of the business case tool in terms of the FTEs needed and the OPEX, CAPEX and total costs of deployment.

Business parameters (enter manually)

Variables	Scenario L1: Terminal teleoperation
Transport type	Passenger car
Equipment/vehicle type	Passenger car
Remote control center type	Inhouse

Input: Logistic operations	Value	Assumption
Trips/operations per vehicle (average no./day)	1.500	Number of cars moved per day
Trip duration (h) (excl waiting times, etc)	0,25	Assuming 15min per movement
Salary manual driver	29	25 €/h for the car driver, 25/6 for the bus driver
Waiting time per trip (h)	0,25	15min to be driven back
Resting per trip (h)		Not relevant for this UC
Shifts (no./day)	1	Assumed
Shift duration (h/shift)	8	Assumed
Operational days (no./year)	250	
Vehicle maintenance (€/year)	0	Not relevant for this UC
Vehicle insurance (€/year)	0	Not relevant for this UC

Input: Logistic operations with TO		Assumption
Idle time per trip (h) with TO	0	
Salary remote driver	25	

Business case (yearly basis)

Socio-economic impact	Output
Required FTEs pre-TO	99,73
Required FTE with TO	49,87
Change FTEs with TO	-49,87

Cost differentiation	Incremental value
Salaries post TO	-€ 3.125.000
TO equipment costs	€ 144.614
Vehicle equipment costs	€ 4.612.500.000
TOTAL	€ 4.609.519.614

Figure 12. Operational business case for the passenger cars Use Case in Zeebrugge.

Business case (yearly basis)

Socio-economic impact	Incremental gain
Change in required FTEs	-49,87

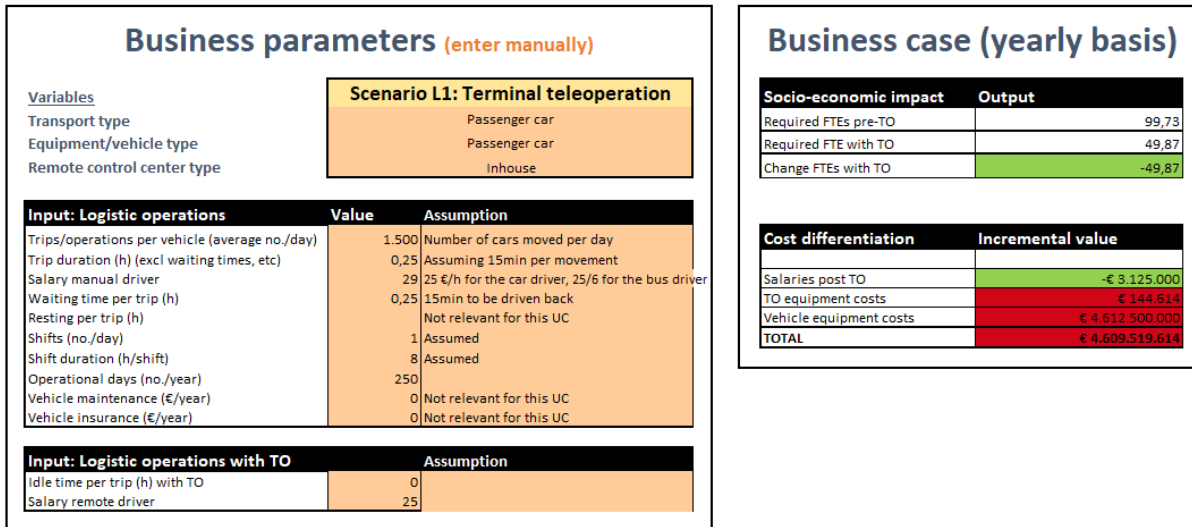| Cost differentiation	Incremental gain
Operational costs	€ 4.609.519.614
TO center infrastructure costs	€ 254.129
5G subscription costs	€ 0
TOTAL	€ 4.609.773.743

Business case (cumulative 10y)

Cost differentiation	Incremental gain
Operational costs	€ 46.095.196.144
TO center infrastructure costs	€ 2.541.287
5G subscription costs	0
TOTAL	€ 46.097.737.431

Figure 13. TCO of the passenger cars Use Case in a Zeebrugge terminal.

Under the assumed parameters, we can conclude that there is no business case for a company like Toyota or ICO to invest in TO *only to move these vehicles* – meaning: if no additional TO UCs can be materialised at a later stage. This is due to the fact that retrofitting each vehicle with TO technology only to remotely operate it within a terminal for logistics purposes is prohibitively expensive. Compared to the other types of vehicles that 5G-Blueprint's UCs consider for remote operation, passenger cars are not treated as a 'tool' but as cargo. Therefore, using TO only for logistics purposes would mean making the TO technology investments only for a very short part of their lifetime.

However, if equipping the vehicles is done by the manufacturer already during the manufacturing process and it is the OEM that bears these costs, a positive business case emerges. Equipping vehicles at the factory stage would of course be cheaper than retrofitting

the technology. Having vehicles with C-V2X and TO technology would enable also other Use Cases that could be monetized during the lifetime of the car, such as valet parking or ride sharing that uses remote operation to relocate the vehicles. Eventually, the cars may also be sold to customers at a premium.

Therefore, we consider two alternatives:

a) one in which we consider the TO equipment costs as external, and therefore we assume them away in the cost model, and

b) one in which we spread the costs throughout the lifetime of the vehicle (assumed to be 12 years for passenger cars), therefore substantially reducing the yearly expenses. Regarding alternative (a), in the case of ICO in ZeeBrugge, for instance, it would received TO-enabled vehicles, and the cost of including the technology would have been previously borne by each given OEM. Regarding alternative (b), note that previously, the full cost of retrofitting a vehicle was included as a one-year expense, as each vehicle would be retrofitted for the sole purpose of moving it around the port.

Under alternative (a) there is a positive business case. Part of the benefits can be passed to the OEM in the form of quicker handling services, as discussed during the business models section, in order to incentivise OEMs to equip their cars with TO capabilities. A financial incentive would probably be less convincing, since the cost efficiency gain per car is small, just 7 EUR per vehicle.

Business case (yearly basis)

Socio-economic impact	Output
Required FTEs pre-TO	99,73
Required FTE with TO	49,87
Change FTEs with TO	-49,87

Cost differentiation	Incremental value
Salaries post TO	-€ 3.125.000
TO equipment costs	€ 144.614
Vehicle equipment costs	€ 0
TOTAL	-€ 2.980.386

Figure 14. Operational business case output for the Zeebrugge example where cars are already equipped with TO tech.

Business case (yearly basis)

Socio-economic impact	Incremental gain
Change in required FTEs	-49,87

Cost differentiation	Incremental gain
Operational costs	-€ 2.980.386
TO center infrastructure costs	€ 254.129
5G subscription costs	€ 0
TOTAL	-€ 2.726.257

Business case (cumulative 10y)

Cost differentiation	Incremental gain
Operational costs	-€ 29.803.856
TO center infrastructure costs	€ 2.541.287
5G subscription costs	0
TOTAL	-€ 27.262.569

Figure 15. Business case tool output showing the overall business case for the Zeebrugge example where cars are already equipped with TO tech.

Under alternative (b), the business case is still substantially negative, although we consider the costs of equipping vehicles to be 33% cheaper than retrofitting.

Business case (yearly basis)

Socio-economic impact	Incremental gain
Change in required FTEs	-49,87

Cost differentiation	Incremental gain
Operational costs	€ 253.269.614
TO center infrastructure costs	€ 254.129
5G subscription costs	€ 0
TOTAL	€ 253.523.743

Business case (cumulative 10y)

Cost differentiation	Incremental gain
Operational costs	€ 2.532.696.144
TO center infrastructure costs	€ 2.541.287
5G subscription costs	0
TOTAL	€ 2.535.237.431

Figure 16. Business case tool output showing the overall business case for the Zeebrugge example where the site owner needs to equip cars with TO tech.

We can conclude that for the UC of moving passenger cars within a logistics site, the business case of 5G-based teleoperation is only possible, even when a 5G network is already available,

if automakers are convinced of the value of equipping their cars with TO technology, which would require them seeing a potential use of teleoperation during the lifetime of the car. Therefore, enabling this UC would require the expectation that TO can also be used for passenger transport. Examples of passenger transport UCs include the remote delivery of rental cars or ride-sharing cars, remote valet parking of privately owned passenger cars, etc.

In general, any cost efficiency benefits of this UC arise from time efficiencies, which translate into less costs from salaries. The number of required FTEs is halved in our model, although in this case it should be interpreted in the sense that the same number of employees can do the job in half of the time, as the idle times from travelling to pick up the cars are avoided. With remote operation, the driver can take over a new vehicle as soon as the previous one arrives at its destination. The job that would become redundant would be that of the bus driver that brings the manual car drivers back to the starting point. It follows that the costs of acquiring or renting new buses would also be avoidable in the future, although this has not been included in the model.

Next, we extend the previous example to a more general one in which a port terminal makes use of an existing a private 5G network and adopts the UCs of remote operation of cranes, reach stackers and terminal internal tractors. We assume that 1,500 containers are processed each day. The other variables are also assumed for illustrative purposes. We assume that the waiting times and the TO idle times stay the same for the reach stackers and the internal tractors that move the containers. Since these variables remain constant but the trip or move time of internal tractors is longer (we assumed 10min per trip), because they transport containers farther away, the relative benefits of teleoperation are smaller, because more TO kits need to be purchased and more vehicles retrofitted with TO technology.
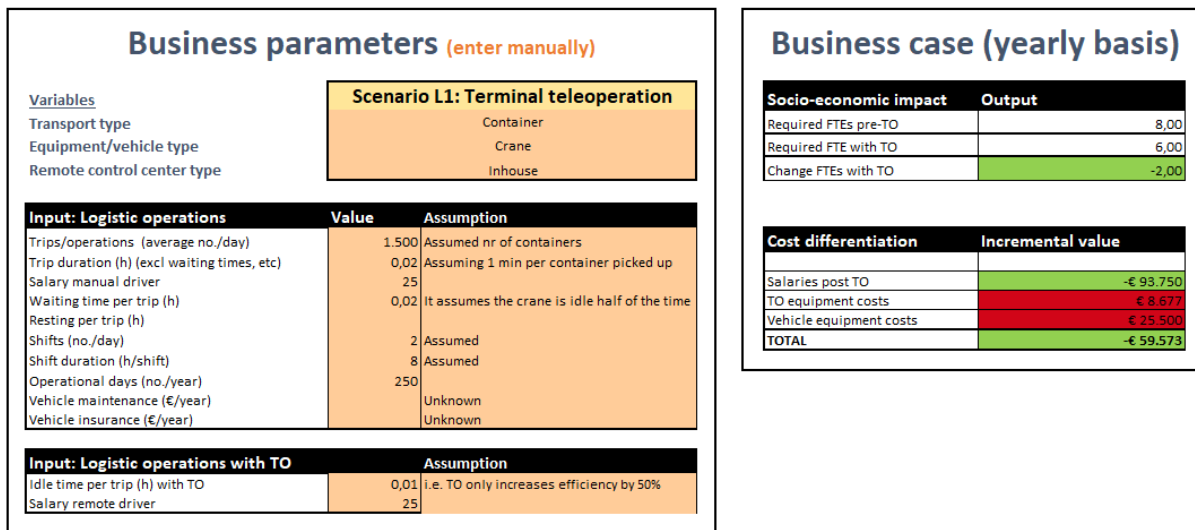

Figure 17. Operational business case output of the example for teleoperated cranes

Business case (yearly basis)

Socio-economic impact	Output
Required FTEs pre-TO	8,00
Required FTE with TO	6,00
Change FTEs with TO	-2,00

Cost differentiation	Incremental value
Salaries post TO	-€ 93.750
TO equipment costs	€ 8.677
Vehicle equipment costs	€ 4.290
TOTAL	-€ 80.783

Business case (yearly basis)

Socio-economic impact	Output
Required FTEs pre-TO	36,00
Required FTE with TO	34,00
Change FTEs with TO	-2,00

Cost differentiation	Incremental value
Salaries post TO	-€ 93.750
TO equipment costs	€ 49.169
Vehicle equipment costs	€ 22.880
TOTAL	-€ 21.701

Figure 18. Operational business case output for TO reach stackers (left) and internal tractors (right).

The total business case for the three types of vehicles and machinery that become remotely operated in this hypothetical port terminal is presented below.

Business case (yearly basis)

Socio-economic impact	Incremental gain
Change in required FTEs	-6,00

Cost differentiation	Incremental gain
Operational costs	-€ 162.009
TO center infrastructure costs	€ 88.187
5G subscription costs	€ 0
TOTAL	-€ 73.822

Business case (cumulative 10y)

Cost differentiation	Incremental gain
Operational costs	-€ 1.620.091
TO center infrastructure costs	€ 881.867
5G subscription costs	€ 0
TOTAL	-€ 738.224

Figure 19. Total TO business case for our example with cranes, reach stackers and internal tractors within a port terminal.

To extend the analysis, we reduce the assumption that a 5G private network is already present at the site, as it was the case in the example of the Port of Antwerp-Bruges at the Zeebrugge site. In this last hypothetical example, assuming a pessimistic/realistic adoption of teleoperation – in terms of number of vehicles/equipment covered in the upcoming 10 years[11] –, the business case remains positive as long as the size of the port area where the 5G network upgrades are deployed is less than 3,2 and 4,5 square kilometres for private network and coverage-on-demand deployments, respectively. The image below illustrates the case for a private network covering 3km^2.

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[11] The definition of the adoption expectation scenarios and the forecasts of specific vehicle amounts covered over time were formulated in D3.3 using the Bass Diffusion Model.

Business parameters (enter manually)

Variables	Scenario L1: Terminal teleoperation		
5G network deployment model	Private network		
Size of the area to be covered (km2)	3,0		
Adoption forecast expectations	Pessimistic/realistic		

Operational business case result	Required FTEs TO	Change FTEs	Result op. costs
Cranes	6	-2	-59.573
Reach stackers	6	-2	-80.735
Terminal internal tractors	22	-2	-21.701

Business case (yearly basis)

Socio-economic impact	Incremental gain
Change in required FTEs	-6,00

Cost differentiation	Incremental gain
Operational costs	-€ 162.009
TO center infrastructure costs	€ 83.480
5G subscription costs	€ 74.764
TOTAL	-€ 3.765

Business case (cumulative 10y)

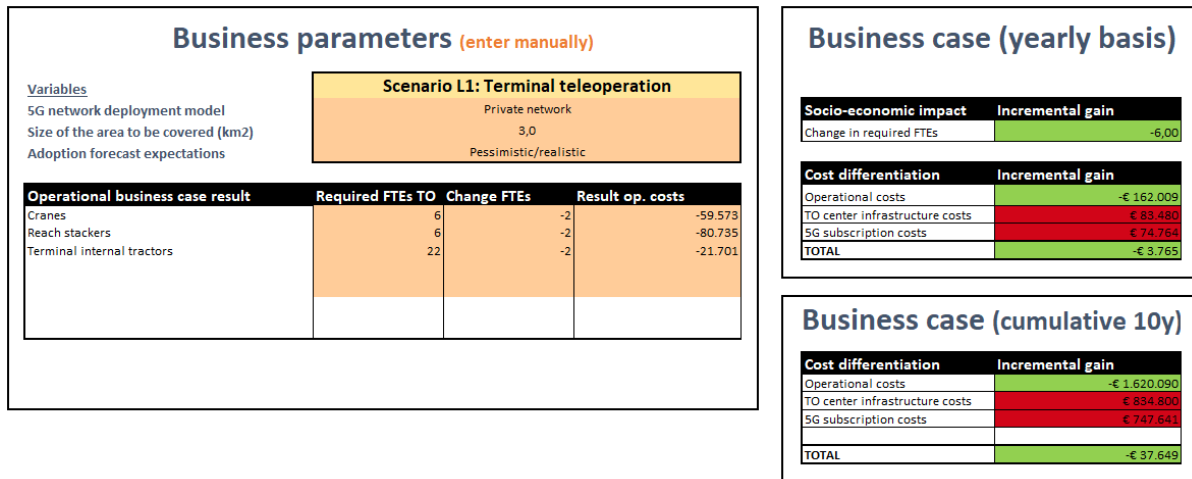| Cost differentiation	Incremental gain
Operational costs	-€ 1.620.090
TO center infrastructure costs	€ 834.800
5G subscription costs	€ 747.641
TOTAL	-€ 37.649

Figure 20. Total TO business case for our example with cranes, reach stackers and internal tractors within a port terminal, assuming a new private 5G network is built.

The specific cost of training employees to become capable and licensed remote operators is not included in our model. Therefore, part of the estimated profits will need to cover these investments. Nevertheless, the option of outsourcing the TO service implicitly incorporates such costs in the higher prices that the external service provider charges for the TO service.

Lastly, for the sake of completeness, and to estimate the relevant costs in the second option in the business models described for scenario L1 ('Option 2' in Table 9. Summary of validated business model options for Scenario L1.), we apply the business case tool to a setting in which an independent, international TO service provider is contracted to provide the remote operation service in the area. The 'outsourcing' option assigns the responsibility of investing in the TO equipment and TO centre to the external service provider. Therefore, these costs are not accounted for in the tool, which takes the perspective of a terminal or transport company seeking to adopt TO for its operations. However, the costs per hour of operation are assumed to be higher: the TO service provider is assumed to charge per hour, at a rate 20% higher compared to 'inhouse' remote operator salaries.

Business parameters (enter manually)

Variables	Scenario L1: Terminal teleoperation		
5G network deployment model	N/A		
Size of the area to be covered (km2)			
Adoption forecast expectations	Pessimistic/realistic		

Operational business case result	Required FTEs TO	Change FTEs	Result op. costs
Cranes	6	-2	-12.000
Reach stackers	6	-2	-33.210
Terminal internal tractors	22	-2	247.888

Business case (yearly basis)

Socio-economic impact	Incremental gain
Change in required FTEs	-6,00

Cost differentiation	Incremental gain
Operational costs	€ 202.678
TO center infrastructure costs	€ 0
5G subscription costs	€ 0
TOTAL	€ 202.678

Business case (cumulative 10y)

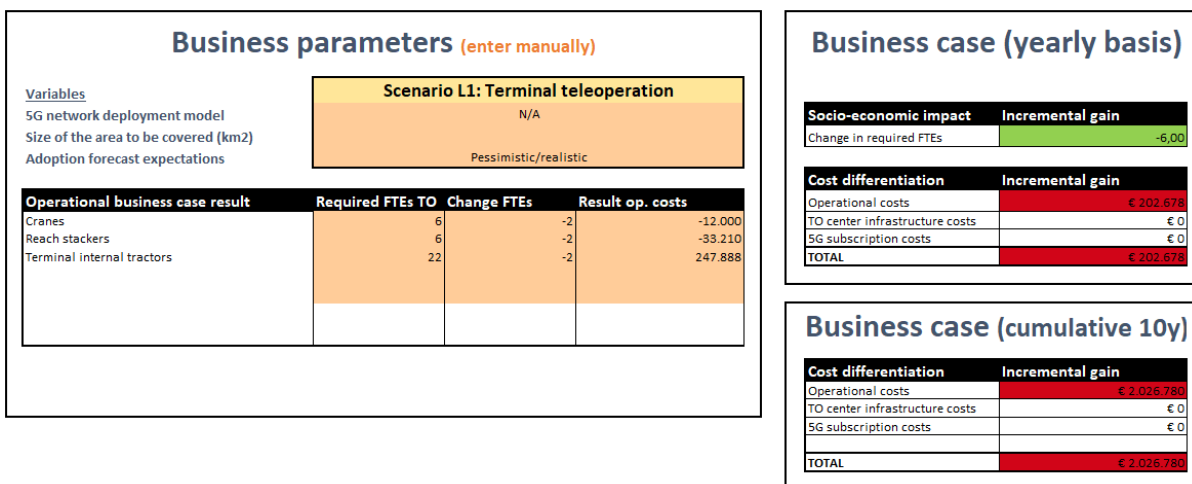| Cost differentiation	Incremental gain
Operational costs	€ 2.026.780
TO center infrastructure costs	€ 0
5G subscription costs	€ 0
TOTAL	€ 2.026.780

Figure 21. Total TO business case for our example with cranes, reach stackers and internal tractors within a port terminal, for the business model with an external TO service provider.

Using the same example considered above, the 'outsourcing' model results in a negative business case. In the case of terminal tractors, for which – under the present, illustrative assumptions – the benefits of TO in terms of idle time reduction were limited, adopting TO

would actually result in a loss. While the remote operation of cranes and reach stackers would still yield a small but positive business case, this benefit evaporates once any kind of 5G network upgrades are considered.

While the findings under the current specific setting and assumptions should not be liberally generalized, this goes to show that **the business case in this scenario is highly dependent on the operational efficiency gains** and the possibility of translating them into savings in terms of FTEs and salaries.

The last example also shows that the business model of outsourcing the TO service to an external company is, all else equal, a less sensible option in the limited scope of a scenario L1 deployment in a port terminal or other logistics site.

In contrast, while in the present exercise it would not impact the TCO in the long term, the business model option of forming a joint venture between sites or terminals can be appealing to split the upfront costs of 5G network upgrades.

Besides the hypothetical nature of the present exercise, we must note the limitation from the fact that several aspects are not taken into account due to the difficulty to quantify them, either from lack of data or too much uncertainty.

On the one hand, there are also certain economic benefits for port terminals and other logistic sites that are not quantified in the model for lack of clear data on them, but that would provide additional motivations to these sites to invest in TO Use Cases. Economic benefits for ports include the ability to process more cargo from vessels if the space in docks is made available quicker by reducing idle times. Having cars in storage for a shorter amount of time will reduce the OPEX of terminal operators. Another type of benefit relates to space usage efficiency from the storage of containers, cars, etc. A better ability to compact cargo will result in operational efficiency gains. For instance, if a terminal operator like ICO, who stores large numbers of vehicles, is able to process vehicles more quickly thanks to TO, it will achieve a higher stock turnover and in turn increase revenues. Removing this idle times means that they can move more cars per hour, therefore increasing operational efficiency.

On the other hand, it must be noted that this analysis presents the return on the financial investment but excluding the important risk element of said investment and the associated organisational changes.

5.2 Business case / cost-benefit analysis of scenario L2

Scenario L2 may involve public roads (even inside the port) even if distances are very short. For example, a shuttle run between a port terminal and a warehouse outside the port may cover only a handful of kilometres but require a remotely operated truck to enter and drive through the open road and navigate mixed traffic.

This is the case of the example we will use as reference in this section to apply the business case tool of scenario L2. We consider a shuttle run around the Vlissingen site of the North Sea Port, more specifically a trajectory between the terminals of Kloosterboer/Lineage or Verbrugge and nearby warehouses (such as that of MSP Onions, which is plotted in the map below). This represents a stretch of about 6km through a bi-directional open road, mostly having one lane per direction, which is currently frequented by trucks but also passenger vehicles.

Figure 22. Map of the setting of reference for our Scenario L2 calculations.

Under this deployment scenario and the trucking Use Case, we assess the benefits of TO arising from operational efficiency: remote transport would allow each driver to supervise more than one vehicle during the same journey, by taking over a different truck when another is idle. In the future, if in line with the feasible evolutionary path of teleoperation Use Cases, the TO-to-vehicle ratio goes down from the adoption of automation and the more indirect use of use of TO, cost-efficiency benefits will be higher.

Other sources of benefits of an economic nature that we do not quantify through our model include the following:

- A quicker dispatch of containers: if the container stays longer than 24h in the port awaiting to be transported, the transport company must pay. If by reducing idle times, TO can provide a substantially quicker processing of containers, it will result in indirect cost savings for the transport company.

- Relieving job shortages: transport companies struggle to have a manual driver available at a specific point in time, especially for night shifts. The higher the TO-to-vehicle ratio, the lower number of drivers that will be needed for the same scale of operations.

- Truck platooning. In addition, truck platooning would fraction driver needs by the size of the platoon (which is expected to be realistic for small groups of 2 or 3 trucks). However, the practical sense of doing platooning in the short-haul needs to be explored for each implementation area; more specifically, to assess whether there would be enough availability of trucks that share trajectories and delivery times.

The business model options defined in section for scenario L2 were the following:

- **Option 1**: Private network with co-investment from port and TO platform from logistics partners.

- **Option 2**: Private network with co-investment from city and TO platform from local transport firms.

- **Option 3**: Public MNO network coverage on-demand and independent TO provider.

Both options 1 and 2 imply an inhouse TO centre deployment and a private 5G network deployment in terms of TO and 5G infrastructure, respectively. The difference between these business models will therefore not be at the cost level but at the operational and commercial levels in terms of the agreements that the co-investing parties and the joint venture partners

will need to reach between and within themselves.

Below we show the results of applying the business case tool to the mentioned scenario and under the different business model options.

For its business case calculations, D3.1 [2] used three reference cases, based on empirical data of transport companies operating in the Zeeland region (located in the south of the Netherlands), as is the case in our reference shuttle run example. Out of those transport companies used as reference, the present section will use the example of Transport Roosens, which is a consortium partner and, in D3.1's dataset, exhibited the most relevant trip types in terms of length (an average of 1.5h, compared to multiple hour journeys in the other 2 cases). The average number of trips (or transport orders) that is executed per day was estimated to be 276.

We assume a trip length of 20min for the return (driven) trip, plus 5min of waiting time – a conservative assumption, since this figure could be much higher in a large port – and 30min for the loading and unloading of the containers. In such short-distance trips, we assume that the driver can perform a regular shift of 8 hours and start and end its daily assignments in the same location; therefore, we assume that there is no difference in resting times for manual and remote drivers in this scenario.

We also perform a simple sensitivity analysis by changing the amount of idle time that remote operation can avoid, which is linked to the TO-to-vehicle ratio. A TO-to-vehicle ratio of 1 (or 1:1) would mean that the remote operator stays with the same truck all of its time, either supervising it, waiting, or directly controlling it. A TO-to-vehicle ratio of 0.5 (or 1:2) would mean that each operator is responsible for 2 continuously operating trucks, on average, during his entire shift. Since in this scenario we consider direct control TO, i.e. that the truck is driven by a human at all times, a 1:2 ratio would imply that during the time that the truck is idle, the operator takes care of the driving of another truck for the equivalent of the entire driven trip – in our example, for an average of 20min or 36% of the total journey, as we assumed 5min of waiting time, 30min for the (un)loading and 20min of driving time. This means that the remote operator would be assigned to the driving of a different truck for 57% of the time during which the initial truck is idle (i.e., 20 out of 35min)[12].

While a TO-to-vehicle ratio of 0.5 may sound appealing, the example above shows that it is quite unrealistic under direct TO. Achieving this ratio would require a considerable availability of trucks and a highly optimised planning, in order for the teleoperator to have, most of the time, an available truck that is ready to be driven once the other one becomes idle. We need to consider that a truck cannot be left in the middle of the road in a stop position waiting for a remote operator to take control of it.

From an idle time perspective, a TO-to-vehicle ratio of 0.8 (1:1.25) under the current assumptions in terms of waiting times would imply that the remote operator is driving for a total of 25min and idle 55% of the time, i.e. 30min per trip (compared to the 35min the truck would be idle). While being more realistic, this may still be challenging to organise in practice and would require a high degree of process optimisation. In contrast, a TO-to-vehicle ratio of 0.70 would imply that the idle time per trip is reduced to just 48% of the original idle time in our example, i.e. from 35 to 26 minutes. Lastly, a TO-to-vehicle ratio of 0.6 would imply that the idle time per trip is reduced to 40% of the original idle time in our example, i.e. from 35 to 22 minutes.

Therefore, we consider the following three cases: (i) a TO-to-vehicle ratio of 0.8 (1:1.25) and (ii) a TO-to-vehicle ratio of 0.7 (1:1.43), and (iii) a TO-to-vehicle ratio of 0.6 (1:1.67).

Regarding the 5G network infrastructure deployments, we assume the area to be covered by 5G to be 8 km^2, based on the real-life example around the Vlissingen port site described

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[12] We assume that both trucks are devoted to the same operations and thus have the same trip and waiting times.

before. We start the analysis with the conservative assumption that the additional capital expenditures derived from improving the 5G network infrastructure on the site will be born by the remote operation use case for the most part, which relies on the assumption that the upgraded network will not benefit many additional use cases. More specifically, we allocate 80% of the costs from the 5G network upgrades to the TO use case. However, after showing the potential business case from this more pessimistic setting, we will relax this assumption in a later step.

We also assume a pessimistic/realistic adoption forecast expectation. More details on the assumptions and calculations behind the 5G network infrastructure deployment costs are provided in section 2.2.

Below we plot the results for each of these three TO-to-vehicle ratios and for the business model options:

Table 17. Business case output for our shuttle run scenario examples, per business model and for three TO/vehicle ratios.

	BM Options 1&2: Private network; inhouse TO centre deployment		
Incremental values with TO	TO/V: 0.8	TO/V: 0.7	TO/V: 0.6
FTEs	0	-2	-6
Salary costs	€ 168.084	€ 24.012	-€ 168.084
TO equipment costs	€ 175.100	€ 169.300	€ 166.400
Vehicle equipment costs	€ 215.214	€ 205.857	€ 196.500
Yearly operational business case	**€ 558.398**	**€ 399.169**	**€ 194.816**
TO centre infrastructure costs	€ 104.192	€ 99.216	€ 89.768
5G subscription costs	€ 418.623	€ 418.623	€ 418.623
Total business case (annual)	**€ 1.081.933**	**€ 917.008**	**€ 907.560**
	BM Option 3: Coverage on demand; external TO service provider (outsourcing)		
Incremental values with TO	TO/V: 0.8	TO/V: 0.7	TO/V: 0.6
FTEs	0	-2	-6
Salary costs	€ 638.719	€ 465.833	€ 235.318
TO equipment costs	€ 0	€ 0	€ 0
Vehicle equipment costs	€ 215.214	€ 205.857	€ 196.500
Yearly operational business case	**€ 853.933**	**€ 671.690**	**€ 431.818**
TO centre infrastructure costs	€ 0	€ 0	€ 0
5G subscription costs	€ 279.082	€ 279.082	€ 279.082
Total business case (annual)	**€ 1.135.015**	**€ 950.772**	**€ 710.900**

The total business case is similar for some TO/V ratios between Options 1&2 and Option 3 because the extra costs from outsourcing the TO centre in Option 3 are compensated by the lower costs from a coverage-on-demand deployment. One must also note that, in the TO/V of 0.8, salary costs go up even if the FTEs remain the same as in the traditional driving setting, even in the business model where in-house drivers are employed. This is because fleet

managers are employed for the (un)loading of the cargo, and are assumed to earn more than drivers.

The low scale of deployment make the business potential of this deployment scenario challenging. In all three business model options, it is clear that the business case is negative under the current, very conservative assumptions. However, we need to consider a setting where the site in which TO is deployed offers more potential for time efficiency gains and for the re-use of 5G network infrastructure. As a reminder, the previous conservative assumptions on this regard were hypothetical – only the data regarding the geographical characteristics and the volume of logistics operations were taken from a real-life assessment of current conditions.

Below, we consider a dual variable change in terms of (i) waiting times and (ii) the availability of additional use cases relying on 5G.

We assume an average waiting time of 20min per trip, equal to the driving time, implying a tougher current bottleneck for trucks entering port terminals. The additional waiting times extend the potential that remote driving has to solve time inefficiencies. As a result, TO service providers have the opportunity to further lower the TO/V by assigning remote drivers to different vehicles during what would be idle times in the case of manual driving. Consequently, the analysis below considers a scenario where the additional 15 minutes – initially, we had assumed 5min – would be entirely used to operate a different vehicle. In our previous example, this would translate in a reduction of the TO-to-vehicle ratio up to 0.5 (1:2) in the case of the initial TO/V of 0.8 and of a ratio of 0.41 (1:2.4) in the most optimistic case above, relating to the initial TO/V ratio of 0.6. This is reflected in the sensitivity analysis in the table below.

In addition, we also perform the cost-benefit analysis for a more optimistic situation in which the extra investments in upgrading 5G infrastructure are shared across different use cases for telecommunications services. From a business perspective, we assume that the availability of extra use cases will result in MNOs diversifying their client base or service portfolio in the area, and therefore allocating a smaller proportion of their costs – thus charging less – to teleoperation customers/contracts. In this particular scenario L2, additional use cases may include IoT or AR/VR intensive applications for safety or warehouse management purposes.

In particular, we assume that the additional costs from 5G network upgrades will be split between the TO use case and alternative ones, either equally or by taking the burden for one-third of the total investment (i.e., 50% and 33% allocated to the teleoperation business case, respectively).

Table 18. Business case output for our Scenario L2 examples, for higher current inefficiencies from waiting times and more 5G use cases.

	BM Options 1&2: Private network; inhouse TO centre deployment		
Incremental values with TO	TO/V: 0.5 % of network costs: 50	TO/V: 0.41 % of network costs: 50	TO/V: 0.41 % of network costs: 33
FTEs	-11	-17	-17
Salary costs	€ -432.216	€ -792.396	€ -792.396
TO equipment costs	€ 175.100	€ 163.500	€ 163.500
Vehicle equipment costs	€ 215.214	€ 196.500	€ 196.500
Yearly operational business case	**€ - 41.902**	**€ - 432.396**	**€ - 432.396**
TO centre infrastructure costs	€ 104.912	€ 89.120	€ 89.120

5G subscription costs	€ 261.640	€ 261.640	€ 172.682
Total business case (annual)	**€ 324.650**	**€ - 81.636**	**€ - 170.594**
	BM Option 3: Coverage on demand; external TO service provider (outsourcing)		
Incremental values with TO	TO/V: 0.5 % of network costs: 50%	TO/V: 0.41 % of network costs: 50%	TO/V: 0.41 % of network costs: 33%
FTEs	-11	-17	-17
Salary costs	€ 38.419	-€ 393.797	-€ 393.797
TO equipment costs	€ 0	€ 0	€ 0
Vehicle equipment costs	€ 215.214	€ 196.500	€ 196.500
Yearly operational business case	**€ 253.633**	**€ - 197.297**	**€ - 197.297**
TO centre infrastructure costs	€ 0	€ 0	€ 0
5G subscription costs	€ 174.426	€ 174.426	€ 115.121
Total business case (annual)	**€ 362.614**	**€ - 22.871**	**€ - 82.176**

Figure 23. Illustration of the tool's output from the previous example, for a TO/V ratio of 0.41.

From the exercise above, we can observe that, under the current assumptions, the business model options involving coverage-on-demand and the in-house employment of remote operators are the variables resulting in a more positive business case. However, it must be noted that, in practice, these decisions entail trade-offs. On the one hand, a private network is more expensive to build, but it can be more tailored to the needs of the site and be more faster to deploy, as the client enjoys a higher agency in the decision-making. In addition, while a specialised, outsourced TO service provider is seen as a more expensive option under the same operational conditions, such a company will likely be more able to pull resources and achieve a lower TO/V, thus possibly providing a cheaper service under the right conditions. Therefore, each business model may be the preferred one by a given company, according to its specific needs.

Given these cost-related challenges of the studied business models, it makes sense to consider the theoretical possibility of a business model that maximises the two most financially-sensible business model variables for the TO centre and the 5G network

deployments, namely a fourth business model option that relies on coverage-on-demand and an inhouse TO centre deployment.

Table 19. Business case example for Scenario L2, for a business model based on coverage-on-demand and an inhouse TO centre deployment.

	BM Option 4: Coverage on demand; inhouse TO centre deployment		
Incremental values with TO	TO/V: 0.5 % of network costs: 50%	TO/V: 0.41 % of network costs: 50%	TO/V: 0.41 % of network costs: 33%
FTEs	-11	-17	-17
Salary costs	€ -432.216	€ -792.396	€ -792.396
TO equipment costs	€ 175.100	€ 163.500	€ 163.500
Vehicle equipment costs	€ 215.214	€ 196.500	€ 196.500
Yearly operational business case	**€ - 41.902**	**€ - 432.396**	**€ - 432.396**
TO centre infrastructure costs	€ 102.320	€ 89.120	€ 89.120
5G subscription costs	€ 174.426	€ 174.426	€ 115.121
Total business case (annual)	**€ 234.844**	**€ - 168.850**	**€ - 228.155**

While this fourth theoretical business model improves the overall numbers, under our current example and assumptions, it is only in the case in which the TO-to-vehicle ratio falls to 0.41 that the overall business case becomes positive.

As explained in section 2.2, the main difference between coverage-on-demand and private network deployments at the cost level in our model is that setting up a private network on a site also entails deploying new infrastructure belonging to the core network, in addition to RAN infrastructure deployments, which logically leads to larger expenses. In practice, the feasibility of one business model option or another will depend on the availability of public 5G networks in a specific area as well as customer preferences, since an MNO may not always be ready to offer coverage-on-demand in a specific site and for the specific customer demands in terms of service and network requirements.

It must also be noted that 5G network infrastructure costs are directly related to the size of the area to be covered by 5G, and that we have assumed that these costs will only be split among other UCs to a certain extent. Since these costs are assumed to be fixed within the adoption forecast scenario (i.e., pessimistic/realistic or optimistic adoption in terms of number of remotely-operated vehicles in the same area), a more efficient TO service in terms of TO/V ratio will, all else equal, improve profitability. In contrast, expanding the scale of operations will only increase the total business case as long as there are positive margins at the operational level.

In conclusion, the business case of this scenario will depend on the specific characteristics of each implementation area and the current challenges in terms of inefficiency of logistics operations that the transport companies of that area experience. The financial difficulties for finding a positive business case in this scenario make the role of external funding and commercial opportunities – i.e., the importance of investment kickstarters and of leveraging alternative 5G Use Cases – more important. In addition, the financial challenges highlight the importance of exploring related CCAM technologies to try to leverage their potential economic benefits in combination with teleoperation. In this scenario, it would be most relevant to try to incorporate the Use Case of teleoperated truck platooning, which would further reduce

operational costs and workforce needs, and which was expected to be technically feasible in the short to mid-run.

While it must be noted that this scenario presented a relatively small-scale setting in which remote operation is used by a single company around a single side, even in this restrictive case, our analysis shows that teleoperation has the potential to yield a positive business case from a higher efficiency in the use of resources; specifically, from allowing drivers to operating a different truck while one is idle.

5.3 Business case / cost-benefit analysis scenarios L3 & L4

Longer-haul road transport scenarios present great implementation challenges in the short term. Scenarios L3 and L4 involve trucks driving remotely in long stretches of public roads, where overtakings and entry/exits are common, speeds are higher, and road density is often high. In these situations, occasional interruptions in connectivity (even if milliseconds long), bring a higher chance to cause a collusion; on-board systems can add an additional layer of safety if they are able to automatically react and bring a vehicle to a safe stop until connectivity is restored and the teleoperator can take control again.

Therefore, in section 3 it was argued that teleoperated transport Use Cases in these scenarios will only become feasible in the mid- to long-run (at least 5 years from now, regulatory issues aside), once automation technology is mature enough for highly autonomous (i.e., level 4 automation) vehicles to become commercially available.

In addition, on the business side, the challenge of deploying 5G network infrastructure along roads looms large. Scaling up to highway scenarios will require network upgrades in areas where the demand for alternative 5G connectivity Use Cases is not seen as promising compared to urban areas. Therefore, the analysis for these scenarios starts again with the conservative assumption that the cost for 5G network upgrades is born by the teleoperation use case. In a later step, we relax this assumption and consider a situation where multiple 5G use cases use the same infrastructure and therefore share the costs of upgrading infrastructure along highways.

This section tries to clarify the business case of teleoperated transport in highway scenarios; in other words, whether the cost-efficiency gains of CAD are enough to cover the costs from the required investments in equipping TO technology into vehicles, setting up TO control centres, and investing in telecommunications network infrastructure deployments, in addition to other costs associated with the adoption of teleoperation. A detailed discussion of the sources of costs and their values, together with the underlying assumptions of the model, is presented in Section 2.

We consider a scenario in which direct remote control of level 4 automation trucks (i.e., highly autonomous vehicles) is used in the following situations:

- In more complex local roads, for the first- and last-mile of a trip, up until the point in which a truck enters a highway, and again from the point a truck exits it.[13] The remote operator would also take care of (or at least actively supervise) the manoeuvre to help the truck enter or exit a highway. During the highway part of the trip, the truck

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[13] More complex roads and traffic types are expected to remain a challenge for AD systems. This is more likely to be the case for the first- and last-mile of long-haul trips, which often represent local roads that involve more connections between modes, interaction with road users, roundabouts, traffic lights, etc., and are less standard than highways. In contrast, this may be an easier design domain for teleoperation: lower speeds reduce the impact of a potential incident due to connectivity failures, while the more interactive and unpredictable traffic conditions represent situations that a human driver is accustomed to.

would drive autonomously, in normal conditions.

- In addition, for driving the highly-autonomous trucks on the highway when necessary, i.e. either in the case a sudden fallback if the on-board system failed, or when weather and road conditions are too extreme for the AD system to handle reliably – in other words, when the vehicles face complex traffic situations outside of their operational design domain (e.g., during road works or specific weather conditions). Since operational design conditions (e.g., weather or road status) are not completely predictable, it could happen that in exceptional cases the vehicle's system becomes unable to drive itself safely in the middle of the journey. A highly-autonomous vehicle would still be able to perform the driving fallback task, i.e. the response action to minimize the risk of an accident, which may entail stopping or driving away from active lanes of traffic. In such a circumstance, vehicles left stranded in the middle of their trip could be remotely driven by a human driver to their destination or to a safer place.

By definition, high-automation (i.e., level 4) trucks can drive autonomously albeit within a limited operational design domain. Here, we consider this domain to be predetermined, geo-fenced highway routes. A truck is driven up to a highway by a remote operator, and then for the highway part of the trip the truck drives autonomously. Nevertheless, the self-driving domain is further restricted in case of (a) challenging, low-frequency but high-impact weather conditions, such as heavy snowfall or storms, and (b) road works that increase the complexity of driving on the motorway and navigating its temporary signalling. To govern that, a control centre gives clearance for the routes in advance, guaranteeing that road and weather conditions are permitting. This control or operation centre decides if the climatic, connectivity and road traffic conditions are permitting to allow AD at a specific moment in time, by having a real-time overview of the road situation and the vehicles traveling a specific route.

It remains unclear who would invest in and operate this centre. Different stakeholders, such as traffic management authorities or TO service providers have a potential interest in doing so, and could even invest in it as a consortium.

In our illustration for the longer-range scenarios, we start by applying the business case tool to a hypothetical case of containers transport by truck between the ports of Zeebrugge and Antwerp (i.e., scenario L3). This is an example of a frequent standard route within the national borders of one country, in this case Belgium. From a regulatory perspective, one way to allow TO or self-driving of trucks before legislation is updated would be by granting an exemption. This is seen as something more feasible for one specific route within one single country.

For simplicity, we consider the following approximate distances for each part of the trip.

Table 20. Trip measurements for our national highway scenario example.

Part of the trip	Road type	Distance	Duration (driving)
First-mile: from the port of Zeebrugge	Local/regional road	5km	15
Highway: A11 & N49/E34	Motorway	95km	80
Last-mile: entering the Port of Antwerp	Local roads	5km	15
	Total:	105km	110min

We consider the transport from one port to the other to be one trip. The "return" from Antwerp to Zeebrugge would be a second trip. We assume a total driving time of 110min per trip, which includes any slower driving due to congestion; dense traffic and congestion is common in this route during the day, and actual driving times fluctuate, but this number can be consider a rough average between daytime and nighttime trips. We also assume a total trip waiting time of 15min around the ports, which represents the time in which the truck is fully stopped and

thus a remote operator could safely take over another vehicle. This excludes (un)loading of containers, which is assumed to take 30min per trip, in line with the assumptions in previous scenarios.

In this example, a teleoperator-to-vehicle ratio of 0.5 or 1:2 would indicate that a remote driver takes care of 2 vehicles, on average, for each 'teleoperated' part of the trip. In practice, it means that for each full non-automated part of the trip – lasting 75min between the remote driving, (un)loading and waiting times – the remote operator takes care of the remote driving of 2 full trucks. This implies that it spends 60min driving and remains idle for the other 15, waiting for a truck to become available for driving. Lower teleoperator-to-vehicle ratio become realistic under this example compared to the assumptions in previous scenarios. The automated part of the trip is considered separately for this metric, because the model already does not count this part as time in which remote operators are employed (i.e., the driverless part of the trip already reduces the FTEs required variable).

The first- and last-mile parts of the trip, as well as the entering and exiting of the highway, are done by a remote operator. The highway part, in normal conditions, relies on self-driving. Therefore, the remote operation time is assumed to be 30min for this trip, while the self-driving time is assumed to be 80min minus the assumed percentage of times in which road or weather conditions would force a remote operator to take over the vehicle to perform the driving task.

We assume 2 shifts, 300 operational days and no resting time due to the distance of the trip. We also assume that the remote driver's salary is the same as the manual driver's, 25 euro per hour.

Regarding 5G network deployments, we make the conservative assumption that the area to be covered by such deployments, using coverage-on-demand, would be the entirety of the highway. The first- and last-mile parts of the trip represent port or urban areas, which in the envisioned future of at least 5 years from now can be expected to be – or keep being – covered by 5G connectivity. Again, in terms of the number of vehicles incorporating TO technology, we assume a pessimistic/realistic adoption evolution over the 10 year span considered by the cost.

The clearance rate is assumed to be 95%. That 1 in 20 trips a remote operator will need to take over the responsibility of driving the truck on the highway is quite a conservative assumption, but here we have in mind an early stage of the technological maturity of autonomous systems.

We conduct a sensitivity analysis based on the variable of 'teleoperator idle time', considering different teleoperator-to-vehicle ratios. We also do a sensitivity analysis on the basis of the variable 'number of trips per day'. The output of the model is presented in the tables below. The first table refers to a deployment based on an 'outsourced' TO centre, while the second refers to an 'inhouse' deployment.

Table 21. Annual incremental costs from TO in our Scenario L3 example with an outsourced TO centre.

		TO-to-vehicle ratio		
		0.9	0.7	0.5
Trips per day	50	€ 3.165.437	€ 2.957.723	€ 2.876.723
	150	€ 2.658.573	€ 2.054.144	€ 1.792.430
	450	€ 1.137.980	€ - 665.949	€ - 1.441.734

Table 22. Annual incremental costs from TO in our Scenario L3 example with an inhouse TO centre.

		TO-to-vehicle ratio		
		0.9	0.7	0.5
Trips per day	50	€ 3.234.080	€ 3.043.265	€ 2.973.565
	150	€ 2.602.632	€ 2.053.412	€ 1.815.397
	450	€ 720.958	€ - 918.690	€ - 1.622.864

Next, to add robustness to our analysis, we perform another iteration of the business case model to consider another feasible kind of situation. More specifically, we consider a situation where the incremental capital expenditures from upgrading 5G networks can be born by multiple use cases. Within the timeframe in which more advanced automation technology becomes available in the market, it is realistic to assume that new use cases relying on the same network infrastructure upgrades will also become available. Examples of alternative UCs in highways include, for instance, applications for passenger transport. Naturally, the ability to split costs will make the business case of teleoperation in scenario L3 even more positive and from an even smaller scale of vehicles. In the example below, we assume that remote operation will bear either 50% or 33% of the costs arising from 5G network infrastructure upgrades. We conduct the analysis for the business model using an outsourced TO centre, i.e. a specialised TO service provider.

Table 23. Annual incremental costs from TO in Scenario L3 with an outsourced TO centre and multiple 5G use cases reusing the infrastructure.

	Sensitivity parameters		
Incremental values with TO	TO/V: 0.9 % of network costs: 50% 150 trips/day	TO/V: 0.7 % of network costs: 33% 150 trips/day	TO/V: 0.5 33% of network costs 450 trips/day
FTEs	-10	-41	-138
Salary costs	€ - 1.125.225	€ -1.692.225	€ -5.805.675
Vehicle equipment costs	€ 374.286	€ 336.857	€ 950.429
Yearly operational business case	**€ - 750.939**	**€ - 1.355.368**	**€ - 4.851.246**
5G subscription costs	€ 1.704.756	€ 1.125.139	€ 1.125.139
Total business case (annual)	**€ 953.817**	**€ - 230.229**	**€ - 3.726.107**

Below, we plot a comparison of how much each cost source contributes to the total business case for the 'middle-point' scenario above, i.e. one in which there is an outsourced TO service provider, an assumed TO/V ratio of 0.7, 150 trips per day and one third of the total 5G infrastructure costs allocated to the remote operation use case.
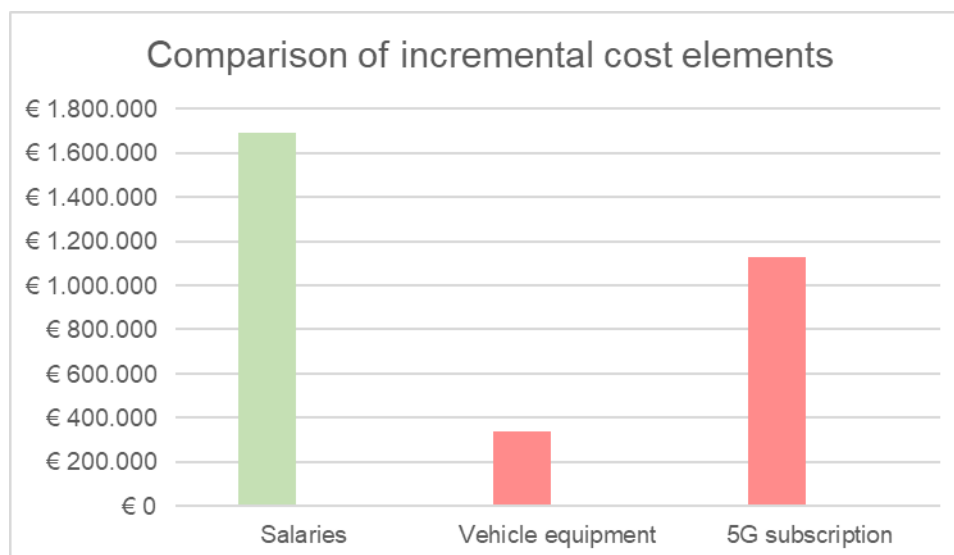
Figure 24. Contribution of each element to the business case from the previous Scenario L3 example.

From all the results above, we can extract the following **conclusions for the L3 scenarios** considered (i.e., TO on a highway within national borders):

- The business case under the specific assumptions and characteristics of the deployment area, and the most conservative assumption in which TO is the single UC paying for the 5G infrastructure upgrades, only becomes positive for a large volume of operations and efficient teleoperator-to-vehicle ratios, which would probably require multiple companies in the region equipping their fleets with TO capabilities. In fact, the business case is only positive for values above 310 average trips per day in any case. More specifically, the breakeven for a teleoperator-to-vehicle ratio of 0.5 is 342 and 310 trips for outsourced and inhouse TO centres, respectively. For a teleoperator-to-vehicle ratio of 0.7, it is 413 for the inhouse built only.

- After considering that additional UCs will 'split the bill' and leverage the same 5G network investments, we can conclude that splitting the costs of 5G among different use cases is a factor that can make the business case become positive in several of the situations considered above. For instance, under the considerations above, the breakeven point would only be achieved with a scale of 377 trips per day – in the case of a TO/V ratio of 0.7. In the case in which MNOs can expand their portfolio of 5G-based highway UCs and only allocate half of the estimated network costs to charge for the 5G subscription for remote operation services, then this breakeven point lowers to also half the number of trips/day to 189. Even under conservative assumptions, we would argue that a future situation in which 189 trucks are remotely operated under a specific long stretch of highway is an easily achievable volume of operations. However, actual adoption will depend on transport sector companies and regulators alike seeing the business case, business models and societal benefits of remote operation.

- The main costs are the ones related to 5G network infrastructure deployments. These represent a fixed CAPEX that does not change (under our model) with the different scales of operation in terms of connected vehicles, therefore the volume of operations seems to be the variable making the most impact on improving the business case.

- The source of cost-efficiency is the reduction in salary costs. In any of the studied

possibilities (in terms of average trips per day and operators per vehicle), the cost reductions from salaries outgrow the combined expenses from TO equipment, TO centre infrastructure, and vehicle equipment. Therefore, it is the size of the 5G network infrastructure costs, and whether alternative 5G UCs are present, that will ultimately determine whether the business case remains positive.

- Regarding the changes in required FTEs, the effects of automation become evident compared to the previous scenarios. The lower the teleoperator-to-vehicle ratio, the more drastic the reduction of FTEs required to perform the same scale of operations. For the 0.9 operators per vehicle ratio, slightly less of the current needs become redundant; for 0.5, about two thirds of current requirements could become unnecessary. Most of the employee needs come from remote operators in any case, but additional manpower would be needed on-site to support with the temperature control of containers. This support need is in approximately 1.6 people per 100 daily trips.

Next, we consider a hypothetical long-haul international trip across multiple EU countries (i.e., scenario L4). The deployment areas of reference we selected to apply the business case tool in this scenario are the European TEN-T highway corridors, consisting of international roads that link important transport hubs such as the continent's busiest ports, thus presenting a high demand for constant goods transport.

To calculate deployment distances, which form the basis for the 5G infrastructure costs, we use the 'North Sea-Mediterranean' corridor, which links, in two strings of highway, the port of Marseille and Paris with the ports of Rotterdam, the North Sea and Antwerp. If we assume that our trip of reference goes from the port of Rotterdam to Lyon, the approximate distances for our example journey would be the following:

Table 24. Trip measurements for our international highway scenario example.

Part of the trip	Road type	Distance	Duration (driving)
First-mile: from the port of Rotterdam	Local/regional road	5km	15
Highway: North Sea-Mediterranean corridor	Motorway	790km	600
Last-mile: entering the metro area of Lyon until a logistics hub	Local/regional road	5km	15
Total:		**800km**	**630min**

We assume a total driving time of 630min per trip – from Rotterdam to Lyon, without a return leg – and a total trip waiting time of 60min at the port, for customs, etc., which represents time during which the truck is fully stopped and thus a remote operator could safely take over another vehicle. The (un)loading of containers is assumed to take 30min per trip, in line with the assumptions in previous scenarios. For this long-haul journey, we assume a resting time of 270min for the trip, which are approximated according to regulatory requirements and accounted for only when they take place within the assumed operational hours and shifts for the TO centre (i.e., 2 shifts of 8h).

The first- and last-mile parts of the trip, as well as the entering and exiting of the highway, are done by a remote operator. The highway part, in normal conditions, relies on self-driving. Therefore, the remote operation time is assumed to be 30min for this trip, while the self-driving time is assumed to be 600min minus the assumed percentage of times in which road or weather conditions would force a remote operator to take over the vehicle to perform the driving task (5% of the above, i.e. 30min).

Again, we assume 2 shifts, 300 operational days and no resting time due to the distance of the trip. We also assume that the remote driver's salary is the same as the manual driver's, 25 euro per hour.

We also assume that 5G RAN infrastructure upgrades will be done alongside the entire 790km stretch of the corridor. Lastly, we assume a pessimistic/realistic adoption in terms of the evolution of vehicles using TO in the future and we keep the conservative assumption of no alternative use cases sharing the burden for the investments in additional 5G network upgrades.

Again, we conduct a sensitivity analysis based on the variable of 'teleoperator idle time', considering different teleoperator-to-vehicle ratios. This time, with the longer waiting and rest times, it is more feasible that a teleoperator is made responsible of more vehicles. Therefore, we consider lower teleoperator-to-vehicle ratios than in previous scenarios.

We also do a sensitivity analysis on the basis of the variable 'number of trips per day'. The output of the model is presented in the tables below. The first table refers to a deployment based on an 'outsourced' TO centre, while the second refers to an 'inhouse' deployment.

Table 25. Annual incremental costs from TO in our Scenario L4 example with an outsourced TO centre

		TO-to-vehicle ratio		
		0.8	0.5	0.2
Trips per day	50	€ 24.580.855	€ 24.404.998	€ 23.684.698
	150	€ 17.027.641	€ 16.500.070	€ 14.339.168
	450	-€ 5.632.002	-€ 7.224.073	-€ 13.688.065

Table 26. Annual incremental costs from TO in our Scenario L4 example with an inhouse TO centre.

		TO-to-vehicle ratio		
		0.8	0.5	0.2
Trips per day	50	€ 24.535.925	€ 24.378.795	€ 23.723.030
	150	€ 16.643.651	€ 16.167.365	€ 14.196.781
	450	-€ 7.035.868	-€ 8.471.388	-€ 14.364.425

Below, we show the distribution of incremental costs and benefits from our CAD example compared to the status quo of manual driving. We do so for the case of an inhouse built for the TO centre and an operator-to-vehicle ratio of 0.5. The graph shows the breakeven point of 347 trips per day.
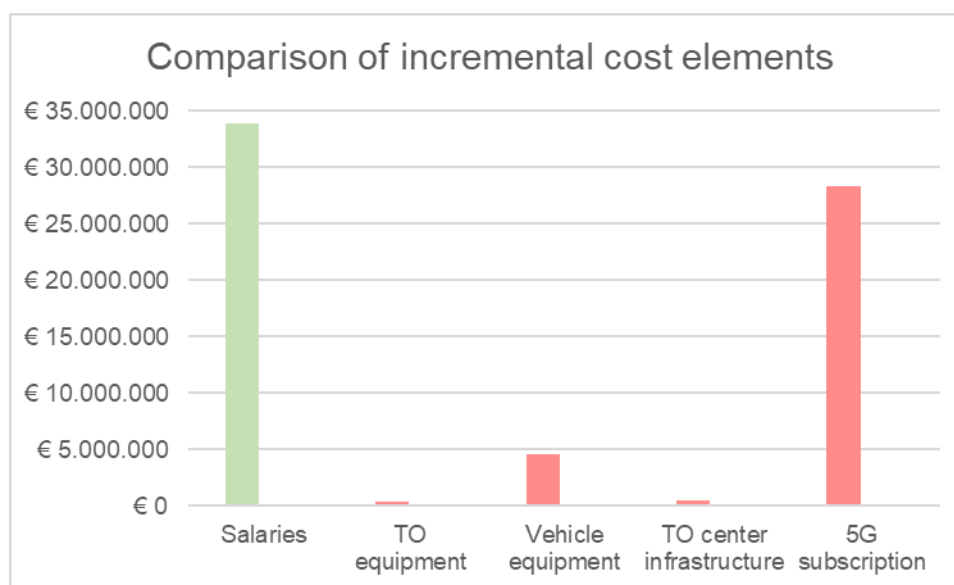
Figure 25. Contribution of each element to the business case from the previous Scenario L4 example.

Our **conclusions** for scenario L4 are similar to those for scenario L3; namely, we conclude the following:

- The business case needs a large volume of operations to become positive, although ~350 one-way trips along the studied TEN-T corridor is not a great sum in relative terms. Since 5G densification along roads would provide coverage in both directions of the highway, 350 daily trips translate to just 175 trucks using this highway route each day. Considering the demand for goods transport along such corridors, the assumed values can be considered very conservative, even for initial stages of adoption.

- In this case, the teleoperator-to-vehicle ratio is not so crucial, since the business case positive for all three studied values.

- The main source of costs is still 5G network infrastructure deployments. But once the breakeven above 5G costs is reached, the profitability potential is huge. From the perspective of a logistics company, the savings potentials represent much lower TCO over the vehicle's lifetime.

- Again, this is due to the cost-efficiency provided by the reduction in salary costs, which comes from a more efficient use of time resources through (i) the use of remote operators that can takeover control of the vehicles that are ready to be driven while another vehicle is idle, but also and to a much larger extent through (ii) the increase in vehicle uptime and autonomy of the driving task provided by self-driving technology.

- Regarding the changes in required FTEs, the effects of automation become even more pronounced in long-haul transport. For the 0.8 operators per vehicle ratio, for instance, the same scale of operations can be maintained with a cut of almost 75% of the workforce; for the 0.2 value, this becomes almost 90%. If TO would be adopted pervasively throughout the trucking sector, such job redundancies would surpass the projected figures in unfilled vacancies and raise concerns over a potential negative disruption in the labour market. While such a large adoption of CAD is still very far away into the future, legislators need to take into account the possibility of such a scenario, and make sure that the benefits of the technology do not unequally accrue to the industry in terms of higher profits at the expense of job losses or lower

purchasing power by truck drivers and other logistics employees. On the other hand, the repurposing of current long-haul drivers into remote drivers could improve the well-being of truck drivers, by avoiding the negative consequences of long-haul trips, such as mental health issues from social isolation and stress from long working hours.

In general, it is important to note that our assumptions are quite conservative, reflecting the pessimistic views and current uncertainty around the availability of related UCs that could provide alternative revenue sources to OEMs and, more importantly, 5G network operators, in order to monetize the same investments that are required for TO. We assumed that, even in this mid- to long-run scenario, 5G RAN infrastructure deployments will be needed alongside the entire highway. To give flexibility to the analysis and consider a conservative situation in any case, we have studied both the situation in which TO will be the only Use Case paying for 5G network upgrades through a 5G subscription, and a more realistic situation in which multiple UCs will bear such costs. In addition, we rely on a cost for retrofitting vehicles with current technology. But in the longer run, both commoditization of hardware and incorporation of the technology in the factory by the OEMs will reduce the costs of equipping vehicles with TO technology.

It must also be noted that 5G costs are expressed as annual subscription costs, but they would represent huge upfront investments that some party or parties will need to assume together with the associated risk. However, the most likely business model is that the costs are monetized by telecommunications companies via the sale of a recurrent connectivity subscription. Regarding the upfront investment itself, it may be borne entirely by an MNO or infrastructure owner (i.e., a neutral host) or shared among different parties: for instance, with the support of an investment kickstarter.

6   CONCLUSIONS AND RECOMMENDATIONS

6.1   Feasible evolutionary path and recommendations for deployment

On the basis of the identified deployment scenarios (4 for land-based transport and 3 for water-based transport), we discussed the Use Cases that are expected to become feasible through time, along with their technical and business challenges.

In the short run (i.e., within the upcoming 3 years), feasible road transport Use Cases are limited to a small geographical scope, namely, first, within logistics sites like port terminals (scenario L1), and second, for transport connections between such sites located in the same area (scenario L2). In the first case, the specific Use Cases involve the direct TO of cranes, reach stackers, skid steers or terminal internal tractors. In the second case, they involve direct TO of trucks for repetitive shuttle runs, possibly including truck platooning. While the business case of these scenarios does not promise high profitability and entails risky investments at low scales of adoption, sites with large waiting times and other inefficiencies have a promising business case from teleoperation as soon as the deployment scale is large enough for remote operators to be able to remain occupied by taking care of multiple vehicles throughout their journey. In these scenarios, TO can already help mitigate the problems of unfilled vacancies.

Also in the short term, waterway Use Cases become feasible, combining remote operation with automation, and already promise economic benefits from the more efficient use of a captain's time, whose idleness can be severely reduced, and from avoiding the need of part of the crew to be on-board of the vessels.

Teleoperation of trucks on highways and for international trips will probably only become feasible in the middle run (>5 years time), once automation technology is mature enough for highly autonomous vehicles to be commercially available in extended operational design domains – what reduces the need for costly 5G-coverage over larger sections where TO is not commercially viable. In the same time frame, higher adoption rates of crewless barges are expected to make the Use Case of teleoperation of semi-autonomous barges more feasible even when considering the challenge to upgrade 5G networks. In the longer-term, the role of teleoperation may probably evolve to be more indirect in such operational design domain, i.e. providing indirect TO to instruct autonomous vehicles to follow certain actions or paths and only intervening to take over the driving task sporadically (e.g., in case of incidents) as well as in complex driving environments (including motorway exits and first and last mile), where direct TO is still expected to be required – especially for driverless vehicles.

To encourage timely deployment and avoid the passivity associated with chicken-egg situations where bottlenecks can arise from multiple sources, we recommend the following actions, classified in two phases covering the short- and medium-run. We consider different types of actions: deployment, preparation in terms of testing/researching and business development/modelling. These recommendations are mainly directed at the entities that would take up the main TO service provision and ecosystem orchestrating roles in the different business models.

Phase 1 (<1 year). In a first phase, in the immediate run, we suggest starting deployments in scenario L1 and scenario W3 in locations where 5G deployment is beneficial for a multitude of UCs and substantial (additional) 5G network upgrades are not needed.

Regarding scenarios L2 and W2, where 5G infrastructure investments may be needed, it is important to tackle the identified bottlenecks early; to that end, we put forward the following recommendations:

- **To start negotiations with other potential adopters** (i.e., logistics companies), either to join forces in a JV business model or to ensure that adoption will reach the scale level where the business case becomes positive in these scenarios.

- **To start establishing conversations with potential clients** (i.e., other logistics companies, vessel or cargo owners) to conduct deployment studies based on specific company data. It is also important to contact vessel owners, as clients of the solution, in order to explore their interest and demand for the Use Cases, and explore co-investment in retrofitting the vessels with TO technology.

- **To start negotiations with MNOs and potential investment kickstarters** as soon as possible, to ensure other parties are interested in helping support initial investments. Another important aspect to mention is that the business case of teleoperation services is reliant, to a large extent, on the 'cost-splitting' of 5G network upgrades among Use Cases; hence, it is important to involve MNOs in the business process to ensure the availability of alternative 5G-Use Cases is leveraged to ensure a cost-efficient implementation.

- In parallel, it is important **to start building awareness about the business case of teleoperated transport Use Cases**, their associated benefits and roadblocks among regulators. It is important to do so early to avoid, as much as possible, that uncertain or delayed regulations pose a bottleneck in a future where the business and technical elements are ready.

- **To support the establishment of connections among the different actors identified in the value network** and providing templates of collaboration based on the necessary interactions and roadblocks identified by 5G-Blueprint. Regional ecosystem orchestrators have a role to play in this phase regarding all the above recommendations but particularly in this last aspect.

Phase 2 (1-3y). After having started with small-scale deployments, we would recommend scaling up gradually and organically towards scenarios L2 and W2. If the dedicated business case studies have shown a potential for profits, the most suitable business models should be defined. Establishing business models and collaboration agreements (e.g., signing LOIs) and contracting network upgrades would be the first step before deploying.

Once the technology and commercial aspect of teleoperated transport have been validated, it is therefore important to start lobbying to regulators to ensure that regulations evolve towards permitting long-haul Use Cases that rely on driving automation.

Regulators and independent organisations should also prepare early to anticipate the impact of longer-haul Use Cases on the job market of a specific region. A holistic approach should be prepared to ensure a smooth transition in terms of the substitution of current job positions and to ensure that the disruption provided by automation is not too severe.

In conclusion, our findings are aligned with the work and conclusions from previous 5G-Blueprint deliverables (see, e.g., [3]) that suggest starting deployments in a geographically limited area, such as a private logistics site and short shuttle runs in public roads, with as many Use Cases as possible (in terms of types of vehicles remotely operated), all while keeping in mind the future ambition to scale up to major national roads and waterways, which will provide the largest economic benefits. To ensure that enough TO adoption is reached in the meantime to justify the required 5G network investments, continuous testing, lobbying and business development efforts are needed.

6.2 Feasible business models

The present work provides a validated list of possible business model options for all deployment scenarios considered. A comprehensive round of stakeholder consultations, mostly from experts within the consortium, allowed us to refine and extend the preliminary list of business models defined in our previous report. Although several business model options are considered realistic, their feasibility will depend on each deployment location and as well as on the timing of deployment.

The identification of the underlying granular choices behind the described business models offers more flexibility to the analysis and facilitates its reuse, hence providing a blueprint for implementation in other contexts.

We have included a series of business model options for a **small-scale scenario** where teleoperated transport is used for internal operations (e.g., TO of skid steers, cranes, terminal tractors, forklifts) within a logistics site such as a port terminal. In that setting, the most realistic business models in the short term involve a site owner that invests in setting up its own TO centre infrastructure, retrofitting its vehicles with TO technology, and employing its personnel to perform the remote operations, since they entail no additional dependencies on other partners. The lower scale and range of operations is expected to allow TO UCs to be adopted without the need to invest substantially in the densification of wireless networks. In the case that 5G network infrastructure needs to be deployed at the specific site, the business models involving a joint venture of site owners would be more feasible at the financial level from the sharing of costs and the possibility to enjoy economies of scale from efficiently allocating remote operators to more vehicles and reusing infrastructure.

To scale up towards scenarios that involve the transport of goods with teleoperated trucks in **short-distance repetitive trips through public roads** (i.e., scenario L2), the recommended business model would depend on the availability of interested service providers that see a clear business case. The business model of having an internationally-minded, specialised TO service provider is seen as an easier model to implement and to scale up to larger deployment scenarios. It is also seen as more likely to become the standard model in the long term. However, an example of an entrepreneurial company that identifies a market opportunity and takes the risk of kickstarting investments is still not present for road transport. In that case, guaranteeing shorter-term deployments would be more realistic if local logistics companies take initiative to adopt teleoperation by joining forces and setting up a joint venture that provides teleoperation services and manages a TO centre. While this would allow them to increase their scale of operations and split costs, the involvement of an external entity that provides investment support is seen as a key aspect to overcome the risk of large upfront investments in TO equipment and 5G infrastructure. Similarly, incentivizing the appearance of a specialized TO service provider in a given area might require co-financing to reduce the risk that the necessary infrastructure will be available, particularly in early stages where deployments are still limited and scattered around Europe. Trusted entities that can provide co-financing as well as help orchestrate new business cooperations include port site owners and authorities at the regional, national or European level. Profit-sharing agreements can be established to recuperate these investments.

For the **longer-haul cross-border transport on roads and waterways**, TO is only considered to be feasible in the longer-term, when it can be combined with higher levels of automation. In the shorter-term, a business model involving a new company with specialized expertise in providing TO services is seen as the most feasible model to scale up towards highway scenarios. The value of such a business model for logistics actors is that it provides

an end-to-end solution that does not require them to build new expertise. The TO service provider would need to establish SLAs with transport companies to assume the liability for the cargo or the vehicles in case damage occurs during the journey.

Transport companies are also logical candidates to adopt such business model, since they directly benefit from the operational efficiency that TO provides and they would try to gain a competitive advantage with respect to traditional competitors. They would also maintain more control over the entire transportation journey. However, transport companies are not exploring, in general, the possibility to adopt this business model; they would also be less flexible in adapting their current business model and building the required expertise compared to a specialized startup. Similarly, OEMs are not seen as likely to invest in providing TO as an extra mobility service for their own vehicles, even though they could leverage the technology and expertise for passenger transport Use Cases as well. Only in the longer-term are the alternative and more disruptive models for road transport seen as feasible: for instance, a business model where a large digital platform provides the match-making between cargo owners, vehicle owners, and TO service providers.

From a **5G connectivity** perspective, the most likely arrangement is that the TO service provider or vehicle owner pays for the 5G service via a recurrent subscription. This subscription may have a fixed fee or be two-tiered, with the first tier being volume-based and the second incorporating a premium for guaranteed bandwidth or priority in certain instances. In longer-range scenarios, the 5G connectivity service provider may be a public MNO, who would also manage the network and the roaming agreements across the EU, or be an MVNO that buys wholesale network resources and tries to build a tailored service to for CCAM UCs or specific for teleoperation – in this last case, an international specialized TO service provider may adopt this MVNO business model the same way as some vehicle manufacturers have studied moving into the B2B connectivity market as MVNOs in the past.

The question of which parties would take or share the financing of 5G infrastructure deployments, assuming that, even in the long-term, strict TO requirements and underserved areas would make large densification efforts necessary. Long-haul TO would require the availability of 5G connectivity across different countries. Co-financing in the case of large canals or corridors would appear more realistic with international efforts, either through the support of a supranational body or the cooperation among Member States. Public funding would be justified from the expected societal benefits of TO in terms of unfilled driver vacancies, health benefits from more stable and comfortable working conditions, as well as for economic benefits. However, there would also be reluctance in using public spending to subsidise UCs that promise a profitability that would accrue to private logistics companies.

To solve these uncertainties, and to reduce the risk of raising private financing as well as to incentivise the proactivity by the logistics sector to take care of initial investments, it is essential to clarify the business case of deploying teleoperated transport UCs in different areas and scenarios. We have developed a simple but comprehensive cost model that assessed under which real-life deployment settings and business models profitability prospects arise, and their potential profitability.

6.3 Business case analysis

We carried out a cost-benefit analysis to assess the incremental costs or benefits that can be expected compared to the status quo of manual driving. While we present a business case calculation tool that relies on many simplifying assumptions, it provides a blueprint that can be adapted to the characteristics of each deployment area, while it also covers all the studied scenarios and all the main Use Cases studied by the project. It is also comprehensive in its

consideration of the main sources of incremental costs and benefits related to teleoperated transport.

In general, we can conclude that the business impact of teleoperation depends on the scale and type of operations. Due to the large infrastructure investments required, the business case of teleoperation is not obvious, but a positive profitability prospect is present in each scenario under certain business models and specially in larger scenarios and when current inefficiencies are substantial.

Scenario L1: terminal teleoperation. The smaller scale scenario in which teleoperation is used within a logistics hub like a port terminal can already provide substantial financial benefits. This is clearer in the case of small-scale adoptions of multiple Use Cases (cranes, skid steers, reach stackers, internal tractors, etc.) on sites that do not require 5G RAN upgrades. But even in the case a private 5G network needs to be built, a positive business case can emerge even with relatively conservative assumptions in terms of the scale of operations and the efficiency introduced by TO. Another initial Use Case we studied is the moving passenger cars within a logistics site, which can provide substantial economic gains but only for a business model where automakers equip their cars with TO technology from the assembly stage, which would require them seeing the potential of teleoperation for passenger transport Use Cases (e.g., to relocate ride-sharing cars or to provide valet parking).

In addition, outsourcing the TO service to an external company is, all else equal, a less sensible option in the limited scale of this scenario, in line with most business model options identified for this scenario, which involve a site owner taking the role and responsibility of providing the TO service – or better said in this case, TO action – for internal operations.

Scenario L2: short-distance shuttle runs with a pre-defined trajectory. The business case of this scenario is less evident and will depend on the specific characteristics of each implementation area and the extend of time inefficiencies for logistics operations present in the area (e.g., waiting times to enter a port or to pick up a container with a truck). These inefficiencies, together with achieving enough scale of operations, will determine whether a remote operator can practically be responsible for the driving of multiple trucks by matching their driving and idle times. The financial difficulties for finding a positive business case in this scenario make the role of external funding and commercial opportunities – i.e., the importance of investment kickstarters and of alternative 5G Use Cases – more relevant. In addition, profitability may rely on incorporating truck platooning to further reduce operational costs per vehicle, a Use Case that was expected to be technically feasible in the short to mid-run.

In this scenario there is already a considerable potential to reduce workforce needs; in our example, a reduction above 40% in required FTEs for a teleoperator-to-vehicle ratio of 0.7. Problems with job vacancies were cited often in our expert consultations for the driving of trucks in the BeNeLux, also for this sort of scenario, and especially for night shifts.

Scenario L3: highway within national borders. In this scenario and the next, we consider a future in which highly autonomous vehicles drive themselves on the highway with normal road and weather conditions. The combined effect of TO and AD brings a substantial cost-efficiency in terms of salary costs. In any of the studied possibilities (in terms of average trips per day and operators per vehicle), the cost reductions from salaries outgrow the combined expenses from TO equipment, TO centre infrastructure, and vehicle equipment. However, given the massive CAPEX from 5G network infrastructure deployments, the business case under the specific assumptions and characteristics of the deployment area considered only became positive for a large volume of operations, which would probably require multiple companies adopting teleoperation, or when multiple 5G-based use cases can leverage the

same network upgrades and distribute the costs among the respective 5G service subscriptions. In realistic situations where alternative UCs, e.g. for passenger transport, are present, an even split of 5G network infrastructure upgrade capex among TO and other UCs can make the business case positive for a very achievable situation in which the operator-to-vehicle ratio is as high as 0.7 and the number of daily trips with trucks in a given highway route is as low as 189.

Scenario L4: cross-border road corridors. As in the previous scenario, TO and AD provide substantial cost-efficiency from the increase in vehicle uptime and lower salary costs. 5G network infrastructure deployment costs are huge, but the profitability potential in the studied application area – a TEN-T highway corridor – has even greater upside, especially considering the demand for goods transport in such cross-border corridors. Thanks to the large part of the trip being automated, this scenario offers the highest prospects in terms of potential profitability.

The associated effect is that the number of drivers required to deliver the same operational volume of goods transport is significantly reduced compared to the case of manual driving, making most current jobs redundant under the working assumptions behind our example. Therefore, legislators need to make sure that the benefits of the technology do not unequally accrue to the industry in terms of higher profits at the expense of job losses or lower purchasing power by truck drivers and other logistics employees. On the other hand, the repurposing of current long-haul drivers into remote drivers can improve the well-being of truck drivers, by avoiding the negative consequences of long-haul trips, such as mental health issues from social isolation and stress from long working hours. In addition, these better work conditions will lead to the truck driver job becoming more attractive, which can help mitigate unfilled vacancies in a transition phase of lower adoption where the job redundancies are not dramatic.

Other implied consequences from teleoperated trucking in the long-haul are the following. First, by making autonomous road freight financially feasible prior to the commercial readiness of full automation, the benefits of AD in terms of reducing road accidents and increasing traffic efficiency will be felt earlier. Second, the increased productivity and cost-efficiency gains for logistics companies could be passed to end customers in the form of cheaper goods and delivery costs and, given the weight of road transport on the European economy, it can also contribute to tangible economic growth. Moreover, the potential cost and price savings could increase demand of long-haul road transport and result in increased energy consumption and emissions; charging fees in the form of road tolls could be a solution to counterbalance part of these savings and mitigate these negative environmental externalities.

While we did not apply the business case tool to illustrate **waterway transport** Use Cases, due to a lack of data and because waterway goods transport is not considered to be as much of a hurdle compared to road transport, with commercial services already existing. In addition, albeit with some simplifying assumptions and caution, our tool can equally be applied to waterway deployments with barges, as many cost elements are shared with road transport and the model includes the costs of equipping barges with teleoperation technology. Higher degrees of automation are already feasible for barges, even when navigating long distances, with current commercial operations largely relying on autonomous navigation paired with the supervision of a remote captain who can supervise multiple barges, which increases uptime and efficiency. However, this makes it more complicated to provide a reliable estimation of the financial impact of TO transport for waterway transport. Furthermore, depending on the type of vessel and service used, teleoperated transport UCs can also lead to vessels operating with

a reduced crew, which further increases cost efficiency but at the same time requires additional assumptions specific to each setting.

6.4 Overall observations and limitations

The present deliverable consists of several analyses that differ in nature but that complement each other. Putting all our findings together, we were able to provide some clarity on the following questions: What Use Cases are expected to become feasible at different points in time and under which deployment scenarios? What business models are more appropriate for each scenario and transport type? Where does the business case of teleoperated transport start to make sense from an economic perspective? What are the factors behind its financial feasibility? How can adoption be incentivized in the initial stages where investment risk is high?

To improve the preliminary business models, feedback from initial validation consultations suggested the need to address the following aspects. Accordingly, the present report elaborates on the following research objectives:

- Clarify the business case for the identified potential teleoperation service providers in the context of road transport. The role and responsibility of teleoperation service provider is a central one to achieve the adoption of the previously identified business models, and thus the studied Use Cases. While the potential for cost savings in the logistics sector was clear from the previous project studies, the business case for these key actors remained uncertain.

- Elaborate on arrangements for cost distribution and revenue sharing.

- Define convincing value propositions to encourage key actors to assume uncertain value network roles.

- Examine incentives for international service providers or kickstarters to provide financing.

- Develop dynamic models with alternative options and combinations, considering the context and timing.

Due to technical and financial feasibility concerns, we conclude that teleoperated transport deployments should start at a small scale scenario, focusing on Use Cases within a logistics site (e.g., the remote operation of harbour cranes, skid steers, inventories of passenger cars, etc.) followed by teleoperation of trucks for repetitive shuttle runs around logistics sites.

For sites that can rely on existing network infrastructure for their own operations, the most realistic business models in the short run involve the site owner (e.g., a port terminal operator) investing in its own TO centre and service for its internal operations. This model entails little complexity from an organisational perspective and introduces no dependencies on other partners.

In the case that 5G network infrastructure needs to be deployed at the specific site, the business models involving a joint venture of site owners or transport companies would be more feasible since they would allow the sharing of costs and the possibility to enjoy economies of scale from efficiently allocating remote operators to more vehicles and reusing infrastructure.

Alternatively, the business model of a specialised TO service provider start-up would be more straightforward to implement and to scale up to larger deployment scenarios. It is also seen as more likely to become the standard model in the long term. However, from the point of view of a specific area that wishes to adopt TO, this model would be a more passive one, as it entails 'waiting' for such an entrepreneurial company to see a market opportunity and take the risk of kickstarting investments in that specific area.

From a financial perspective, in small-scale scenarios, the business case for logistics companies becomes positive earlier when they invest in building their own TO centre infrastructure and workforce rather than outsourcing it, although in larger scenarios the economies of scale of a specialised TO service provider that operates in several areas (i.e., from the efficiency gains of reducing operator-to-vehicle ratios) would reverse this logic.

When scaling up to highway national and cross-border scenarios, technical challenges become more constraining; in fact, teleoperation of trucks for long-distance goods transport is only considered feasible in the long term once highly autonomous vehicles are available commercially and allowed to drive on public roads. In 'normal' conditions – i.e. unless weather and road conditions make it unsafe –, we assume that the truck would rely on its autonomous systems to drive on the highway. From a financial point of view, the increase uptime and cost-efficiency of automation increases profitability prospects substantially, especially for the long-haul, once a certain threshold in terms of volume of operations is reached.

Regarding waterway transport, the business model and business case are clearer compared to the case of 'land-based' scenarios. The business model of an entrepreneurial service provider that specialises on remote operation but does not own the vessels appears to be the most evident model for the short term; in fact, it is a model that has already been adopted in real life. In the longer term, current logistics players may enter the market and invest in building and managing their own TO centres as well as in taking up the responsibility for adopting the remote operations of vessels themselves. Regarding the financial feasibility of teleoperation Use Cases, waterway transport offers a more immediate business case from the fact that automation technology much more advanced than for the road transport and that CCAM allows to reduce the size of the crew that needs to be on-board of a vessel – and thus working on that single vessel only – without the need to make the ship navigate entirely unmanned if safety or other concerns require people to remain on board. Nevertheless, a potential higher adoption and thus density of remotely-operated vessels navigating through a specific inland waterway would increase the need to densify the network and deploy costly 5G network infrastructure.

The specific additional investments in 5G networks along roads and canals pose the *greatest financial challenge* in our study's examples, not only in terms of the amount of resources but the fact that they mostly represent up-front capital expenses, creating a chicken-egg problem: upgrades must be made before many teleoperated vehicles hit the roads, instead of trailing demand; similarly, truck owners cannot passively wait for network infrastructure to be ready before equipping the vehicles with TO capabilities, since the commercial demand for alternative 5G Use Cases that also require constant, stable coverage with high bandwidth and low-latency is unclear[14]. Therefore, it is crucial for business models to consider the role of an investment kickstarter and/or orchestrator that reduces the risk of initial investments by supporting them and by helping set up the business and regulatory environment.

While the involvement of a given stakeholder will depend on the business case and characteristics in each area, we discussed which actors should be more prone to provide co-financing or taking the responsibility to orchestrate deployments. In smaller scenarios, i.e.

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[14] It must be noted that the business case analysis has relied on conservative assumptions about the availability of additional Use Cases and therefore customers of the relevant infrastructure. It remains a realistic possibility that in the future, alternative Use Cases, and thus revenue sources, become available to 5G and EF service providers that can reuse part of the infrastructure the costs of which our model has allocated entirely to our studied teleoperated transport Use Cases. However, we have focused on a rather pessimistic view about this possibility to reflect the pessimistic views of the interviewed experts. It also remains uncertain, in the case that other UCs become available in time, to what extent the same RAN infrastructure elements can be shared, and thus the costs be split, across UCs, given the specific and strict network resource requirements of TO in terms of uplink, reliability and latency. In any case, it is important to note that we do not expect the Use Cases of teleoperated transport to drive the development and deployment of 5G networks in general nor on its own.

within logistics sites and shuttle runs roads around them, infrastructure owners like port authorities are trusted parties that can orchestrate deployments and have high incentives to invest in TO; they would benefit from the higher efficiency, increased safety, and reduced personnel vacancies of their tenants and terminal operators. Likewise, local authorities may be interested in enhancing the competitiveness of their area's industrial sector. For larger deployments along waterways or roads, road authorities or governments could potentially justify public funding from the existence of positive externalities from TO, including higher traffic efficiency and safety, and from the need to test the technology in initial stages. Road authorities can monetize these investments by applying (additional) distance-related charging (e.g., tolls as a function of distances travelled by teleoperated trucks) or by charging their network usage. While we have shown that the profitability prospects for transport companies are optimistic for relatively low levels of adoption in long-haul scenarios, from reduced personnel wages and overcoming driver and captain shortages, important factors remain uncertain; hence, the high upfront costs represent a considerable risk. Co-investment with associated revenue sharing arrangements can help incentivize investment and, in turn, deployment of teleoperated transport Use Cases.

Notwithstanding the importance of said kickstarters and orchestrators, we hope that our cost-benefit analysis helps resolving the feelings of uncertainty around the business case of teleoperation in the different scenarios. Clarifying the business models and business case of teleoperated transport was identified both in literature and our stakeholder consultations as a main concern behind the uncertainty of teleoperation being feasible business-wise. Uncertainty is behind investment risk, and acts as a disincentive to adoption.

However, behind uncertainty stands more than just the business model and business case questions: questions related to technology, governance and regulations also contribute to such uncertainty. Understanding this, 5G-Blueprint conducted complementary analyses covering all these topics. Therefore, this report does not stand alone, but we recommend the reader to consider it in conjunction with the other reports of the project; foremost, we recommend the reading of the upcoming D3.5 report, which will provide a roadmap for deployment and governance-related recommendations for the main deployment challenges associated with teleoperated transport.

7   REFERENCES

[1] Camps-Aragó, P. et al. (2022). D3.2: Delineation of Business Models. 5G-Blueprint.

[2] Verduijn, T. et al. (2021). D3.1: Business cases and initial value network. 5G-Blueprint.

[3] Chiha, A. et al. (2022). D3.3: Techno-economic analysis. Revision v1.0. 5G-Blueprint.

[4] Saakel, R., Scheich, T., Alhallak, W., & Nambiar, A. (2022). 5G for CAM: A Deployment Metastudy A synthesis of three Pan-European studies on 5G deployment for connected, automated mobility in border regions. DETECON Consulting.

[5] Lindenbergs, A. et al. (2022). D1.10 Report on 5G-ROUTES CAM deployment plan and longer-term deployment strategies v2.0. 5G-ROUTES WP1.

[6] De Clerck, Q., Van Lier, T., Messagie, M., Macharis, C., Van Mierlo, J., & Vanhaverbeke, L. (2018). Total Cost for Society: A persona-based analysis of electric and conventional vehicles. Transportation Research Part D: Transport and Environment, 64, 90-110.

[7] Janssen, R., Zwijnenberg, H., Blankers, I., & de Kruijff, J. (2015). Truck Platooning: Driving the Future of Transportation. TNO. Available at: https://publications.tno.nl/publication/34616035/dLIjFM/janssen%E2%80%902015%E2%80%90truck.pdf

[8] Sari, T. et al. (2021). D6.2: Plan and preliminary report on the business models for cross border 5G deployment enabling CAM. 5GMOBIX. Available at: https://www.5g-mobix.com/assets/files/5G-MOBIX-D6.2-Plan-and-preliminary-report-on-the-business-models-for-cross-border-5G-deployment-enabling-CAM-v2.pdf

[9] NOS Nieuws (2021, Nov 5). Recordaantal ongelukken met pijlwagens en botsabsorbers bij wegwerkzaamheden. Available at: https://nos.nl/artikel/2404425-recordaantal-ongelukken-met-pijlwagens-en-botsabsorbers-bij-wegwerkzaamheden

ANNEX A. INTERVIEW GUIDE

T3.4: Business model validation

Guide for interviews with project experts and AB members

imec

0. Interviewee's profile and contextual data	
Name(s) and initials	
Organisation(s)	
Title/Position(s)	
Role in 5G-Blueprint	[Project partner or Advisory Board member]
Stakeholder type	[e.g. public authority, university, telecommunications industry, logistics sector company, etc.]
Date of the interview / focus group	
Comments	

Section A: Background questions

Necessary background material

- Value network graph from D3.2 *presented as* part of the document shared as background material via email.

Question A.1. With which of the following stakeholders do you identify:
- Telecommunications network operator
- Vehicle OEM
- Teleoperation technology/service provider: TO OEM
- Logistics
    - Port authority
    - Software provider
    - Transport company
- Connected mobility: service provider
- Public authority responsible for road/water management and authorisation
- Other, please specify ......

Additional material: Graph showing 5G-Blueprint stakeholders; shown in slides on the screen during the interview

Answer: highlight above

Section B: Feasibility of the business models

Necessary background material

- Business models defined in D3.2, *presented as* part of the document shared as background material
- Deployment scenarios assumed for WP3, *presented as* part of the document shared as background material
- Key takeaways from D3.3, *presented as* part of the document shared as background material

Overall instructions. If time allows it, try to consider the feasibility of the business models at the granular level: element by element (e.g. is it feasible to have a JV perform that role? to deploy a private network? etc.)

Question B.1. Score the feasibility of each of the 6 business models from a financial perspective, based on the following variables:
- TCO/Break-even point considering the assumed adoption levels and timing
- Potential for revenue generation (return)

Instructions:
- Consider (a) what is feasible for the project's context in practice; (b) what could be feasible in other contexts (e.g., countries, ports), thus thinking of the models as a blueprint
- Consider such feasibility, if possible, from both your stakeholder and role's perspective (selected in Section A)
- Please justify your answer

Additional material
- Online poll (e.g., Slido) showing scoring ranges

Answer:

#BM	Score	Why?
BM1		
BM2		
BM3		
BM4		
BM5		
BM6		

Question B.2. What factors would increase the feasibility of each of the 6 business models from a financial perspective?

Instructions:
- Consider (a) what is feasible for the project's context in practice; (b) what could be feasible in other contexts (e.g., countries, ports), thus thinking of the models as a blueprint
- Consider such feasibility, if possible, from both your stakeholder and role's perspective (selected in Section A)

Answer:

Question B.3. Score the feasibility of each of the 6 business models from a technical perspective.

Instructions:
- Consider (a) what is feasible for the project's context in practice; (b) what could be feasible in other contexts (e.g., countries, ports), thus thinking of the models as a blueprint
- Consider such feasibility, if possible, from both your stakeholder and role's perspective (selected in Section A)
- Please justify your answer

Additional material
- Online poll (e.g., Slido) showing scoring ranges

Answer:

#BM	Score	Why?
BM1		
BM2		
BM3		
BM4		
BM5		
BM6		

Question B.4. What factors would increase the feasibility of each of the 6 business models from a technical perspective?

Instructions:
- Consider (a) what is feasible for the project's context in practice; (b) what could be feasible in other contexts (e.g., countries, ports), thus thinking of the models as a blueprint
- Consider such feasibility, if possible, from both your stakeholder and role's perspective (selected in Section A)

Answer:

Question B.5. Score the feasibility of each of the 6 business models from an operational perspective.

Instructions:
- Consider, especially, the entities taking care of the main roles (5G network deployment and service provision; TO centre management and service provision)
- Consider (a) what is feasible for the project's context in practice; (b) what could be feasible in other contexts (e.g., countries, ports), thus thinking of the models as a blueprint
- Consider such feasibility, if possible, from both your stakeholder and role's perspective (selected in Section A)
- Please justify your answer

Additional material

- Online poll (e.g., Slido) showing scoring ranges

Answer:

#BM	Score	Why?
BM1		
BM2		
BM3		
BM4		
BM5		
BM6		

Question B.6. What factors would increase the feasibility of each of the 6 business models from an operational perspective?

Instructions:
- Consider (a) what is feasible for the project's context in practice; (b) what could be feasible in other contexts (e.g., countries, ports), thus thinking of the models as a blueprint
- Consider such feasibility, if possible, from both your stakeholder and role's perspective (selected in Section A)

Answer:

Section C: Input to improve the defined business models & support the roadmap for deployment

Necessary background material

- Business models defined in D3.2, *presented as* part of the document shared as background material
- Deployment scenarios assumed for WP3, *presented as* part of the document shared as background material
- C.1: Value network graph from D3.2 *presented as* part of the document shared as background material via email.
- C.2: T3.5's goals and main topics *presented as* part of the document shared as background material via email.

Question C.1. For those models considered feasible, who could take over the key open value network roles?

Instructions:
- Explore it, whenever relevant, based on (a) financial interest and (b) technical capacity

Answer:

Question C.2. If we were to implement the 'feasible' models in the BeNeLux, which governance/implementation challenges would we face?

Instructions:
- Explore, whenever relevant, (a) *issues related to:*
  - TO service agreements & liability
  - Legal framework: Conditions; Authorisation; Certification
  - SLA for Cross-Border continuity / handovers
  - Data and Exchange
- Also discuss, if possible, how to overcome these challenges

Answer:

Question C.3. If we were to implement the 'feasible' models in the BeNeLux, what would be a realistic timeline for the earliest implementations and to move to larger deployments?

Instructions:
- BMs were defined per scenario. Consider the feasibility of moving to more complex areas. Help clarify the timeline, considering any the challenges described above regarding moving towards larger deployments.

Answer:

Section D: Preferences

Necessary background material

- Business models defined in D3.2, *presented as* part of the document shared as background material

Question D.1. Which of the discussed models would you prefer?

Instructions:
- Consider from the perspective of your organisation and stakeholder type
- Consider the original versions of the BMs plus the discussions above on how to improve them
- Try to generalise to similar stakeholders beyond our geographical scope
- Please justify your answer

Answer:

Section E: Impact assessment of the business models

Necessary background material

- Business models defined in D3.2, *presented as* part of the document shared as background material

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Question E.1. Score the impact of each business model in terms of its incremental impact on safety compared to the status quo

Instructions:
- Consider (a) what is feasible for the project's context in practice; (b) what could be feasible in other contexts (e.g., countries, ports), thus thinking of the models as a blueprint
- Consider such feasibility, if possible, from both your stakeholder and role's perspective (selected in Section A)
- Please justify your answer

Additional material
- Online poll (e.g., Slido) showing scoring ranges

Answer:

Question E.2. Score the impact of each business model in terms of its incremental impact on the job market compared to the status quo

Instructions:
- Consider (a) what is feasible for the project's context in practice; (b) what could be feasible in other contexts (e.g., countries, ports), thus thinking of the models as a blueprint
- Consider such feasibility, if possible, from both your stakeholder and role's perspective (selected in Section A)
- Please justify your answer

Additional material
- Online poll (e.g., Slido) showing scoring ranges

Answer:

Question E.3. Score the impact of each business model in terms of its incremental impact on the modus operandi of (the organisations in) the logistics sector compared to the status quo

Instructions:
- Consider (a) what is feasible for the project's context in practice; (b) what could be feasible in other contexts (e.g., countries, ports), thus thinking of the models as a blueprint
- Consider such feasibility, if possible, from both your stakeholder and role's perspective (selected in Section A)
- Please justify your answer

Additional material
- Online poll (e.g., Slido) showing scoring ranges

Answer:

ANNEX B. WHITE BOARD FOR ADVISORY BOARD WORKSHOP

ANNEX C. TABLE WITH COST VALUES AND SOURCES

Cost category	Variable	Value	Scenarios	Source	Comments
Fleet manager salaries for the (un)loading and on-site fuelling	per FTE	1.5x truck driver's	L1-L4	[2]	
TO centre infrastructure set up (build) for barges	per unit	25000	W2-W4	[3]	
TOC setup (build) for trucks	per unit	3000 to 5000	L2-L4	[3]	Assumed 5000; support and maintenance assumed 200 per month based on rent vs buy estimations and figures for a full station
TOC setup (build) for cranes	per unit	5000	L1	[3]	
Cost of buying a trailer per transport type	per unit	20-100,000	L1-L4	[2]	Container: € 20.000 Cargo (pallets): € 50.000 (ISO) Tank: € 100.000
(Un)loading time required per trip	hours	0,5-2	L1-L4	[2]	Container: 0,5h Cargo (pallets): 2h (ISO) Tank: 2h
(Un)loading local support required per trip	hours	0-2	L1-L4	[2]	Container: 0h Cargo (pallets): 2h (ISO) Tank: 0,5h
Fleet manager support (e.g., for temperature control, docking, etc.)	hours	0-0,25	L1-L4	[2 & consortium input]	Container: 0,1h Cargo (pallets): 0,25h (ISO) Tank: 0,25h Passenger cars: 0h
Barge lifespan	per unit	40	W2-W4	[3]	
Cranes, terminal tractor, skid steer lifespan	per unit	10	L1	[3]	
Truck lifespan	per unit	7	L2-L4	[1&2]	
Vehicle insurance (incremental / premium for teleoperated vehicles)	per unit	10%	All		Based on the assumption in [2] for trucks.
Truck maintenance (incremental)	per unit	6500	L2-L4	[2]	Includes inspection and/or calibration of the retrofitted equipment.

TOC energy consumption	per sqm of TOC, annual	150 kwh	All	Online sources & [3]	Data from [3] (23,260 kwh/y for a large-scale consumer) was adapted to reflect the uncertainty of future energy costs in the EU. We assumed a min. value of 23260 kwh per year (equivalent to an office of 155 sqm, i.e. for ~10 operators), i.e., for <10 operators, a 23,260 kwh/y consumption was assumed.
TOC office rent	sqm, annual	275	All	[1&3]	
Space per operator in TO centre	per operator	16 sqm	All	[3]	
TO remote station truck (rent, incl. support and maintenance)	per unit, annual	9600	L1-L4	[3]	renting one mobile station, costs would lower with multiple units in one centre
TO remote station with control setup i.e. screens, steering wheel and pedals (rent, incl. support and maintenance)	per unit, annual	18600	L1-L4	[3]	with 2 setups
Equipping a barge with TO tech	per unit, over the useful life	175000		[3]	Full Seafar control system with retrofit
Equipping a barge with TO tech new	per unit, over the useful life	125000		[3]	Full Seafar control system new
Equipping a skid steer with TO tech	per unit, over the useful life	14300		Consortium input	Retrofitting costs include: (a) integration work, which varies based on whether the vehicle already has the gateway install by the OEM, (b) UE, (c) cameras (4 units for cars and skid steers, 6 units in trucks), (c) TO unit, (d) DBW solution from Roboauto
Equipping a crane with TO tech	per unit, over the useful life	85000		[3]	
Equipping a car with TO tech	per unit, over the useful life	12300		Consortium input	
Equipping a truck with TO tech	per unit, over the useful life	15300		Consortium input	
Costs to set up automated docking	per truck	1,200	L1-L4	Consortium input	2x RTK receivers in each vehicle (i.e., 4 for a semitrailer truck).
EFs: dashboard and information services fees	total	120,000	L2-L4	Consortium input	Conservative estimation due to limited data. In practice, costs include platform HW set up and maintenance, and variable message costs depending on nr of vehicles

5G connectivity service fees (ARPU)	per user	20% profit margin	All	Assumed	We assume a profit margin of 20 % to derive the ARPU
Internet (fibre)	per TOC, annual	1200	All	[3]	
Maintenance rate MNO		7%		[3]	on top of CAPEX + OPEX
Overhead cost rate MNO		7%		[3]	on top of CAPEX + OPEX
Cost KWh TO centre		0,27		[3]	

ANNEX D. THE ROLE AND FEASIBILITY OF TRUCK PLATOONING USE CASES

In this section, we discuss the feasibility of adopting truck platooning in the land-based scenarios involving frequent short transports (i.e., scenario L2) as well as highways (i.e., L3 and L4). We also discuss the role that truck platooning can play to help make teleoperated transport Use Cases more feasible to deploy.

In the short term, we considered the possibility of using direct TO to drive platoons of driverless trucks in scenario L2, (from start to finish of the short-distance shuttle runs. Potentially, we could have a benefit by avoiding the idle time from drivers. From our expert consultations, two different viewpoints arose regarding the feasibility of platooning in scenario L2. While the two views share common ground in acknowledging that platooning is a possibility in scenario L2, they differ in their assessment of its feasibility and the associated challenges and benefits.

The first viewpoint shows a positive outlook for platooning in scenario L2. According to this viewpoint, direct teleoperated platoons could be a feasible option in short-distance scenarios. First, the technology for coupling multiple vehicles is already available and standardised today. In the shorter term, however, AD technology will not be ready, so it is seen as more feasible that the leading vehicle is remotely operated and the following one(s) is (are) driverless. Using a remote human driver in the first vehicle would reduce the need from high automation, while adding driverless trucks would already bring cost savings. The benefits mentioned include avoiding idle time from drivers and the potential for operational time savings. Furthermore, the concept of forming a platoon for direct delivery could be advantageous, provided that containers can be directly loaded onto trucks and taken to their destination without additional handling.

In contrast to the previous viewpoint, the other perspective expresses scepticism about the economic benefits of platooning in the short-distance scenario of L2. It questions the potential for forming platoons between two companies due to uncertainties about when goods need to be delivered and the challenges of bundling trucks into a platoon when immediate deliveries are required. Dynamic platooning with matching trucks from multiple origins has always struggled to find commercial success, so using teleoperation to help trucks join/leave platoons does not make sense, especially in smaller scenarios. Additionally, the limited availability of external trucks at key sites is considered as an obstacle. There are also safety concerns from the need for trucks to interact with other road users and cross intersections. Lastly, some internal operations in warehouses are already largely optimized, and adopting platooning would require changing processes. Therefore, the return on investment is still unclear and would need to be inspected more in-depth, taking into account the total scope of impact that platooning can have on the entirety of logistics operations.

From the discussion above, we can conclude, with caution, that a feasible Use Case for our blueprint would be the platooning concept with the remote operation of the lead vehicle in a 2-truck platoon for the entire journey from a port terminal to a nearby distribution centre a few kilometres away, with all vehicles sharing the same origin and destination. A platoon would be formed for direct delivery –when a container from a vessel is directly loaded onto a truck and taken to a warehouse, so to avoid containers being loaded in the stack–, although this may not be possible in all ports. Operational time savings would arise from the quicker processing of containers and from reducing a driver's idle time. The fact that there would be reliable demand from using these currently known, frequent, standard short transports would increase the business feasibility of this Use Case. A specific example in the context of 5G-Blueprint would be a platoon of two semi-trailers or 'eco combis' that takes a journey from MSP Onions to the Vlissingen terminal.

In addition, during the journey, timeslot reservations at intersections via intelligent traffic lights would also be relevant to help a platoon drive smoothly. At the arrival at the site, automated

docking would support the remote operator for this difficult task.

Similar to the discussion above, our expert consultations also yielded two different perspectives regarding the role of platooning teleoperated transport Use Cases in longer-distance scenarios like L3 and L4.

On the one hand, it was mentioned that so there would be more demand for the road transport of multiple containers for certain longer trips that would have common starting and ending points, such as from one EU port to another or between big industrial/operational hubs. Platooning of two or three trucks would reduce the number of remote drivers needed to drive the same number trucks on the highway, thereby reducing costs from wages and helping overcome driver shortages. A platoon could be formed from trucks that are waiting on the same parking lot of a factory or port and share a common highway journey. The first vehicle would be teleoperated, and the trailing vehicles driverless, although not driving autonomously but rather in "slave mode".

On the other hand, the added value of platooning on the highway was questioned at a point in time where AD is already available, because self-driving trucks would not need to form a platoon where the leading vehicle is responsible for driving and the trailing vehicles just follow. In that case, the only apparent benefit would be reduced fuel consumption from shorter following distances, but AD already offers benefits in that sense compared to manual driving. In addition, when considering the size of infrastructure investments, remotely operated platoons may have no business case without AD.

The strongest concern was in terms of safety, similar to the one mentioned before in the discussion of teleoperation of trucks on highways with high speeds. Platoons in faster, more complex roads would expectedly result in more break ups and higher risk if a disconnection happens, and thus more need for AD to help re-form the platoon or stop safely. In addition, in the dense road networks of Belgium and the Netherlands, with frequent highway entries and exits and where trucks are highly mixed with other road users, the traffic safety of forming platoons was also questioned.

Therefore, we conclude that the feasible Use Cases of platooning for scenarios of L3 and L4 would appear only in the long term where high automation levels are available. We discern between the following two:

- **Using direct TO to lead platoons of driverless trucks for a short period of time and get them on and off the highway** (until/from the highway entry/exit), but relying on AD for the highway part of the trip.

- **Using direct TO to monitor and assist highly autonomous trucks and only intervening** (i.e., remotely driving the lead truck in a platoon) when multiple trucks face complex traffic situations outside of their operational design domain (e.g., during road works or specific weather conditions). In cases where multiple vehicles require assistance simultaneously, a coordinated platooning approach could be employed: the remote operator would directly control the platoon leader while providing indirect control (path setting) for the other vehicles in the platoon, reducing the network uplink requirements to remotely operate all the trucks.

From a more technical perspective, enabling truck platooning may require road infrastructure investments or changes in traffic rules. Safely forming a platoon on EU roads is seen as a complex task, due to the short distances between highway entries/exits and the subsequent challenge of safely mixing platoons with normal traffic. In Belgium, traffic is dense, and vehicles entering a highway do not have priority, so the platoon may need to stop. Traffic complexity around cities is even more challenging. Another issue is that, on the highway, truck platoons can cause slow moving traffic and annoyance, since other road users would have to drive as slow as the platoon (likely substantially below the speed limit). To enable platooning, road authorities could keep a lane free for truck platoons to get into the highway or to drive.

Other measures include giving priority to enter highways, or allowing traffic managers to send messages to other vehicles alerting that a platoon is about to enter the road. For the latter, requirements would include having more connected vehicles and revisions of the ITS directive granting traffic managers more rights to access vehicles' OBUs and send safety messages to vehicles.