The importance of business and governance model blueprints for teleoperated transport in cross-border settings

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Abstract

Teleoperated transport solutions are expected to address several logistics-related issues such as driver shortage and job attractivity. 5G connectivity will be a key enabler due to the different requirements to realize teleoperated transport, such as very low latency, high capacity, and reliability. Although this is technically challenging, the focus of this paper is to present techno-economic methodologies to assess the challenges form a business and governance perspective. In order to develop blueprints for sustainable business and governance models, which can be extrapolated to other transport axes in Europe, several legal and business uncertainties, as well as new collaboration strategies in this complex ecosystem need to be evaluated. To achieve this goal, a generic methodology has been developed to get insights in the ecosystems of cross-border logistics and connectivity, as well as the impact on their business cases using lesson learned from similar projects. In addition, first results are discussed.

Keywords: Teleoperated transport, 5G networks, business and governance models.

1. Introduction

The transport sector is facing a significant labour market shortage in several European countries such as in Belgium and the Netherlands. For instance, in the Netherlands there were 4,900 job vacancies for truck drivers in Q1 of 2019 which did not get filled [1]. Research from the IRU makes clear that driver shortage is expected to grow fast across Europe [2] – equally confirmed in Flanders [6] – what may harm the economic growth of multiple activities for numerous transport companies, e.g. around 41% of the Dutch transport companies indicated this to be the case [3]. In addition, waiting times at container terminals and warehouses are a tremendous waste of valuable resources such as truck, forklifts and mobile cranes' drivers. As calculated by the Dutch Ministry of Infrastructure and Water Management [7], these waiting times result in an annual economic loss between 26 and 47 million euro. Furthermore, according to the IRU annual report [2] the trucking profession has a very poor public image, thus inhibiting acquisition of new employees. Truck drivers are perceived to operate under poor labour conditions, long working hours and long periods away from home. This reduces enthusiasm for the profession of females (in Europe, only 2% of employed truckers are female) and of young professionals. The divergent evolution in supply and demand for truck drivers all together results in structurally unfilled vacancies which hamper growth opportunities for logistics companies, put pressure on their profitability and lead to higher overall market prices of transportation (an increase by 3 to 6 percent in recent years).

Therefore, there is a clear need to find solutions in the short to medium run to help the sector overcome this structural personnel challenge. Measures to increase the attractiveness of the trucking (and shipping) profession would be warmly welcomed and would have a high business value.

In this paper we propose teleoperated transport (trucks and barges) based on 5G connectivity as a solution to alleviate the shortage in professional truck drivers (and shippers) to a large extent in the short to medium run, while equally making better use of available manpower. Teleoperated trucks, cranes and barges will reduce the unfilled vacancies, by making the profession more attractive due to a better work-life balance, and by keeping the number of drivers (and skippers) needed stable in case of increased economic activities. In the case of container handling in harbours, supervising the crane from a control room would allow crane operators to enjoy a safer, less physically strenuous, and more social working environment [8].

Although safety is critical, it poses less of a challenge for teleoperated driving (relative to L4/L5 autonomous driving) from an artificial intelligence point of view, because a human remains in control of the vehicle. Automation remains needed at the vehicle to allow safe teleoperation, but here the target is the ability to bring the vehicle to a safe stop in case of malfunctioning of the teleoperation functionality, and not the safe navigation through traffic under all thinkable circumstances, including extremely rare, unexpected and unconventional traffic situations. However, from a connectivity point of view the requirements are challenging, since vehicle connectivity needs to be guaranteed at all time to allow the remote operator to remain in control of the vehicle. Hence, teleoperation will not be possible without 5G technology. 5G aspects such as latency, reliability and coverage, security, bandwidth and network capacity are crucial for enabling the proposed solutions [9].
5G-Blueprint [10] is a European funded project that aims to design and validate a technical architecture, business and governance models for uninterrupted cross-border teleoperated transport based on 5G connectivity. At the core of the project are two teleoperation use-cases, on the road and on the water respectively. In the first use-case, yard truck and road-going vehicles will be equipped for remote-controlled operation, which is to be tested in a port environment as well as on sections of public roads. In the second use-case, remote-controlled operations will be tested on a barge. On top of these use-cases, additional functionalities for Connected and Automated Mobility (CAM) are developed with the aim to further increase efficiency of the teleoperators, (i) automated docking functionality in the port along with a tele-operable mobile harbour crane (presented in Figure 1); and (ii) Cooperative Adaptive Cruise Control-based (CACC) platooning. The project will study these different use cases in the Belgian-Dutch corridors, hence was the focus of study on Belgium and the Netherlands.

Within this promising 5G-Blueprint solution many stakeholders from different backgrounds such as public authorities, port authorities, data providers, service providers, logistic companies and road users will be part of the CAM ecosystem, which poses several challenges from a business and governance model perspective. Therefore, developing a blueprint for future 5G-enabled CAM business cases, by identifying workable business and governance models is essential for this proposal to become a sustainable solution.

In order to identify those potential business and governance models, the following aspects need to be researched and analyzed:

- The identification of cooperation and collaboration strategies that allow the involved stakeholders to operate and compete within the ecosystem in order to generate the intended beneficial effects of CAM (and teleoperated transport in particular).
- The economics of 5G tools in cross border transport & logistics as well as passenger transport: bringing CAPEX and OPEX into view, both on the supply (Telecom) side and on the demand (Transport & Logistics) side for transformation of current business practices as well as new value propositions.

- The Governance issues and solutions pertaining to responsibilities and accountability within the value chain dependent on cross border connectivity and seamless services relating to the Dutch & Belgian regulatory framework (telecommunications, traffic and CAM experimentation laws, contracts, value chain management).

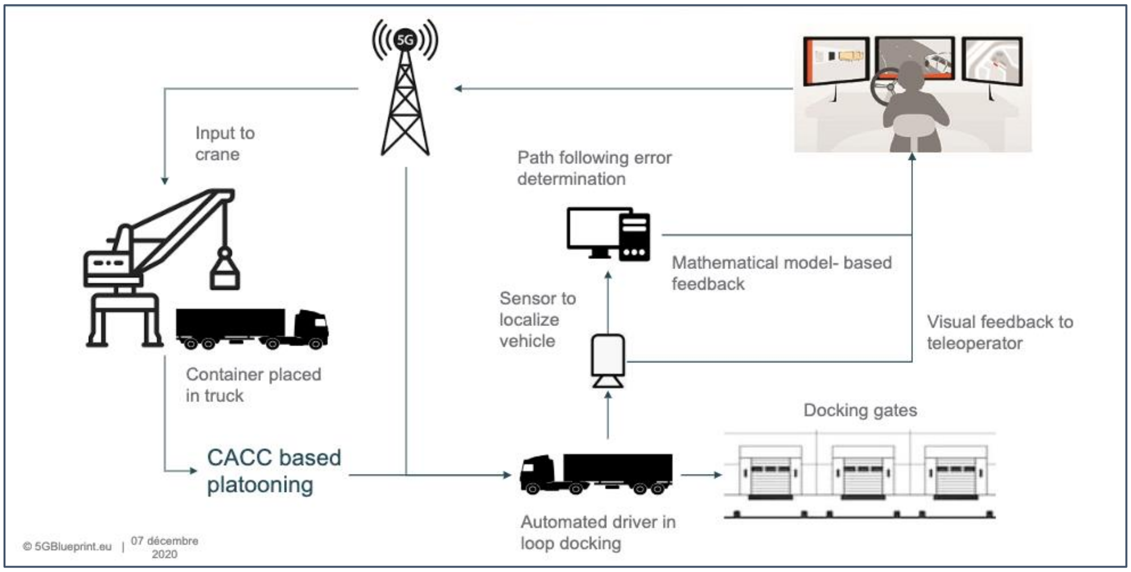

Figure 1 Technical architecture of the automated docking functionality in the port [10]

In this paper we firstly present our methodology in tackling these research aspects, secondly, our position comparing to the state of the art, and finally present first results and our next steps to achieve the defined research objectives.

2. Proposed research methodology

To address the research pillars discussed previously and to develop a blueprint for future 5G-enabled CAM business use cases by identifying sustainable business and governance models, we developed a general methodology that consists of the several building blocks represented in Figure 2.

An **Initial Business Case identification** (section 3.1) is performed in order to identify and validate the interest from the different ecosystem players in the proposed solution as well as the potentially generated benefits and the required interactions to generate these benefits. These first insights will help not only building the **Initial Value network** but also drawing the first lines of potential business models (with the **Business Models Identification** , section 4). The outcomes of both the initial value network study and the business models identification will feed the final **Value Network Analysis** (section 3.2) exercise where all involved stakeholders will be captured in addition to their interactions in term of tangible and intangible assets. The Business Model identification together with the value network analysis will define the business models that will be quantitively assessed within the **Techno-economic Analysis** (section 4.2) from a cost-benefit perspective. This later will lead to both a **Business Models Validation & Assessment** and better insight into the **Deployment Requirements**. Which finally is to provide input to the **Governance Models** identification (section 4.4).

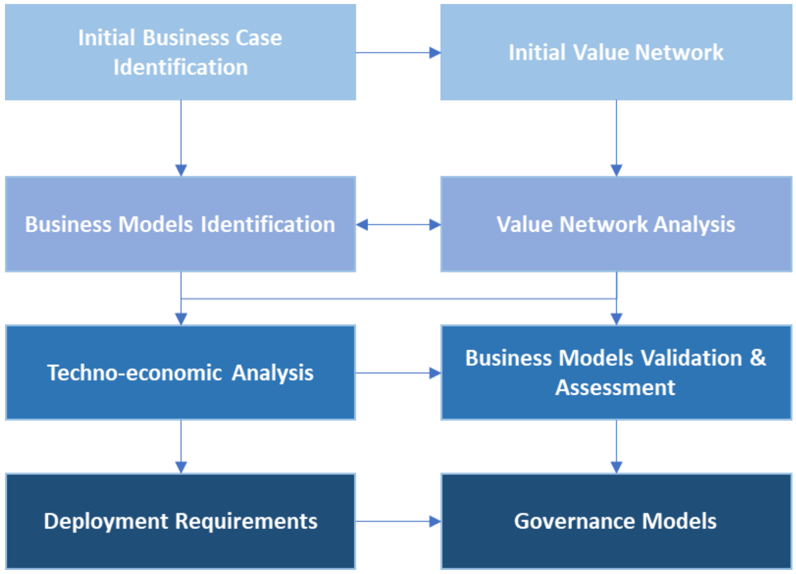

Figure 2: Methodology building blocks

3. Teleoperated transport ecosystem analysis

Teleoperated transport is seen as a promising solution to resolve the logistic field' issues, discussed previously. On the other hand, logistics is already a quite complex ecosystem [11]. Adding the 5G, End-2-End (E2E) connectivity required for the teleoperation results in a multi-stakeholder ecosystem, where the different involved parties have different backgrounds. In addition, this E2E connectivity is needed all the time along the studied transport axis, which implies the involvement of different connectivity providers in different countries to guarantee a seamless 5G connectivity roaming in cross-border environment or between both private and public connectivity networks. Adding these elements, 5G E2E connectivity provision, the cross-border environment and roaming between private and public networks, to an already complex transport ecosystem is not only challenging from a technical perspective, but also from a business perspective. Therefore, a careful and deep analysis of the teleoperated ecosystem is crucial for identifying sustainable business and governance models.

3.1. Initial Business Case identification

To be able to assess the economic impact of teleoperation in cross-border logistics settings, as well as to draft sensible business and governance models, we need to consider the entire ecosystem. The main stakeholders whose involvement is crucial to enable the business cases include traditional stakeholders such as vehicle manufacturers and regional/national public authorities. For simplification, we just zoom into those stakeholders that are more specific to the use cases and 5G aspects.

- Connectivity service providers. Vehicles must communicate with other vehicles (V2V) and with infrastructure (V2I), or in general with any other road or port user (V2X), while the same applies for infrastructure elements (I2X). The providers of 5G connectivity services, for instance a connectivity subscription or a network slice, will be Mobile (Virtual) Network Operators (i.e., MNOs or MVNOs).
- Logistics employees. The introduction of tele-operated driving and barging will change the work of drivers and skippers and reduce the need for the traditional role of driver. In addition, the new position of a tele-operation driver, skipper or crane operator is created with different job requirements and employment conditions. Physical tasks and certain responsibilities with respect

to safety and cargo handover that are now performed by a driver will be taken over by employees at a logistics centre, which will lead to new responsibilities for said centre.

- Transport companies. Transport companies carry out the physical transport activities with drivers and a fleet of own or leased vehicles. They take care of the transport directly on behalf of a shipper or indirectly for a logistics service provider with outsourced transport.
- Logistics centres. The logistics centres are locations (warehouses and terminals) where tele-operated vehicles and barges load and unload goods. These locations must be adapted to receive and handle tele-operated vehicles. This requires adjustments in communication with the tele-operation driver and solutions for the tasks that are currently still being performed by drivers.
- Technology providers. Technology providers provide the technology for the vehicle and for the control room with which a teleoperation driver can control the vehicle or vessel. On the one hand, this consists of the technology aimed at creating and increasing the situational awareness and on the other hand creating the optimal human machine interface to allow the tele-operated driver to function optimally. Because a wide range of different technologies is used in a tele-operation solution, integrators will arise who offer complete solutions and relieve logistics users.
- Equipment providers: Trucks and barge must be adapted to be served by tele-operators. In the first phase, the OEMS do not yet deliver these solutions and retrofit solutions will be built into existing equipment by technology developers. In time, the OEMS will supply equipment that makes tele-operation possible or which are tele-operation ready, making it easier to build in technology.
- Service operators: the introduction of tele-operation also makes new roles possible, for example providers of tele-operation services, i.e. those service providers where a transport company on demand requests a driver from a service operator to drive a specific vehicle from a to b . The service thus provides a tele-operated driver on demand.

3.2. Value Network Analysis

A value network analysis will help understand the roles and responsibilities of different public and private stakeholders, while also plotting the flow of goods, data and money between these actors. The analyses will put focus on specific challenges involved in the studied settings: for instance, cross-border CAM services along the Flemish-Dutch corridor will most likely raise the issue of seamless cross-border roaming obligations and agreements. Through surveys and workshops with project partners, we will identify which actors have the capabilities to perform each role, and what they would require from others in order to so, in terms of the aforementioned variables, i.e., goods, data, etc.

While some value network roles are implied by the stakeholder categories above, considering roles expands the list, as it considers all the business functions required to enable the different use cases in practice.

For instance, from the point where cargo arrives at a port by ship until it reaches the motorway with a truck, multiple roles can be involved at different stages of the process: besides remote supervision and operation of cranes and reach stackers in ports, forklifts in warehouses and trucks in distribution centers and on open road, other roles entail docking, (un)loading, identifying and assigning containers in real-time, and providing navigation, localization and estimated time of arrival. Furthermore, specific communications roles and responsibilities include, amongst others, the provision of the connectivity service, the issuing of network slice instances, the hand-over between networks when the border is crossed, the governance of roaming, and the processing of data in the cloud. As mentioned before, 'clouds' can be in central locations or in edge node, which entails a trade-off between the cost-efficiency of a centralized approach and the lower latency and higher privacy of edge computing [12] and [13]. Lastly, other support roles include traffic management, homologation of vehicles, coverage of liability, and so on. An Initial value network is under progress and a first result is depicted in Figure 3.

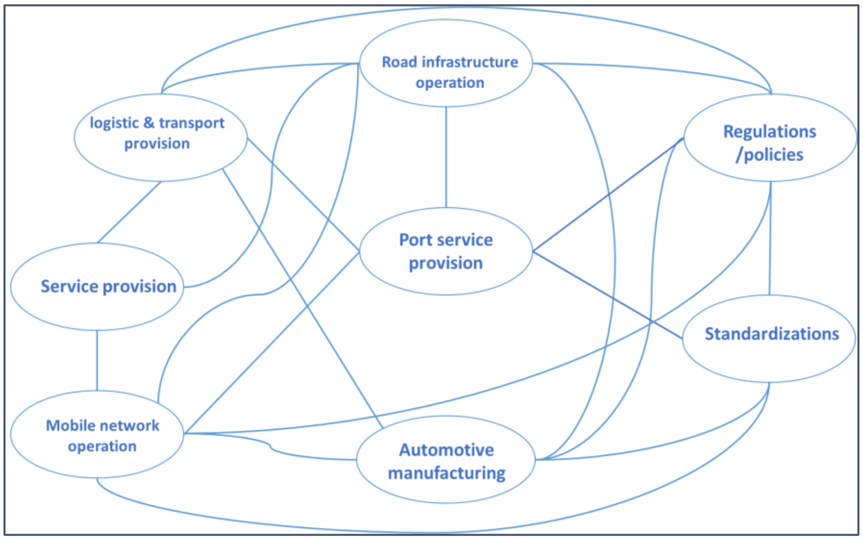

Figure 3 Initial Value Network of Teleoperated solution

4. Business and governance models analysis

The aim of our work is to develop a blueprint for future 5G-enabled CAM business cases, by identifying workable and sustainable business and governance models. To limit the scope of the studied scenarios, reference scenarios are proposed in section 4.1. In section 4.2, the adopted methodology to perform the business modelling and the techno-economic analysis is detailed. Section 4.3 presents the first insights resulting from the application of the proposed methodology to the reference scenarios.

4.1. Reference scenarios

In order to limit the scope of the teleoperated transport scenarios from a business and governance models perspective, a set of reference scenarios has been defined. These scenarios are based on several metrics, such as the geographical coverage of the teleoperated operation, the control of the teleoperation (TO) center, 5G connectivity provisioning, etc. These scenarios are as follows:

Scenario 1: geographically limited area with numerous (short distance) transports: for example, a port area/ industrial zone with interconnected supply/ manufacturing chains. In this scenario, the TO center can be constructed as a central center in the studied area serving all interested users. The 5G connectivity can be made available through private or public networks.

Scenario 2: major transport axis – significant transport flows: TO operation can be offered by an independent Service Provider and/or may concur with 'in house' operated TO (larger players). Since public roads often cover a significant part of such transport axis, 5G connectivity providers must cover these segments as well.

Scenario 3 - public road, across national borders: In this scenario, derived from the previous one, a new framework for TO operation *across borders* is crucial to identify. In addition, there is a change of the 5G connectivity providers e.g. MNOs, for which we need to ensure seamless hand-over (connectivity & service monitoring) in order to avoid loss of control.

4.2. Business models for teleoperated transport

4.2.1. State of the art of CCAM projects

At the European level, several public and private initiatives pertaining to cooperative, connected and automated mobility (CCAM) have explored business model issues. Whereas the main focus of these projects is the development, testing and deployment of CCAM systems, they also aim at ensuring the interoperability and seamless availability of CCAM services in the EU through multiple pilots. A selection of projects is presented in the following table.

Name	Year launched	Technical scope	(Co-) Funding	Geographical scope (countries by ISO code)
5GMED	2020	CCAM, in road and railways	EC, consortium partners	Mediterranean corridor (ES & FR)
5G Routes	2020	CCAM, in road, rail and shipways	EC, consortium partners	'Via Baltica-North' corridor (LV-EE-FI)
CONCORDA	2017	C-ITS, focusing on interoperability of communication protocols	EC, consortium partners	Test sites in BE, NL, FR, DE, & ES
5G cross-border highway corridors (5GCroco, 5G-Carmen, 5G- Mobix)	2018	CCAM in cross-border corridors, focusing on providing uninterrupted connectivity to support L4/L5 autonomous driving.	EC, consortium partners	Corridors and trial sites in the EU (FR, SE, ES, LU, IT, AT, DE, GR, PT, FI & NL) and beyond (TR, CN & KR)
C-MOBILE	2017	C-ITS	EC, consortium partners	BE, DK, FR, DE, GR, IT, NL, ES, UK

Table 1 State of the Art of CCAM projects

While preceding projects have proposed business models adapted to their particular technical scope focus, the novelty of the 5G-Blueprint project stems in its combined technical validation of remote operation use cases in cross-border settings, across multiple transport modes, making use of 5G connectivity, and with a strong focus on business and governance aspects aiming at generating a real Blueprint that can be extrapolated to other cross-border corridors in all Europe. Nonetheless, valuable knowledge resulting from these previous projects, for instance, insights on business models for seamless roaming [14] and on Tele-Operated Driving use case [15] for cars which needs to be extrapolated into other areas such as port area and waterways, will be used as input for this project.

4.2.2. Business modelling and Techno-economic methodology for teleoperated transport

A **business model analysis** will assess questions related to the control and distribution of the assets and rents within the ecosystem, the functional architecture and interoperability of different vendor solutions, the value proposition offered to prospective customers and the strategies to generate revenue associated with each business model. To this end, we will use the business model matrix approach to assess, in a structured way, twelve parameters that underly these aspects [14]. This analysis is to result in an understanding of the impact that the specified 5G-enabled business cases may exert on current business models, together with the identification of novel business model designs. In addition, this exercise will be iterated through the validation of all consortium partners. Moreover, next to the validation of the identified business models, a quantitative assessment is required.

The assessment will be **techno-economic** in nature, measuring the associated economic costs, benefits and allocation models for the different architectures, business cases and stakeholders. Via this techno-economic evaluation we want to indicate and quantify the added value of 5G connectivity for the selected use case compared to the available LTE technologies. The techno-economic analysis relies on a generic Total Cost of Ownership (TCO) model to quantify the investment (CAPEX and OPEX) to realize the different business models. On the other hand, a benefit model will be developed to study and quantify the expected benefits resulting from teleoperation. Benefits like save on waiting time for loading cargos or docking thanks to the enabling function ETA (Estimated time of arrival) which leads to more efficient planification and use of logistic resources. In addition, cost-benefit allocation models will be designed to distribute the costs and potential benefits among the involved stakeholders for specific business cases. These models are designed to support the complexity of the ecosystem as well as the new technologies used within 5G networks that enables multi-actors/verticals to be involved in the connectivity provisioning such as network virtualization and network slicing. These new proposed models are built using the cost allocation model we developed for network slicing [17].

4.3. First results of the application of the defined methodology to the reference scenarios

For the first scenario, presented in section 4.1, we started with analyzing the different 5G connectivity provisioning business models for the case of ports. Two initial business models have been identified, the first one relies on using a private 5G network within the port area, yet the second one is based on using a network slice from one of the MNOs covering the port area.

Private 5G network business model: in this model the port authority will engage a 5G connectivity provider to deploy its 5G private networks to cover all the port area. This private network should be adapted to the different services that the port is providing, being IoT- based services, and teleoperated services that require high capacity together with very low latency. In this business model, the port authority needs to pay for the deployment of the 5G private network to the connectivity provider. The advantages of such an approach are: i) Full control of the network : security & autonomy, ii) data management is local and centralized, iii) port might have multiple use cases to serve with this private network, so might define multiple network slices, for example one eMBB slice to serve the port employees and one IoT/mMTC slice to serve the teleoperated docking manoeuvre and teleoperated cranes etc.. The resource allocation towards these slices can be realised dynamically based on the demand of its provided services which leads to more efficient resource usage comparing to leasing different network slices from MNOs and hence might be more cost-effective. On the other hand, the main challenges facing this business model are: i) Mobile network knowledge is required to maintain and troubleshoot the private network, this can be solved by hiring network experts or outsource this task. Which might be costly compared to leasing network slicing from MNOs since the network maintenance is part of the contract in this case; ii) The coverage of the network is limited to the port site, so when leaving the site, a connectivity handover is needed to ensure the continuity of the services for certain use cases, e.g. teleoperated trucks and barges. However, one can argue that this point is not a real issue for ports if the transportation of goods does not belong to their core business but to the transportation companies/ logistics. This case will be studied in detail within the scenario 2 (described in section 4.1). Examples of companies that already are using a 5G private network: Arcelor Mittal, Brussels Airport and the port of Zeebrugge (with Citymesh) [18].

The second business model relies on the concept of **Slice-as-a-Service (SaaS) business model**, where the port authority leases a customized slice according to its services requirements from MNOs. The port authority pays to MNO in order to lease a network slice that complies with its needs. The requirements of this network slice are described in detail in an SLA between the two parties. According to [18] charging systems or even billing systems, it is much easier to customize towards the specific needs of a customer comparing to the past model where such customization would result in time-consuming system integration. The main advantages of such a business model are: i) the network slice is customized to the connectivity KPIs required by the different port' services; ii) the troubleshooting and maintenance of the network slice, which can be seen as "virtual private network", is on not the responsibility of the port authority comparing to the first business model; iii) Less technical barriers for seamless connectivity roaming are to be resolved when leaving the port area to the public roads comparing to the first model where we have a private network. Nevertheless, this business model has limitations comparing to the first business model such as i) less flexibly in term of network resources management, if a significant variation in the traffic is observed, a new agreement has to be made with the MNO to adjust the network slice accordingly. ii) if different services need different network connectivity requirements (e.g. IoT vs eMBB), different network slices have to be leased from the MNO comparing the freedom in term of the number of services that a 5G private network can support. This business model apparently is gaining more and more interest from several verticals such as healthcare providers, automotive, transportation and logistics companies, factories and energy and utilities providers, according to [19]. Based on the same source, the global market size of network slicing is forecasted to grow from USD 161 million in 2020 to USD 1,284 million by 2025.

4.4. Governance models

The project aims to provide recommendations on optimal governance strategies for different organizational and policy goals. Three important challenges to address are (i) the cross-border collaboration between mobile operators for roaming and handover issues, in order to ensure a continuity of services, (b) the sharing of data between the different (cross-border) locations, and (c) an end-to-end coverage in terms of liability. In addition, clear governance will be needed to assure all necessary roles and responsibilities are filled and stakeholder coordination is sustained. Previous research in the context of European transport corridors (TEN-T) recognises the importance of governance design to facilitate the involvement of many stakeholders. As possible specific tactics, authors in [14] suggest assigning a coordinator for each corridor, setting up a corridor consultative forum, working groups, and a concept of 'future ideas' laboratories. Another important question centers on the degree of involvement of public entities in incentivizing private parties to adopt important roles or in taking responsibility for these and to participate in the concerted financing strategies. Finally, the governance recommendations also are to include strategies for the deployment and implementation of the required infrastructure and services, building on the technical outcome and the business models explored and defined.

5. Conclusion

In this paper, the importance of defining new and sustainable business and governance models to unlock the potential of teleoperated transport has been discussed. Challenges facing these models such as E2E seamless connectivity across the border and the different transport axes, suitable collaboration models for the key actors involved, and the complexity of the analysed ecosystem in terms of cost-benefit trade-offs, are addressed in this study. Two potential business models are identified for the port authority to offer teleoperated services within the port area, being the private 5G network business model and the Slice as a Service business model. These business models were analysed qualitatively in terms of advantages and challenges/limits. Alternative business models and collaboration strategies combined with quantitative analyses will be investigated at later stages of the project. These insights, resulting from the proposed methodology will be used to formulate blueprints for sustainable business and governance models that can be extrapolated to other transport axes in Europe.

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References

[1] S. i. T. &. Logistics, "Sectormonitor transport en logistiek," 2019.

[2] IRU, "International Road Transport Union Annual report," 2018.

[3] L. .nl, "Logistiek," 2019. [Online]. Available: https://www.logistiek.nl/carriere-mensen/nieuws/2019/09/arbeidsmarkt-transport-en-logistiek-blijft-onverminderd-krap-101169571. [Accessed February 2021].

[4] P. o. Antwerp, 2018. [Online]. Available: https://www.portofantwerp.com/en/news/port-antwerp-track-fifth-record-year. [Accessed 2019].

[5] N. S. Port, July 2019. [Online]. Available: https://en.northseaport.com/best-half-year-ever-for-north-sea-port-freight-transshipments. [Accessed November 2019].

[6] V. D. v. A. Bemiddeling, June 2019. [Online]. Available: https://www.vdab.be/nieuws/pers/openstaande-opleidingsplaatsen-voor-vrachtwagenchauffeur. [Accessed February 2021].

[7] P. Swaak, "Talking Logistics Alliance, Concept Plan van Aanpak,," January 2018.

[8] abb, "Remote crane operations," [Online]. Available: https://new.abb.com/ports/solutions-for-marine-terminals/our-offerings/container-terminal-automation/remote-crane-operation. [Accessed February 2021].

[9] F. H. R. W. L. A. M. T. L. &. P. P. Boccardi, "Five disruptive technology directions for 5G," *IEEE communications magazine,* vol. 52, no. 2, pp. 74-80, 2014.

[10] 5gblueprint, 2020. [Online]. Available: https://www.5gblueprint.eu/. [Accessed 2021].

[11] P. P. Boschian V., "The Evolution of Business Models within a Business Ecosystem for Cooperative Logistic," *IFIP Advances in Information and communication technology,* vol. 400, 2013.

[12] M. Satyanarayanan, "The emergence of edge computing," *Computer,* vol. 50, no. 1, pp. 30-39, 2017.

[13] H. H. A. M. S. &. L. T. V. Chang, "(2014). Bringing the cloud to the edge," in *IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)*, 2014.

[14] 5gcarmen, "5gcarmen," 2018. [Online]. Available: https://5gcarmen.eu/. [Accessed February 2021].

[15] 5gcroco, "5gcroco," 2018. [Online]. Available: https://5gcroco.eu/. [Accessed February 2021].

[16] P. Ballon, "Business modelling revisited: the configuration of control and value," *info,* vol. 9, no. 5, pp. 6-19, 2007.

[17] A. V. d. W. M. C. D. &. V. S. Chiha Ep Harbi, "Network slicing cost allocation model," *JOURNAL OF NETWORK AND SYSTEMS MANAGEMENT,* vol. 28, no. 3, p. 627–659, 2020.

[18] CityMesh, "reference cases," [Online]. Available: https://citymesh.com/en/references. [Accessed February 2021].

[19] G. W. Paper, "5G Network Slicing for Vertical Industries," 2017.

[20] m. a. markets, "network slicing market," [Online]. Available: https://www.marketsandmarkets.com/Market-Reports/network-slicing-market-120515704.html. [Accessed February 2021].

[21] M. N. K. L. &. J. C. Öberg, "Governance of major transport corridors involving stakeholders," *Transportation Research Procedia,* vol. 14, pp. 860-868, 2016.