5G-enabled innovation in ports' logistics: expectations from the 5G-LOGINNOV Project and relevance for the Physical Internet

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Abstract: *The EU funded 5G-LOGINNOV Project will support the generation of new 5G-enabled technologies for logistics operations in three Living Labs (LLs): Athens, Hamburg, and Koper. Athens mainly deals with technologies for real-time tracking and enhanced visibility of 5G yard-trucks for service optimization, job allocation and predictive maintenance; Hamburg addresses the usage of 5G to improve port operations, specifically for connecting the Hinterland to the port's facilities; Koper focuses on 5G enabled technologies to improve the automation of logistics processes in ports and to support mission critical services in the port area. Therefore, the Project will ensure relevant advancements for Physical Internet, pushing for supply chain synchronization and "5G-intelligent" approaches for the management, routing, and optimization of operations in ports areas. This study presented in the paper aims to present the methodology to assess stakeholders' expectations on the potential benefits of 5G-enabled technologies on business models and operation. While preliminary results of the assessment have been presented, the analysis will continue until the end of the demonstration period by assessing if stakeholders' expectations have been met.*

Keywords: *5G, logistics innovation, stakeholders' expectations.*

Conference Topic(s): *business models & use cases; logistics and supply networks; PI impacts; PI implementation; ports, airports and hubs.*

Physical Internet Roadmap (*Link*): *S47(Proje(ant)(a9-13(the)os(ternet)-2re)3lev)(ant)(a9-10am( )]TET* capable of developing new products and services applying 5G technologies within logistics processes and contribute to the development of globally harmonized standards for the implementation of 5G devices in the field of logistics and transport processes. To this end, the 5G-LOGINNOV project will contribute to the development and implementation of different Use Cases (UCs) in three port cities, namely the Living Labs (LLs) of Athens, Hamburg, and Koper, with the aim of supporting the future usage of 5G-enabled innovations in logistics processes.

2 Linked works and motivations for the study

With the massive increase of flows of people and goods, various limitations related to traditional logistics solutions have been brought into light. In this regard, Montreuil et al. (2011) underline the unsustainability of logistics, highlighting various aspects that limit the efficient use of resources and the optimization of processes. The first of these disadvantages is that containers travel empty or not fully loaded in most cases, constituting a waste of resources and time, and affecting the efficiency of the logistics chains. In many other cases, the goods are unnecessarily moved through logistic chains that extend for several kilometers, without there being a clear and smart planning of the chain capable of optimizing the logistics processes. Logistics networks are developed in a disorderly way and do not communicate effectively with each other, using different operating standards and with infrastructures that are often inadequate to interact in a multimodal system. Another fundamental aspect is linked to the safety of drivers, who are forced to make long journeys and encounter various health problems due to a lifestyle that keeps them away from their families and loved ones. Finally, a system thus developed constitutes damage to the environment, causing a strong increase in CO2 emissions and compromising the air quality in inhabited areas.

The PI paradigm has been designed to overcome these limits, representing an open and interconnected logistics system, in which goods can travel through multimodal logistics chains on standardized containers (Montreuil et al., 2012). In the definition of Ban et al. (2021), the Physical Internet "*enables hyperconnected logistics which is capable of transforming the freight transport fragmentation, logistics and distribution industries into a single manufacturing. Goods would be encapsulated and designed in standard for logistics that are modular, smart and reusable PI-containers…. (that) can be routed from end to end through open hubs by developing real-time identification, tracking, and communication systems. Also, PI containers can store data or information required during different operations in terms of handling and transportation*". In this view, Physical Internet is a concept that conceives logistics networks as an interconnected system which, similarly to the Internet, uses standardized languages and models to allow its parts to communicate effectively by exchanging information. Unlike current logistic processes, this data is exchanged between one logistic node and another using common protocols, such as to allow the exchanged units, i.e., containers, to be transported more efficiently. These units must necessarily have common standards in order to function effectively. In particular, the containers must have standardized dimensions to make transport more efficient, and at the same time they must be equipped with devices capable of providing information on the external and internal environment, in order to guarantee the monitoring of the transported content. Furthermore, it is necessary that they are recognizable, i.e., that they have unique identifiers according to a common standard in order to guarantee tracking, management and storage. At the same time, the means used for handling containers, i.e., all the devices and tools used to move the latter from one point to another, must be designed to interact with the units being transported. This implies the adoption of technologies such as IoT systems that allow a continuous exchange of information on logistics processes and increase the flow of data aimed at supporting decision-making processes. Finally, logistics nodes and protocols are two building blocks of the Physical Internet. The logistics nodes are represented by all those infrastructures used for the management of flows, or rather the starting and arrival point of the latter. Together with protocols, they are a fundamental part of transport network management, and have the key role of facilitating the inbound and outbound flow of containers. Inside the logistics nodes, the information flows are processed by means of sets of rules and standardized procedures, or rather the protocols, which serve to implement the ability of the logistics network to communicate in all its parts.

The application of a system designed in this way implies the need to implement technologies capable of effectively connecting all the components of the logistics chain. To this end, IoT devices, such as wireless sensors, AI, GPS devices that exploit the 5G internet network can be used to optimize logistics processes, being able to be integrated with the components of the production cycle, increasing efficiency. Tran-Dang et al. (2020) summarize these technologies into four basic groups:

1) Data acquisition technologies. This set identifies all IoT systems and devices aimed at acquiring information on logistics processes. They include systems aimed at identifying cargo and containers, such as QR codes and bar codes, those used to collect information about the surrounding environment, such as sensors, and those aimed at tracing the different components, such as GPS and GRPS systems.
2) Connectivity technologies. This vast group includes all the technologies that serve to speed up and make more efficient communications between the various components of the logistics chain. They apply to all activities of the production cycle and include the mobile communication networks that allow the functioning of the Physical Internet. This set also includes 5G technologies, which exploit cellular technology to implement all the other components, such as sensors, tracking technologies, warning systems, etc.… Connectivity technologies are therefore applied to other technologies and increase their operating capacity, acting on factors such as the speed and amount of data exchange, thus supporting decision-making processes and the management of the logistics system.
3) Data processing technologies. This set identifies all the technologies used for data processing and storage. The growth in data volumes generated by logistics flows has contributed to the diffusion of cloud-based platforms to which data is transferred and managed in a centralized way. In this sense, big data travels on the internet and is processed by these platforms to then be stored in the servers. Data processing technologies concern not only cloud services for the management and processing of information, but also the development of analysis algorithms that allow these processes to be optimized, thus supporting decision-making processes.
4) Middleware. This group of technologies identifies all the components and applications that serve to effectively coordinate data flows between IoT components. This whole is vast and heterogeneous and accompanies other technologies, facilitating communication between its parts.

Within this conceptual framework, 5G-enabled technologies constitute a fundamental element of the logistics chain. They have the function of supporting the operations of data acquisition systems, implementing the transmission of information from one component of the logistics system to another, and supporting decision-making processes.

3 Objectives of the study and methodological approach

The main objective of the study is assessing the current market scenario in the context of the 5G-LOGINNOV LLs by collecting information on the products and services used for the UCs implementation. Moreover, the study aims to analyze, for each product or service:

- the "5G operational" relevance, to assess to which extent the uptake may benefit 5G-enabled logistics operations of the area.
- the "Business Model" relevance, to define to which extent the uptake may benefit the business models of the LLs.

For this purpose, a bottom-up approach was adopted aimed at collecting data on the products and services developed in the three different LLs. Therefore, in Phase 1, a data-set was built aimed at classifying the information on the technologies developed, their functions within the logistics processes and the expectations of stakeholders on the future impact of the products and services developed on logistics and business models. In Phase 2, the aggregation of data led to the creation of a taxonomy, aiming at clustering the products and services and allowing for an easier comparison. A conceptual framework for the analysis has been developed, aiming to guide the definition of preliminary results. In Phase 3, preliminary results have been provided; however, as this is an ongoing study, continuous updates and feedback rounds with LLs stakeholders are implemented, by continuously feeding the data-set of information on products and services. The final results will be made available at the end of the project, when expectations will be matched with real outcomes of the LLs trials.

3.1 Phase 1: Data-sets building and data clustering

The information collected by LLs actors was clustered into two data-sets. The first data-set regarded the characteristics of the products and services and their functions, the second concerned the expectations of stakeholders on the future use of products and services in LLs.

More specifically, the first data-set has grouped the following information:

- General information about the product/service. This set of information included the description of the functionalities of the products and services, or their ways of functioning. Within these data it is possible to distinguish: the name of the product/service; the supplier of the product/service; the description of the features and the purpose(s) of the product/service.
- Application areas. This set of information defined the areas in which the product/service have been planned to be applied in the single LL. For this purpose, a set of application areas was selected, following what was indicated by the stakeholders operating in the three Living Labs. This process has led to the identification of the following application areas: Network slicing; MEC; NFV-MANO; Precise Positioning; Traffic Management Applications; High-performance CCTV Surveillance Applications; Real-Time Tracking & Enhanced Visibility; Maintenance Support.

The second data-set concerned the expectations of stakeholders on the future use of products and services in LLs. This set is in turn divided into two groups, which respectively define:

- The use of technologies in the different phases of the 5G-LOGINNOV project. For each LL, the use of 5G technologies and IoT devices was studied before, during and after the implementation of 5G-LOGINNOV.

- Stakeholders' expectations about the future impact of products and services. In particular, the expectations of the stakeholders have been analyzed with specific regard to the impact of the technologies developed on the processes and services and on the business models, i.e., on how they are expected to improve the operations of the ports in the different Living Labs.

3.2 Phase 2: Taxonomy creation and establishment of a Conceptual Framework for the comparison

The second phase of the analysis focused on the creation of a taxonomy of products and services, aiming to enable a more reliable comparison between each LL. For this purpose, the information collected in data-sets for each LL have been classified according to five levels of aggregation.

- The first level ("Technology Type") defined the specific type and goals of technology adopted
- The second level ("Area of Application") related to the area of application in the logistics process.
- The third level ("Role in the Logistic Chain") referred to the role assumed by the product or service in the logistics process and to the ways in which the technology developed affected the production cycle.
- The fourth level ("Role in the LLs activities") consisted in the role played by the products and services in all those actions supporting logistics operations, such as decision-making processes and data collection activities.
- The fifth level of aggregation referred to the expected key contribution made by the developed technology on LLs ("Expected Impact").

The first three levels of aggregation represent all the information related to the technical features of the products and services; the latter two levels, instead, are linked to the ways such technologies are used by stakeholders.

The resulting Conceptual Framework, depicted in Figure 1, has been useful to guide the assessment of products and services used in 5G-LOGINNOV LLs and to provide preliminary results.

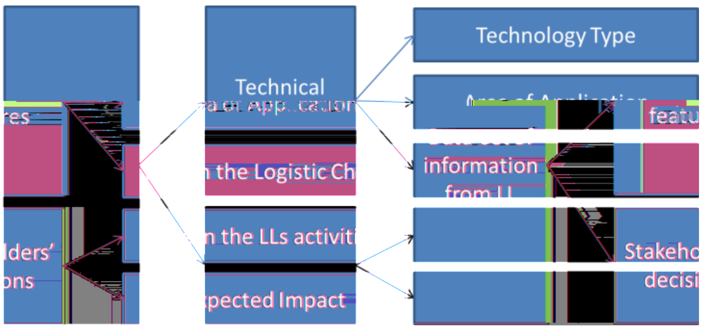

Figure 1 Conceptual Framework guiding the analysis of potential impact and benefits of 5G enabled technologies in the 5G-LOGINNOV LLs

3.3 Phase 3: Definition of preliminary results and continuous monitoring

Within the Conceptual Framework defined above, the products and services used in LLs for the UCs implementations have been assessed: for each level of aggregation, LLs features have been compared and analyzed. Specifically, such comparison has addressed the different expectations of stakeholders for what regards the impact of products and on logistics operations and business models. Moreover, it was possible to discover the relevance of 5G for what concerns PI-friendly logistics technologies.

In line with PI principles, the 5G-LOGINNOV Project highlights the importance of stakeholders' collaboration for enabling logistics efficiency and economic improvements; therefore, the Project's LLs are open to the entrance of new actors in UCs. For instance, during the 5G-LOGINNOV Project, an Open Call for Start-ups[2] has allowed each LL to welcome in UCs implementations new companies: the analysis of products and services is still ongoing and constantly collecting new data to feed the data-sets of information. The final results of the analysis will be therefore available only at the end of the 5G-LOGINNOV project, when the final assessment will address if stakeholders' expectations have been met.

4 Preliminary results of the assessment

4.1 Preliminary analysis conducted in the Athens LL

The products and services developed in the Athens LL consist in 5G and AI technologies, with focus mainly on two application areas:

1. Improvement of human safety and optimization of the operation times linked to the loading and unloading procedures;
2. Increase of maintenance capacity by means of the collection of real-time information on vehicle status, with the scope of making forecasts on required maintenance.

The role in the supply chain of these products and services is related to the detection of the human presence in high-risk areas, aiming to minimize the risk of vehicle collisions, and to the detection of elements linked to drivers' health status and to container seals in vessel loading/unloading processes.

Stakeholders in Athens LL use these products and services for improving data collection, analysis and information forecast, since the specific expectation from such products relate primarily to the acquisition of information about vehicles status and the prediction of possible breakdowns. Also, the data collection and forecast systems are expected to provide real-time information on logistics corridor flows, such as exact positioning, optimal speed, arrival and departure times and waiting times.

The potential impacts on the Business Models are mainly associated to cost minimization and reduction of risks linked to human health, by means of the optimization of loading-unloading processes. The logistics processes optimization may lead to better use of resources, and improved security by the utilization of tools that can substitute or accompany human work in risk areas. Moreover, the potential benefits on Business Models are given by the improvement of data collection and analysis tools regarding the maintenance status of vehicles and relevant supply chain data such as location, travel time, fuel consumption, etc.…

4.2 Preliminary analysis conducted in the Hamburg LL

In the Hamburg LL, the assessed products and services are 5G enabled technologies applied in the port and in the hinterland areas for:

1. Pollutants control

[2] https://5g-loginnov.eu/open-call/

2. Human safety
3. Traffic flow management.

The role of these products and services in the logistics chains are heterogeneous, as they are primarily related to the collection, analysis and forecasting of information in a wide area.

The implementation of these products and services for the LLs scopes is related to the ability to collect information on air quality, fuel consumption and traffic flows inside and outside of the port area. Specifically, the improvement of the accuracy of data regarding precise positioning, vehicle, and flow mapping, and the collection of parameters regarding road characteristics is the main scope of the UCs.

Furthermore, the technologies developed in the Hamburg LL are expected to optimize the traffic flows by means of the integration of the data detecting information such as the quality of the environment, the characteristics of the infrastructure's road traffic and information from vehicles (optimum speed, journey times, fuel consumption, etc.). In this sense, they are expected to minimize the resources' consumption, the waiting times in the parking slots, and will provide innovative tools for supporting decision-making processes on the logistics chain, improving individual behavior by means of an increased amount on real-time data on the micro-dynamics connections between individual vehicles and port infrastructures.

Regarding the expectations on Business Models, the products and the services introduced in Hamburg will be useful to improve the management capacity of the logistics processes, the trucks flow and truck platooning, and the connections among the logistics chain, thus contributing to minimizing the costs of these operations.

4.3 Preliminary analysis conducted in the Koper LL

Products and services used in Koper LL represent 5G technologies related mainly to obtaining high-resolution graphic data, images, and videos, capable of providing a greater amount of information on the logistic chain and assuring a more efficient monitoring of the activities carried out within the port's activities.

The data available thanks to these products and services will serve to implement a more capillary monitoring system of the different parts of the logistic chain, providing real-time visual data on the transport flows with greater frequency, and detecting other parameters linked to human safety in the port's area. Furthermore, the novel data collection system improves the communication network by means of the integration of the existing communication technologies with the 5G technologies for mobile services.

These functionalities are expected to support the collection of an even-greater amount of data, for the improvement of the resolution of the visual information, and for the increase of communication speed. These elements, taken as a whole, have the scope to foster the greatest number of collected data and their resolution, increasing the ability to analyze information, optimize the resources, and improve the security by means of mobile systems designed on cloud-native principles supporting Network Functions Virtualization Management and Orchestration.

The Business Models' expectations in Koper concern the creation of a more flexible and interconnected infrastructure, by developing or improving systems with 5G technologies that can be used to implement different solutions according to the different Use Cases. The products and services will support greater automation and digitalization, fostering the resilience and adaptability of the port infrastructure and the optimization of resources spent in the logistics processes.

5 Conclusive remarks

The technologies developed in t8d(At[he)n(ks)]TJETBT1 0 0 168.3784 731.62 Tm -13.62c[LL(8)]TJETBT1 0