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5G and Companion Technologies as a Boost in New Business Models for Logistics and Supply Chain

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Abstract: The transport and logistics industry plays a crucial role in supporting the economy, but it faces various challenges, including high costs and the need for operational efficiency. To address these challenges, the industry is embracing digital transformation, and 5G networks are expected to play a significant role in this process. This paper explores the benefits of 5G technologies in the transportation and logistics sector, focusing on device density, low latency, network slicing, supply chain visibility, port operations, and enhanced communication. Additionally, the paper emphasizes the importance of stakeholder engagement and sustainability considerations in the adoption of innovative technologies. The research methodology involves an online survey administered to stakeholders in the port logistics sector, aiming to assess their knowledge and implementation of innovative technologies. The paper also reviews the relevant literature and highlights the potential of digital technologies, such as IoT, blockchain, AI, and 5G, in optimizing supply chains and port operations. The findings provide insights into the current state of knowledge and implementation of innovative technologies in port operations and the potential for market adoption and contribute to understanding the benefits and challenges of 5G technology in the logistics industry.

Keywords: transport and logistics; 5G networks; digital transformation; supply chain optimization; stakeholder engagement; sustainability

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1. Introduction

The transport and logistics industry is a fundamental sector that acts as the backbone of a country's economy and plays an essential role underpinning other core sectors, such as manufacturing and retail. Challenges and opportunities facing the transport and logistics industry are also closely tracked and influenced by national and local governments, who are often responsible for investments in supporting transport infrastructures. As the movement of people and goods across the world increases, the industry is evolving to meet these demands. However, it faces challenges in doing so: significant pressure on the logistics industry, high capital and fixed operating costs, and differentiation strategies of companies. Despite growing demand, many firms are suffering from eroding margins. Therefore, the focus for the majority of the industry is on cost-cutting and improving operating efficiency. For many companies, investing in new technologies provides an opportunity to transform their operations and drive efficiencies. There is significant scope to do this since the industry as a whole is generally not as digitized as other verticals and because there is room to make improvements to currently under-utilized assets. For the industry to

address these challenges and achieve efficiencies, it will need to adopt new technologies. The catalyst for digital transformation will be data—in particular, the generation of richer and more comprehensive data and the analysis of this data to produce insights for the decision-making process. The role of 5G networks and companion technologies mainly relies on the potential to help drive digital transition and address some of these challenges, helping to catalyze the digital transformation journey in logistics. As 5G is rolled out, it could have a significant effect on supply chains, the wider transport industry and society more generally.

The key benefits that 5G technologies can provide to the transportation and logistics industry are as follows:

- Device density and data volume: 5G technologies are able to connect and support more smart devices (from temperature-monitoring sensors to vehicles) than their predecessors, with a huge amount of data collected and shared through the network.
- Low latency: Latency refers to the end-to-end communication delay. Fifth-generation technologies have good latency performance so that data are captured in real time, allowing the highest mobile connection speed, even when the number of objects connected to the network is large. With faster speeds and a low time gap, smart devices can communicate faster with one another, close to real time, fostering the adoption of time-sensitive internet-of-things device applications relevant in the logistics and transportation field.
- Network slicing: Network slices are separate virtual networks that run on the same physical network infrastructure to meet different connectivity needs.
- Minimizing supply chain risks improving the visibility: With 5G implementation supporting a large number of sensors, it will help provide end-to-end communication and improve the supply chain visibility, which represents one of the biggest challenges in the logistics industry today.
- Faster and safer port operations: 5G technologies' performance allows fast and reliable connection, helping to create lean, secure and effective operations in ports.
- Enhanced communication, repairs and problem solving through virtual reality or augmented reality technologies.

However, to foster the actual market adoption of the innovative products and services, it is important to engage all the stakeholders involved and the potential final users in order to assess their real needs and highlight the impacts of the innovative solutions on their daily activities.

Moreover, an important aspect to consider is the sustainability of the innovative products and services, encompassing the economic (to ensure the long-term viability and profitability of logistics operations), social (to analyze the impact of logistics operations on people, workers, communities, and society as a whole), environmental (to minimize the environmental impact of logistics operations and promote ecological conservation), and operational (to ensure the efficiency, reliability, and resilience of logistics operations) dimensions. By considering these aspects of sustainability, logistics companies can create long-term value, mitigate risks, and contribute positively to the well-being of stakeholders and society.

The main objectives of the paper are the assessment, through an online survey, of the level of knowledge and implementation of innovative technologies in the port logistics sector, and the analysis of potential business models to foster the market penetration of innovative products and services. The survey was administered to various actors and stakeholders directly involved in the logistics chain of ports. The technologies and 5G-based applications and services analyzed in this document are relevant for the use cases demonstrated in the context of the project 5G creating opportunities for the logistics supply chain innovation (5G-LOGINNOV). This project is the flagship European initiative that aims to design an innovative framework to integrate and validate 5G-based solutions and business models in the ports logistics sector [1].

Specifically, the 5G-LOGINNOV project promotes the development of new products and services based on 5G and companion technologies. It supports the entry of new actors, such as startups and SMEs, into the market. The development process of these new products and services for logistics optimization follows the GUEST methodology [2]. The GUEST methodology is widely used in industrial and EU-funded projects to analyze the market potential of innovative products and services [3–7]. It aims to control the process from the original idea to implementation and provides a conceptual and practical tool for various stakeholders to communicate their vision, difficulties, and opportunities.

To enhance the market acceptance and exploitation potential of the project's results, the first step of the GUEST methodology is to define the characteristics of potential actors and stakeholders involved in port operations through a survey. The survey also assesses their level of knowledge and the implementation of innovative technologies, as well as their expected results. The assessment results serve as a starting point for the development of new products and services based on innovative technologies. Additionally, the assessment helps potential new entrants in the logistics sector to provide innovative solutions and services that address the actual needs of the actors and stakeholders involved, thereby increasing the potential for market adoption.

The structure of the paper is as follows. Section 2 reviews the literature on port competitiveness and its evaluation. Section 3 presents the adopted methodology. Sections 4 and 5 discuss the analysis of the survey outcomes, including a cluster analysis to present the different types of companies in the port logistics environment. Finally, Section 6 concludes the paper by providing an overview of the survey's outcomes.

By following this structure, the paper provides valuable insights into the level of knowledge and implementation of innovative technologies in port operations, as well as the potential for market adoption of new products and services based on these technologies.

After the first assessment of the stakeholders' and users' requirements, and the definition of the potential impacts of the innovative technologies on the logistics sector, the development of the business models is a necessary step for the future exploitation of the solutions implemented in the context of the 5G-LOGINNOV project. In particular, the role of the business models relies on their capacity to provide a standard framework to describe the development and commercialization of an innovative solution and to increase the scalability and replicability potentials of the solution in other contexts and wider markets.

2. Fifth-Generation-Based Projects and Literature Review

The global demand for freight transportation continues to increase in order to meet the requirements of the modern economy. One of the significant implications of this growth is the increased importance of data collection from various sources across the supply chain. Consequently, there is a need for connectivity solutions that can enhance the secure and reliable sharing of data. Several papers and European projects have highlighted the necessity for a technology infrastructure that integrates blockchain, internet of things (IoT), and cloud. This infrastructure supports data sharing while preserving data integrity and security [8–10]. To address these challenges and facilitate digital transformation in logistics and transportation, 5G technologies are gaining momentum [11,12]. Fifth-generation technologies offer key benefits to the transportation and logistics industry, including the following:

- Device density and data volume: 5G enables the connection and support of more smart devices, facilitating the collection and sharing of a massive amount of data through the network.
- Low latency: With faster speeds and reduced communication delay, smart devices can interact with each other in near real time, which is crucial for time-sensitive IoT applications in logistics and transportation.
- Network slicing: This feature allows the creation of separate virtual networks on the same physical infrastructure to meet diverse connectivity needs.
- Minimization of supply chain risks by improving visibility.

- Faster and safer port operations.
- Enhanced communication, repairs, and problem solving through virtual reality or augmented reality technologies.

2.1. Fifth-Generation-Based Initiatives, Projects and Implementations

Several initiatives, projects, and implementations have been funded by national and European bodies to address the applications of 5G technologies in the supply chain, particularly in the port domain. By integrating 5G technologies with other companion technologies, such as artificial intelligence, big data, IoT, and autonomous vehicles, the development of port automation is expected to increase, providing a competitive advantage to innovative ports. The adoption of 5G implementations in port operations enables massive real-time data collection and analysis, leading to cost reduction and improved efficiency, thus enhancing competitiveness.

As part of the COREALIS program [13], the Port of Livorno in Italy hosted the project "5G Port of the Future" and the initiative "Logistics of the Future in Sustainable Smart Ports". The objective of these initiatives is to demonstrate how integrated information from different devices and ships within the port area, coupled with improvements from augmented reality technologies and advanced control algorithms at a centralized level, can optimize loading and unloading operations and enhance personnel safety.

The Chinese Port of Ningbo-Zhoushan (NZP) [14], one of the world's busiest ports, embarked on a pilot project in 2018 to adopt 5G technology. The pilot project focused on enhancing remote gantry crane operations, management, and video backhaul applications using the 5G network.

The 5G Infrastructure Public-Private Partnership (5G PPP) [15] is a joint initiative between the European Commission and the European ICT industry. Its aim is to provide solutions, architectures, technologies, and standards for next-generation global communications. The objective is to ensure European leadership in areas where Europe has the strength or the potential to create new markets, as well as to improve the competitiveness of the European industry in global markets and open new opportunities for innovation. The 5G-PPP enabled system focuses on supporting new implementation scenarios for different market segments, providing optimized support for various services, traffic loads, and end-user communities. It involves stakeholders from different sectors, both public and private, to bring together the diverse competencies needed to achieve the project's goals. Among the 5G-PPP projects, several are particularly relevant:

- 5G-MoNArch— Mobile Network Architecture. The 5G Mobile Network Architecture for diverse services, use cases, and applications in 5G and beyond [16] is a project aimed at gaining knowledge and experience from using the 5G network slicing in a real-world environment, proving and improving the underlying technical concepts and methods. The overall goal is to provide a wireless infrastructure that can handle a large number of operations of the port's day-to-day work.
- 5G-EVE—European 5G validation platform for extensive trials. The 5G-EVE project [17] has the aim to implement and test advanced 5G infrastructures in Europe, to foster the adoption of AGVs, real-time image processing, 5G end-to-end facilities, and smart transport. The final goal is to interconnect four existing European sites (in Italy, Spain, Greece, and France) to form a unique 5G end-to-end facility, which is composed of various elements, such as 5G new radio, distributed cloud, MEC, and slicing [18].
- 5G-GENESIS. The 5th Generation End-to-end Network, Experimentation, System Integration, and Showcasing (5G GENESIS) project [19] has the aim to develop a set of end-to-end and experimental platforms (each one associated with a specific city) to facilitate 5G and related trials.
- 5G-SOLUTIONS. The 5G Solutions for European Citizens [20] project has the aim to validate that 5G is a prominent technology starting from five significant industry vertical domains in five countries to exploit the real commercial potential of 5G. In particular, the Norwegian pilot site aims at developing innovative use cases regarding

smart solutions to optimize and improve operational efficiency and reduce logistics costs in the port.

- 5G-MOBIX. The 5G for cooperative and connected automated MOBIility on X-border corridors project [21] aims to develop and test automated vehicle functionalities using 5G core technological innovations along multiple cross-border corridors and urban trial sites, with a focus on truck platooning, vehicle remote control, highway lane merging, road user detection and urban environment driving.
- VITAL-5G. The VITAL-5G project [22] will create an open, virtualized and flexible experimentation facility comprised of an intelligent virtual platform, three distributed European 5G-testbeds in Antwerp, Athens and Galati (Danube), and associated vertical infrastructure, to enable the testing and validation of T&L Network Applications (NetApps) in real-life conditions, utilizing 5G connectivity. It will capitalize on recent 5G research (5G-BLUEPRINT, 5G-SOLUTIONS and 5G-EVE) by exploiting and developing the results for the T&L (transport and logistics) vertical, impacting large-scale actors and SMEs active in the T&L ecosystem. It aims to deliver three main innovation elements (the Vital-5g Service Portal, the Vital-5g Facility at T&L Sites, and the Vital-5g Open Online Repository&netapps) to be offered to third party experimenters through a joint commercialization approach with key consortium partners.

2.2. Literature Review

Supply chain optimization through the development of innovative, technology-based solutions is gaining importance in addressing the continuously growing requirements of the modern economy. In their literature review, Del Giudice et al. [23] explore the capacity of digitalization and new technologies for sustainable and innovative development in shipping and seaports. The focus is on the development of innovative business models that can achieve environmental, economic, and social goals. The review, covering publications from 1969 to 2020, highlights that the literature primarily focuses on environmental externalities.

According to Uusitalo et al. [24], several key enabling technologies for port automation are ready for adoption. These technologies include autonomous vehicles, augmented reality, cloud computing, big data analytics, and artificial intelligence. The authors emphasize that new 5G communication networks will play a crucial role in integrating these technologies and enabling their practical implementation. In contrast, Wi-Fi-based networks are considered insufficient for the scope of port automation use cases.

In the realm of smart supply chains, Gerasimova et al. [25] analyze transnational smart supply chains from a service design perspective. Their study focuses on the integration of blockchain technology and smart contracts in logistics processes. From the study, there emerge the critical role of IT strategic planning to boost and make effective the IoT-driven business processes redesign, the need for collaborating with high-profile technological partners to design suitable IoT infrastructures, and the relevance of project management to support business processes redesign via the IoT. Similarly, Philipp [26] investigate the potential of blockchain technology and smart contracts in optimizing value chain operations and fostering the implementation of business models.

The Port of Hamburg serves as a case study in the work of Ferretti and Schiavone [27], which examines how IoT technologies have redesigned business processes in a smart port. The study concludes that the adoption and effective utilization of the IoT-driven business processes redesign rely on port-specific factors, such as management practices and infrastructure investments, as well as stakeholder-related aspects like strategic partnerships and IT choices. The study highlights the critical role of IT strategic planning, collaboration with technological partners, and project management in supporting business processes redesign through the IoT.

The implementation of IoT technologies and the smart port concept are also evaluated in the context of the Port of Le Havre by Rajabi et al. [28]. The authors explore how IoT technologies facilitate data collection, monitoring, intelligent decision making, and logistics and transportation management in ports.

In their analysis of the Port of Livorno in Italy, Cavalli, Laura, and Giulia Lizzi [29] discuss the benefits of introducing 5G, augmented reality (AR), and AI-based use cases. These advancements contribute to economic, social, and environmental benefits, such as reducing transit time, decreasing vessel and unit operations, maintaining safety conditions, minimizing environmental impact, and enhancing system automation and service flow.

The experience of the Port of Oulu in Finland confirms the strong link between the value proposition of the port ecosystem and various technological components, including 4G/5G wireless connections, fixed optical fiber connections, sensor networks, big data storage, digital twin technology, and analytics powered by artificial intelligence and machine learning [30]. The authors propose an innovation of the "4C Typology" business model layers (connection, content, context, and commerce) due to the influence of digitalization.

Ahokangas et al. [31] focus on the Port of Oulu as a use case to develop a multi-stakeholder engagement process for the introduction of a 5G-enabled common data platform and associated regulatory challenges. They emphasize that enhanced situational awareness can bring value to multiple stakeholders in the ecosystem through an optimally hybrid data platform with centralized connectivity. They also highlight the need for widespread approval from regulatory bodies to achieve industry-level legitimacy and scalability of solutions, particularly for local and private 5G network deployments.

Examining the port of Motril-Granada in Spain, Seisdedos and Carrasco [32] analyze the role of innovative technologies in improving the quality and effectiveness of port operations. Beyond enhancing operational efficiency, these technologies encourage the integration of new players, such as private companies, research institutions, technological centers, and universities, into the existing port ecosystem, fostering the emergence of innovative SMEs and startups.

In their work, Henríquez et al. [33] underline the significance of technological innovation adoption in seaports for business models. They demonstrate how IoT technology's "building blocks" are associated with the adoption of policies and strategies that increase standardization, cooperation, and information sharing among ports and stakeholders. Furthermore, the investment in an IoT-related infrastructure is expected to lead to additional knowledge-intensive investments.

These studies collectively demonstrate the growing interest in leveraging digital technologies, such as IoT, blockchain, AI, and 5G, to optimize supply chains, enhance port operations, and foster sustainable development. By embracing these innovative solutions and integrating them into business models and processes, ports and stakeholders can achieve various economic, social, and environmental benefits, driving positive transformations in the maritime industry.

The literature review highlights that, despite the high and growing importance of innovative technologies in the logistics industry to face the challenges of the current global economy, there is a lack of a holistic vision of the potential benefits of digital transition in the logistics sector and, in particular, in port logistics. The goal of this paper is to fill this gap through an assessment and an analysis of the potential benefits of 5G networks and innovative technologies based on interviews with experts.

3. Methodology

As specified in the Introduction, to perform the assessment and the analysis included in this paper, we use the GUEST methodology [2], a lean business methodology that starts from the collection of the requirements of the potential final users of an innovative product/service and develops the business models to ensure its actual market adoption. In particular, the assessment of the actual level of knowledge and implementation of innovative technologies in the logistics sector, as well as of the requirements of the stakeholders involved in the port ecosystem, is the first step to developing the business models and exploitation strategies for the innovative products and services tested in the 5G-LOGINNOV living labs. The innovative solutions developed in the 5G-LOGINNOV project will be tested in three living labs in the European ports of Athens (Greece), Hamburg (Germany), and

Luka Koper (Slovenia). It is important to define, in each living lab, the level of knowledge and implementation of innovative technologies in port operations, to set the starting point from which the development of new technology-based products and services must start. The survey was thus administered to a set of companies directly involved in the daily port operations and services aimed at sustaining port activities.

The survey was developed by ICOOR, a project partner of 5G-LOGINNOV, and administered through an online form to a set of actors and stakeholders involved in each living lab. The structure of the questionnaire is as follows:

- Details about the respondent and its organization. These data are useful to define in which living lab the organization is involved, as well as its sector (port operations, ICT provider, port authority, etc.), and the seniority level of the respondent (thus defining the quality of the provided data).
- Assessment of the respondent's awareness and knowledge of Industry and Logistics 4.0 paradigms.
- Assessment of the respondent's awareness and knowledge of 5G and companion technologies.
- Contacts and availability for further participation.

The enabling technologies considered in the assessment are as follows:

- Cloud computing, intended as the technological capability to use IT infrastructures and services that are not installed on a local computer or server.
- IoT, the network of physical objects embedded with sensors, software and other technologies to connect and exchange data with other devices and systems.
- Cyberphysical systems, technologies that integrate the computation, networking and physical processes.
- Cybersecurity systems, technologies that allow companies to protect corporate networks and devices from theft or damage due to cyber attacks.
- Smart sensors, IoT components represented by devices that take input from the physical environment and use built-in resources to perform predefined functions and data processing.
- Big data analytics, technologies allowing the collection and analysis of large amounts of data.
- Artificial intelligence (AI), intended as the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings.
- Blockchain and distributed ledger databases for recording transactions between parties in a verifiable and permanent way.
- Wearable and smart devices that consider any kind of electronic device designed to be worn (e.g., smart glasses and smartwatches).
- Fifth-generation networks, to enable a sharp increase in the amount of data transmitted over wireless systems due to more available bandwidth and advanced antenna technology.

4. Data Collection and Analysis

4.1. Characteristics of the Respondents

At the end of the data-collection phase, the database is composed of 44 complete questionnaires, well balanced between the different living labs of the project (15 from Athens, 16 from Hamburg, and 13 from Luka Koper). Analyzing the industry domain, it emerges that most of the respondents (47.8%) come from the transportation and logistics sector, while IT and TELCO companies are set at 23.9%: it is, therefore, possible to count on specific knowledge of the logistics sector, mixed with information coming from service providers. Moreover, the high professional level of the respondents (managers, senior managers, chief executives in 61.4% of the overall sample) increases the importance and the quality level of the collected data. Considering the size of the company, the sample is

quite totally composed of SMEs and large enterprises (47.7% for each category), largely operating on international markets (77.3% of the respondents).

4.2. Level of Knowledge and Implementation of the Technologies

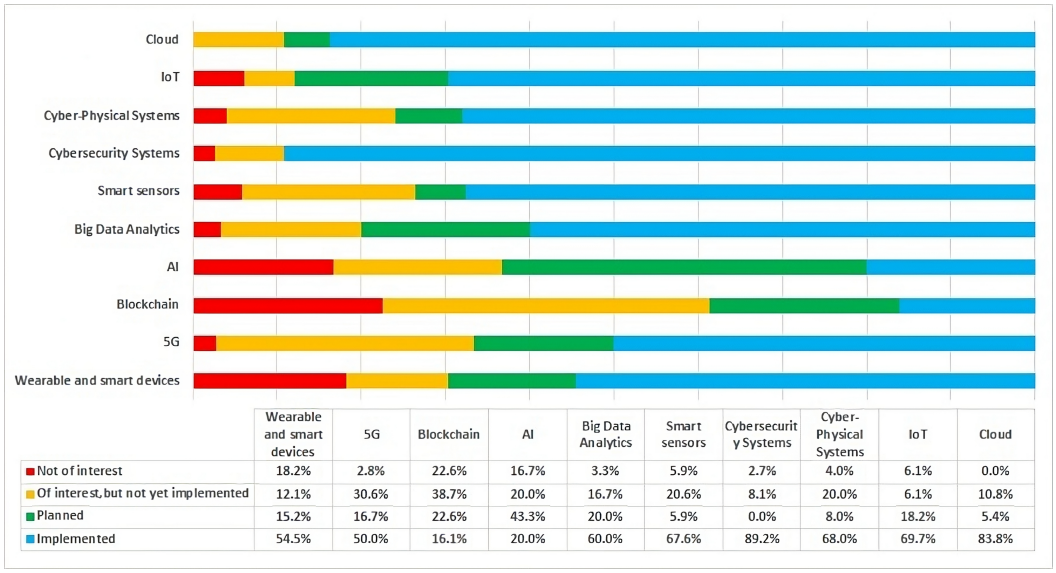
The level of knowledge of Industry 4.0 and Logistics 4.0 paradigms is generally high, with 79.5% of the respondents being familiar with these paradigms.

Figure 1 illustrates the level of knowledge of enabling technologies among the respondents. It reveals that the most well-known technologies are IoT, with 68.2% of the respondents having a high or very high level of knowledge, followed by cloud at 61.4%. Additionally, 70.5% of the respondents confirm that cloud solutions are currently being adopted in their organizations. Other technologies, such as smart sensors, cybersecurity systems, wearable and smart devices, and 5G, also have a significant level of knowledge, with approximately 40% of the respondents having familiarity with them. However, blockchain, artificial intelligence, and cyber–physical systems are relatively less known, with around 50% of the respondents having a low or very low level of knowledge. It is worth noting that none of the respondents possess a very high level of knowledge specifically regarding blockchain technology.

	Wearable and smart devices	5G	Blockchain	AI	Big data analytics	Smart sensors	Cybersecurity systems	Cyberphysical systems	IoT	Cloud
Very low	6.8%	6.8%	13.6%	6.8%	6.8%	6.8%	11.4%	15.9%	4.5%	2.3%
Low	18.2%	20.5%	34.1%	43.2%	25.0%	15.9%	27.3%	34.1%	9.1%	6.8%
Medium	31.8%	34.1%	31.8%	29.5%	43.2%	31.8%	22.7%	29.5%	18.2%	29.5%
High	29.5%	25.0%	20.5%	15.9%	13.6%	25.0%	31.8%	18.2%	50.0%	50.0%
Very high	13.6%	13.6%	0.0%	4.5%	11.4%	20.5%	6.8%	2.3%	18.2%	11.4%

Figure 1. Level of knowledge of the enabling technologies.

Examining the current implementation level of these technologies in organizations, Figure 2 demonstrates that the surveyed companies have already implemented or have plans to implement nearly all Industry 4.0 and Logistics 4.0 enabling technologies in the near future. Notably, almost 90% of the companies have already implemented cybersecurity systems, even if some of them do not express significant interest in their implementation. On the other hand, the least implemented technology among the respondents is blockchain, with only 16.1% having implemented it and 22.6% planning its implementation. However, it is worth mentioning that 38.7% of the surveyed companies find blockchain technology interesting, despite its relatively low implementation rate.



	Wearable and smart devices	5G	Blockchain	AI	Big Data Analytics	Smart sensors	Cybersecurity Systems	Cyber-Physical Systems	IoT	Cloud
Not of interest	18.2%	2.8%	22.6%	16.7%	3.3%	5.9%	2.7%	4.0%	6.1%	0.0%
Of interest, but not yet implemented	12.1%	30.6%	38.7%	20.0%	16.7%	20.6%	8.1%	20.0%	6.1%	10.8%
Planned	15.2%	16.7%	22.6%	43.3%	20.0%	5.9%	0.0%	8.0%	18.2%	5.4%
Implemented	54.5%	50.0%	16.1%	20.0%	60.0%	67.6%	89.2%	68.0%	69.7%	83.8%

Figure 2. Level of implementation of the enabling technologies.

4.3. Expected Benefits

Considering the importance of various activities in the business operations of the surveyed companies, Figure 3 illustrates the findings. It reveals that data collection and analysis emerge as the most critical activity, with 14.2% of the respondents acknowledging its significance. This emphasis on data collection and analysis stems from its crucial role in ensuring the effectiveness of other activities, such as flexibility and resilience (13.8%), automation (10.2%), resource allocation (8.3%), and predictive maintenance (6.7%). Turning attention to activities involving human resources, 12.6% of the respondents recognize the necessity of training employees on new digital tools, while 9.8% consider the engagement of managers in innovation processes as important.

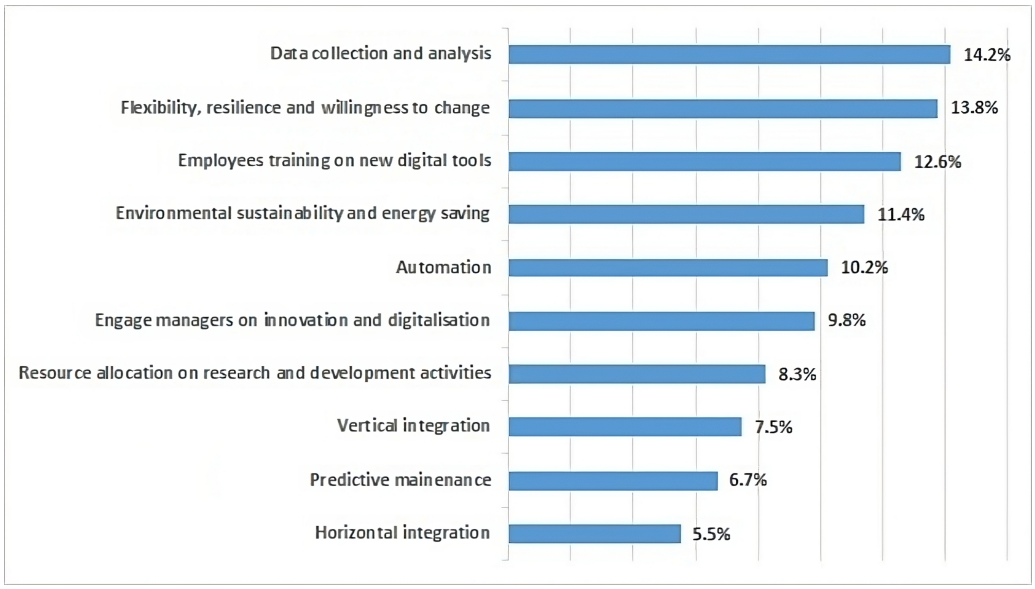


Figure 3. Importance of activities in the companies' business.

In Figure 4, the main expected benefits of technology implementation are showcased. The analysis of these expected benefits reveals strong interdependencies between many of them. Notably, the improvement of efficiency stands out as the most anticipated benefit, with 14.1% of the respondents identifying it as a primary expectation. This improvement in efficiency, in turn, can drive companies towards enhancing service quality (13.3%), reducing

costs (13.7%), and increasing profits (11.1%). Other expected benefits, such as time reduction and energy conservation, though considered less important, are closely linked to the improvement of efficiency. On the other hand, interoperability among different actors (6.7%) and increased transparency and trust (6.3%) are perceived as the least expected benefits.

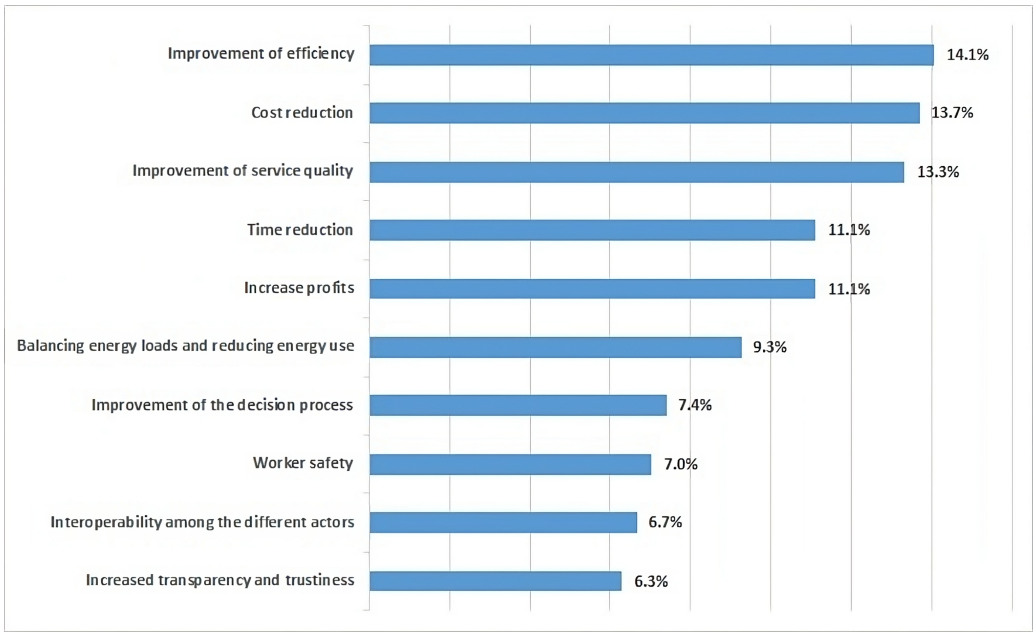


Figure 4. Expected benefits.

4.4. Importance of Technology-Based Implementations

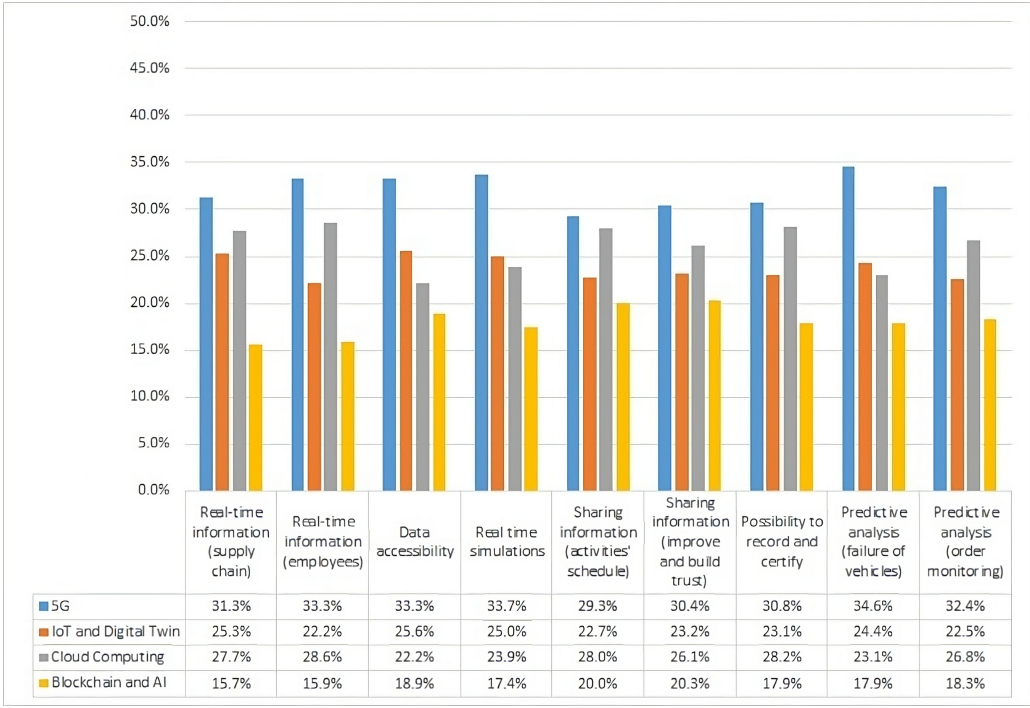
This section examines the most significant implementations of different technologies based on the responses from the survey participants. The study focuses on the following potential implementations:

- Real-time information on the status of the whole supply chain;
- Real-time information on the activities carried out by the employees;
- Data stored in clouds and accessible from any computer/device connected to the network;
- Possibility to exploit the real-time data to perform simulations on the processes, making the processes and resources employed more efficient;
- Sharing information with the different actors in the supply chain to better plan and schedule activities;
- Sharing information with the different actors in the supply chain to improve and build trust;
- Possibility to record and certify in an automatic or semi-automatic way all the processes or activities;
- Predictive analysis, on the data collected, aimed at indicating the future date of failure of vehicles;
- Predictive analysis, on the data collected, aimed at reporting the impossibility of delivering an order in time.

For each statement, respondents were asked to assess the importance of specific technologies (5G, IoT and digital twin, cloud computing, blockchain, and AI) using a five-level scale, ranging from "not at all important" to "very important". To analyze the data in an aggregated manner and identify the most suitable technologies for each implementation, only the responses that rated the specific technology as important or very important were considered.

Figure 5 presents the findings, indicating that 5G infrastructure is considered the fundamental component for the application of all other technologies. It emerges as the

most important technology for all the considered implementations. IoT and digital twin are also regarded as significant technologies for the analyzed implementations, particularly for real-time information on the supply chain, data accessibility, real-time simulations (which align with the main objectives of digital twin), and predictive analysis for vehicle failure. Cloud computing is recognized as an important technology for implementations related to real-time information (on supply chain and employee activities), information sharing for optimizing activity schedules, and the ability to record and certify data and information. On the other hand, blockchain and AI are consistently identified as the least important technologies for all the analyzed implementations.



	Real-time information (supply chain)	Real-time information (employees)	Data accessibility	Real time simulations	Sharing information (activities' schedule)	Sharing information (improve and build trust)	Possibility to record and certify	Predictive analysis (failure of vehicles)	Predictive analysis (order monitoring)
5G	31.3%	33.3%	33.3%	33.7%	29.3%	30.4%	30.8%	34.6%	32.4%
IoT and Digital Twin	25.3%	22.2%	25.6%	25.0%	22.7%	23.2%	23.1%	24.4%	22.5%
Cloud Computing	27.7%	28.6%	22.2%	23.9%	28.0%	26.1%	28.2%	23.1%	26.8%
Blockchain and AI	15.7%	15.9%	18.9%	17.4%	20.0%	20.3%	17.9%	17.9%	18.3%

Figure 5. Importance of technologies for different implementations.

4.5. Data Security Measures

As Industry 4.0 and Logistics 4.0 paradigms usually refer to external services that use company data and information, an important aspect to be considered is the willingness of the companies to allow data sharing with these services. It emerges that 59.1% of the respondents assess that their data are only partially accessible, while data and information are not at all accessible for 27.3% of the respondents, and only 13.6% state that their data are accessible by external services. In particular, the most inaccessible category of data is the one related to the customer profile: in this case, nearly all the respondents (90%) agree in considering these data as inaccessible. Asking the reasons for the inaccessibility, or partial accessibility, of data and information, 85.7% of the respondents state that data must be accessible only by company members, while 7.1% do not trust in security measures, and a similar percentage of the sample does not perceive any economic benefit in data sharing. Concerning the cybersecurity measures adopted by the companies, the main ones are as follows:

- Employee training on cybersecurity (35.6% of the respondents);
- Closed corporate network with anti-intrusion system and firewall (32.2% of the respondents);
- Internal servers with controlled access and backups in safety environments (32.2% of the respondents).

Moreover, it is interesting to highlight that 73.9% of the companies involved in the survey state that all three aforementioned measures are implemented, while 17.4% of

the companies adopts two of them. The most adopted measure is employee training on cybersecurity, which is always adopted in integration with at least another measure.

5. Results, Trends and Development Directions

The analysis of the results reveals a significant interest among stakeholders in improving the effectiveness of logistics processes, with a direct connection to continuous monitoring and optimization of resource usage. The primary goals are to enhance service quality and reduce costs. The survey indicates a generally high level of knowledge regarding the Logistics 4.0 paradigm, with 79.5% of the respondents being familiar with it. Among the various technologies, IoT is the most well known (68.2%), followed by cloud computing (61.4%). Smart sensors, cybersecurity systems, wearable and smart devices, and 5G also have a strong level of knowledge among respondents (around 40%). However, blockchain, artificial intelligence, and cyber–physical systems are less familiar, with only around 50% of respondents having a low or very low level of knowledge about them.

Regarding the implementation of these technologies within organizations, the survey reveals that most companies have either already implemented or have plans to implement Logistics 4.0-enabling technologies in the short term. Blockchain is the least implemented technology, with only 16.1% of respondents reporting its implementation. However, it is worth noting that 38.7% of companies consider blockchain technology to be of interest.

The analysis of the main expected benefits from technology implementation demonstrates strong dependencies among them. The improvement of efficiency is the most anticipated benefit (14.1% of respondents), which can subsequently lead to improved service quality (13.3%), cost reduction (13.7%), and increased profits (11.1%). Other expected benefits, such as the reduction in time and energy consumption, although considered less important, are closely related to efficiency improvement. Interoperability among different actors (6.7%) and increased transparency and trust (6.3%) are less expected benefits.

Furthermore, the analysis highlights that 5G infrastructures are perceived as the backbone for the application of all other technologies. IoT, digital twin, and cloud computing are also considered crucial for real-time monitoring, simulations, and predictive analysis of vehicle failures. On the other hand, blockchain and AI are perceived as less important technologies for the analyzed implementations.

Overall, these findings emphasize the widespread interest in Logistics 4.0 and the adoption of enabling technologies to enhance logistics processes. The results indicate a strong recognition of the potential benefits, particularly in terms of efficiency improvement, service quality, cost reduction, and increased profits. The importance of 5G as a foundational technology is evident, along with the significance of IoT, digital twin, and cloud computing in enabling real-time monitoring and analysis. While blockchain and AI are perceived as less significant in the current context, their potential for future implementations should not be overlooked.

Cluster Analysis

A more in-depth analysis of the results was conducted, categorizing the expected benefits of the technology into three distinct categories: economics (cost reduction and increased profits), process optimization (enhanced efficiency and service quality, reduced time and energy consumption), and process integration (transparency, trustworthiness, and interoperability among different actors). The application of cluster analysis helps shed light on the respondents' preferences, with economic and process optimization benefits being the most valued, followed by process integration. This finding confirms the existing barriers that hinder information exchange among different actors in the supply chain. By categorizing the respondents into these clusters based on their implementation levels and technology preferences, a comprehensive understanding of the current state and trends within the industry can be obtained. These findings provide valuable insights for decision makers and stakeholders in shaping strategies for technology adoption and integration to

maximize the potential benefits in terms of economics, process optimization, and process integration within the supply chain. The cluster analysis reveals three distinct clusters:

- Cluster 1: Low implementation level of innovative technologies (34% of respondents). This cluster primarily consists of technology providers, mainly small- and medium-sized enterprises (SMEs) operating in both national and international markets. The most implemented technologies in this cluster include 5G, wearable and smart devices, cybersecurity and cyber–physical systems, IoT, and cloud computing. The key activities associated with these technologies are data collection and analysis, employee training on new digital tools, and fostering flexibility and resilience to industry changes.
- Cluster 2: Medium implementation level of innovative technologies (41% of respondents). Similar to Cluster 1, this cluster comprises technology providers. However, the companies in this cluster are predominantly large enterprises with annual revenues exceeding EUR 50 million, operating primarily in international markets. The most implemented technologies within this cluster include 5G, big data analytics, smart sensors, cybersecurity and cyber–physical systems, IoT, and cloud computing. The key activities identified in this cluster are employee training on new digital tools, data collection and analysis, fostering flexibility and resilience to industry changes, and prioritizing environmental sustainability and energy conservation.
- Cluster 3: High implementation level of innovative technologies (25% of respondents). The third cluster is composed of IT and telecommunications (TELCO) providers, predominantly large enterprises with annual revenues exceeding EUR 50 million, and operating in international markets. The most implemented technologies within this cluster include wearable and smart devices, big data analytics, smart sensors, cybersecurity and cyber–physical systems, IoT, and cloud computing. The key activities emphasized in this cluster revolve around fostering flexibility and resilience to industry changes.

The following graphs (Figures 6–8) highlight the value given by the different clusters to the three different categories of expected benefits. The graphs provide insights into the expectations and perspectives of companies at different levels of technology implementation.

Cluster 3, consisting of large IT and TELCO enterprises operating in international markets, exhibits a higher technology implementation level. As a result, they have high expectations regarding the potential benefits, particularly in terms of economics, process optimization, and integration. These companies are more attuned to technological developments, actively engaging in the development and testing of innovative technologies and solutions.

Cluster 2 primarily comprises technology providers, also classified as large enterprises operating internationally. Although they possess a medium level of technology implementation, their main anticipated benefits lie in economics and process optimization. However, the value attributed to process integration potentials is comparatively lower in this cluster.

In contrast, Cluster 1 represents companies with a lower level of technology implementation. They prioritize the benefits associated with process optimization while assigning relatively lower importance to the other categories of expected benefits, namely economics and process integration. This cluster primarily consists of small- and medium-sized enterprises (SMEs), some of which operate exclusively at the national level. Considering their limited investment horizon in the development of innovative technologies and solutions, these companies concentrate on optimizing processes as a crucial step towards achieving their economic objectives.

Analyzing the results in terms of expected benefits, it becomes evident that process integration holds significant value for IT and TELCO service providers. These companies perceive the integration of innovative solutions with their customers' existing processes as an essential requirement. On the other hand, the findings indicate that SMEs, forming the majority in Cluster 1, assign less significance to economic benefits. They consider such

benefits as a direct consequence of process optimization, emphasizing the importance of streamlining processes to attain their economic objectives.

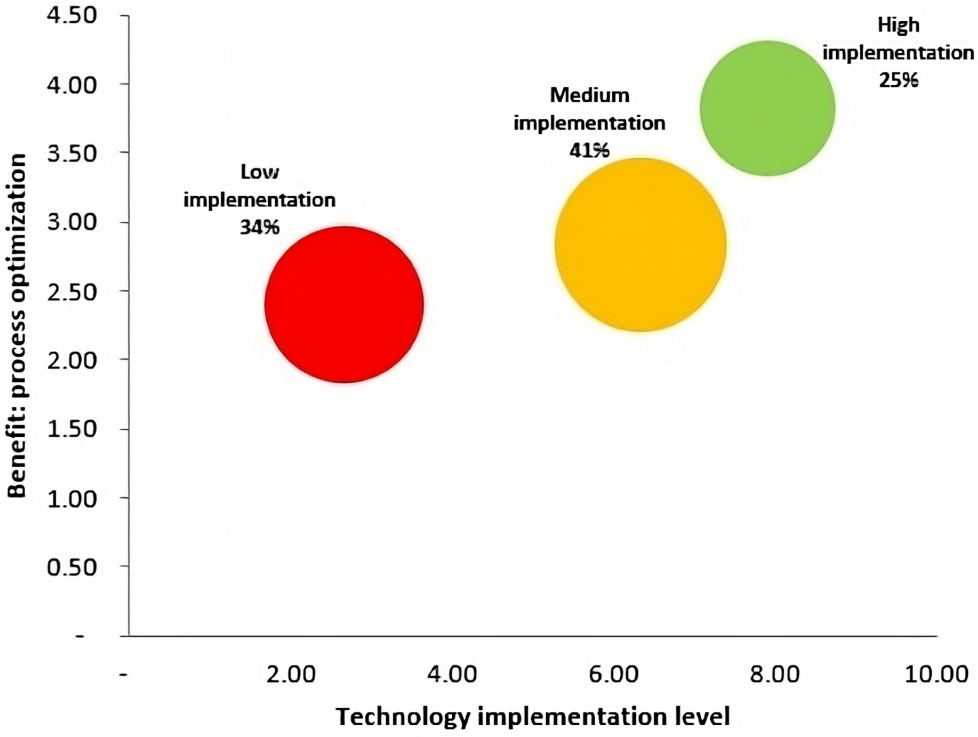


Figure 6. Cluster analysis for process optimization benefits.

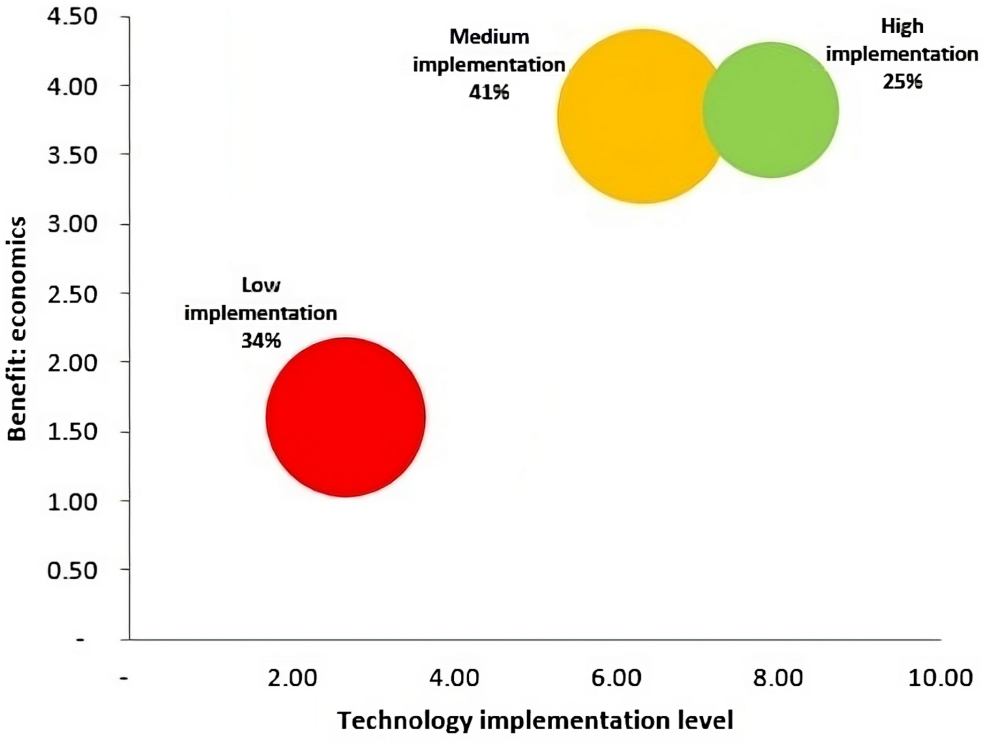


Figure 7. Cluster analysis for economic benefits.

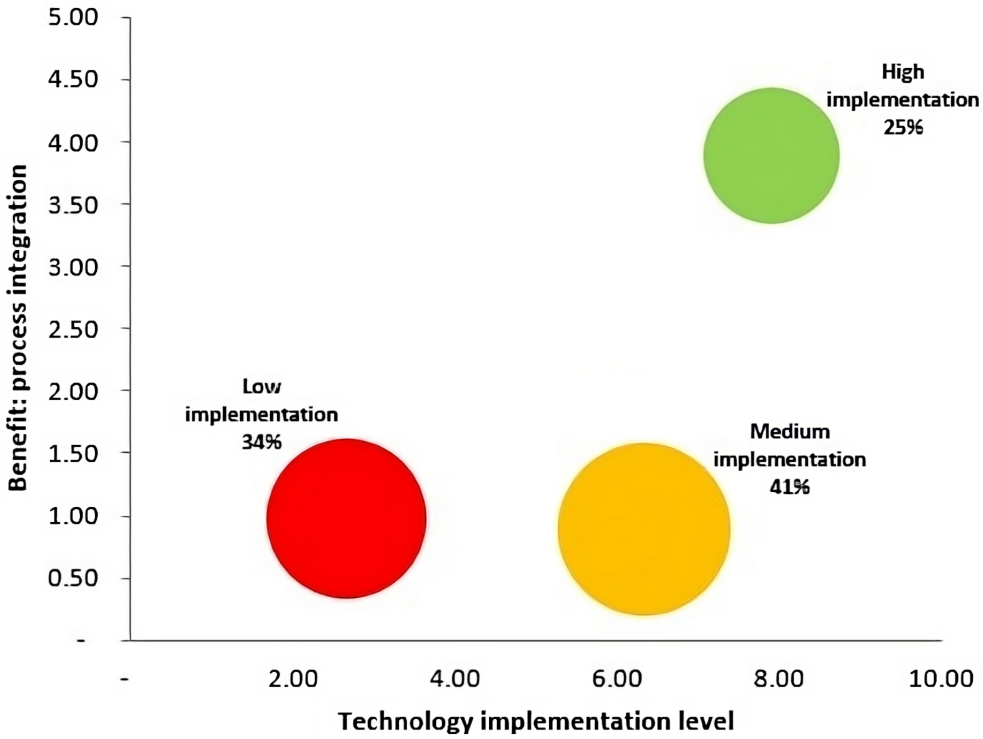


Figure 8. Cluster analysis for process integration benefits.

6. Conclusions and Future Directions

The assessment of technology knowledge and implementation levels among stakeholders in the 5G-LOGINNOV project provides valuable insights into the potential development and adoption of innovative services and solutions within the port logistics sector.

Generally, the levels of knowledge and implementation of innovative technologies are high among the stakeholders, and they anticipate significant benefits from the adoption of these technologies. One common objective shared by all respondents is improving the effectiveness of logistics processes through continuous monitoring and resource optimization.

Fifth-generation infrastructures are regarded as the backbone for implementing other enabling technologies. While blockchain and artificial intelligence are recognized as valuable tools for data collection, sharing, and process forecasting, they are considered less important compared to the role of 5G. Interestingly, there is a low willingness among companies to share data with external organizations, despite recognizing the importance of data security and implementing measures to ensure it. Consequently, the development of new products and services needs to consider the different accessibility levels that companies apply to different categories of data. It is crucial to provide data-sharing solutions that comply with companies' confidentiality requirements.

The cluster analysis conducted on the collected data reveals three distinct clusters of companies with varying characteristics, such as company size and industry domain, as well as different levels of innovative technology implementation. One cluster primarily consists of SMEs with a relatively lower level of technology implementation. These companies focus their efforts on process optimization, considering it the initial step toward achieving broader economic benefits.

On the other hand, the cluster with a higher level of technology implementation comprises large enterprises operating internationally, particularly IT and TELCO providers. These companies actively develop and test innovative technologies to optimize and integrate processes. The integration of these innovative solutions with their customers' existing processes is a critical requirement for their business success.

Concerning the business modeling activity, it emerges that the most impacted stakeholders are the port authorities, with benefits related to the optimization of operations and processes, as well as the improvement of the safety and security conditions inside the port areas. Also, and for the same reason, yard personnel and yard truck operators are impacted by the improvements in their working conditions. Moreover, to ensure the economic sustainability of the innovative products and services beyond the end of 5G-LOGINNOV project, the main sources of revenues rely on usage and licensing fees to companies and operators external to the port environment, even if the most significant sources of revenue are related to cost savings due to the optimization of operations and processes, as well as the improvements of the safety and working conditions for the personnel involved in port activities (e.g., social cost for potential injuries).

Overall, the assessment reveals a positive outlook for the development and adoption of innovative technologies in the port logistics sector. While companies recognize the importance of these technologies, there are variations in their implementation levels based on company size, industry domain, and strategic priorities. By understanding these differences and tailoring solutions accordingly, stakeholders can effectively leverage innovative technologies to drive process optimization and achieve their desired economic outcomes. Despite the high quality of the responses given by field experts, the main limitation of this analysis relies on the sample size, and in their involvement in the three living labs of the 5G-LOGINNOV project. In order to enlarge the field of the analysis, and to provide a more general point of view on the potential impacts of 5G networks and innovative technologies in the logistics sector, further improvements can be reached by increasing the sample size, and focusing on more operational profiles, to collect also the opinions of the potential final users of the innovative 5G-based solutions. Moreover, given the high pace of development of innovative technologies, it is useful to administer the survey at regular time intervals, to monitor the actual state of development and implementation of innovative products and services in the logistics sector.

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