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BOOSTLOG PROJECT

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The BOOSTLOG project consortium consists of:

Part. No	Participant organisation name (short name)	Country
1 (Coordinator)	Alliance for Logistics Innovation through Collaboration in Europe, ALICE AISBL (ALICE)	BE
2	STICHTING SMART FREIGHT CENTRE (SFC)	NL
3	FUNDACION ZARAGOZA LOGISTICS CENTER (ZLC)	ES
4	STICHTING TKI LOGISTIEK (TKI Dinalog)	NL
5	HACON INGENIEURGESELLSCHAFT MBH (HACON)	DE
6	INSTITUTE OF COMMUNICATION AND COMPUTER SYSTEMS (ICCS)	EL
7	Vlaams Instituut voor de Logistiek VZW (VIL)	BE
8	FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V. (Fraunhofer)	DE
9	FIT Consulting SRL (FIT)	IT
10	FUNDACION DE LA COMUNIDAD VALENCIANA PARA LA INVESTIGACION, PROMOCION Y ESTUDIOS COMERCIALES DE VALENCIAPORT (VPF)	ES
11	TECHNISCHE UNIVERSITEIT DELFT (TU Delft)	NL
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Contents

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Definitions and concepts used in this report

Experts are persons with extensive knowledge or ability in an area of study or work.

Results are the main deliverables, publications etc. out of the projects. For EU Horizon 2020 projects, they are available through CORDIS projects pages.

Outcomes are products, services or solutions for business applications aiming at addressing Pain Points and other value-added results potentially impacting the market (by creating it or transform it), the Companies operations as well as polices and regulation. Results that could set direction in Companies and Governments are considered Outcomes too.

Implementation Cases are concrete examples in which causal links between public R&I funding and technology, organizational or process innovation in a specific logistics area can be established.

Logistics Clouds are used in BOOSTLOG to refer in a generic way to a freight transport and logistics domain providing flexibility in the way complex problems are defined and addressed.

EXECUTIVE SUMMARY

In order to optimize European investments in R&I projects in the field of transport and logistics, BOOSTLOG carries out a thorough evaluation process of concluded Research and Innovation (R&I) projects financed with EU-funds.

This evaluation is conducted from the perspective of different key domains of transport and logistics (T&L), (defined by BOOSTLOG as "Logistics clouds") to identify R&I gaps in T&L and prioritize the needs to be addressed in future research programmes, thus contributing to develop an innovation ecosystem for the logistics sector that also contributes to the EU policy objectives.

The present deliverable focuses on Digital Technologies in Logistics, showing the main results and impacts derived from European-funded projects on this area. More specifically, the evaluation of nearly 300 concluded EU-funded R&D projects - from the 5th Framework Programme up to H2020 - has resulted in the selection of 25 projects (see Figure 1), as these are considered key projects with important contributions to the progress and evolution of the digital technologies in logistics.

Figure 1: *European funded R&I Digital Technologies projects in Logistics*

Digital technologies have experienced an increase in attention as far as EU projects are concerned. Nevertheless, the industry as such is still at its early stages since most processes are paper-based rather than paper-less (digital). Based on the analyzed projects, 4 implementation cases have been identified. The cases are a small sample of tangible implementation cases which are slowly gaining traction.

When planning the development or implementation of digital systems in logistics, it is important that the right mix of experts is involved in the execution, including IT developers, experts with knowledge in the specific domain and operational staff. In other words, implementing digital solutions in an industry with low levels of digitalization like logistics, will require a blend of appropriate expertise in many levels of AI, IoT, 5G, digital twins, blockchain and automated transport. Besides technical backgrounds, the relevance and added value needs to be adopted and implemented, and most importantly understood, by logistics industry leaders with non-technological backgrounds to ensure market penetration and actual usability of the digital technologies in logistics.

1. Introduction and methodology

1.1. The BOOSTLOG project

Freight transport and logistics is facing critical challenges to address climate change, to ensure that supply chains are well functioning, and people are served with required type of goods and services. In particular, coping with the expected growth of freight transportation and transition to zero emission logistics up to 2030 requires collaboration and speeding up innovation.

The BOOSTLOG Vision is to transform the European freight transport and logistics R&I ecosystem to perform optimally boosting impact generation out of R&I investment contributing to (1) EU policy objectives towards climate neutrality, pollution, congestion and noise reduction, free movement of goods, internal security, digital transformation of logistics chains and data sharing logistics ecosystems and (2) *Companies* sustainability and competitiveness generating value for society.

In order to do so, BOOSTLOG has identified four main areas of action: (1) Increase visibility and support valorization of R&I project Results, Outcomes and Implementation Cases in the freight transport and logistics field (2) Develop and implement valorization strategies and guidelines to speed up the technological and organizational innovation uptake, including the creation of the Innovation Marketplace and issue recommendations to increase impact of R&I public funding, (3) Define high potential & priority R&I gaps to make efficient uses of R&I investments and (4) Strengthen R&I impacts communication and Stakeholders engagement in the innovation process.

In the framework of the first of those actions, BOOSTLOG has mapped and assessed about 300 EU-funded R&D projects since FP5 in different freight transport and logistics domains (i.e., the Logistics *Clouds*), so as to develop eight comprehensive and industry actionable reports. The last issue of those reports is the present document focusing on Digital Technologies.

These industry-oriented reports will be later complemented by deliverables on valorization strategies and guidelines for public R&I uptake (WP3), an innovation marketplace for R&I uptake (D3.3) and the identification of high priority and potential R&I gaps that need to be prioritized in future R&I actions targeting policymakers (WP4).

1.2. Scope of this deliverable

In the framework of BOOSTLOG WP2, "From R&I projects results to impact generation", Task 2.1 focused on the analysis of the EU funded projects: gathering Outcomes, Implementation Cases in specific Clouds: (1) Freight and Logistics Data Sharing, (2) Coordination & Collaboration, (3) Urban Logistics, (4) Logistics Nodes, (5) Logistics Networks, (6) Modularization and Transshipment, (7) Monitoring and implementing efficient and zero-emission freight transport, and finally (8) Digital Technologies .

This document represents the last report stemming from Task 2.1 that focuses on Digital Technologies in logistics, showcasing both outcomes and implementation cases directly contributing to the field. Given that digital technologies (AI, Automated transport, 5G, blockchain, IoT, Digital Twins) touch upon various domains, there have been certain overlaps with other cloud reports that address data sharing, networks and nodes. Therefore, this report does not focus on the general context of the application areas such as business models facilitated by IoT in ports, but mainly on the technology itself; having the technology as the primary focus and application as the secondary focus.

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The elaborate further on the scope of the Digital technologies report, Figure 2 depicts this Cloud Report (CR) focus in connection with other cloud reports.

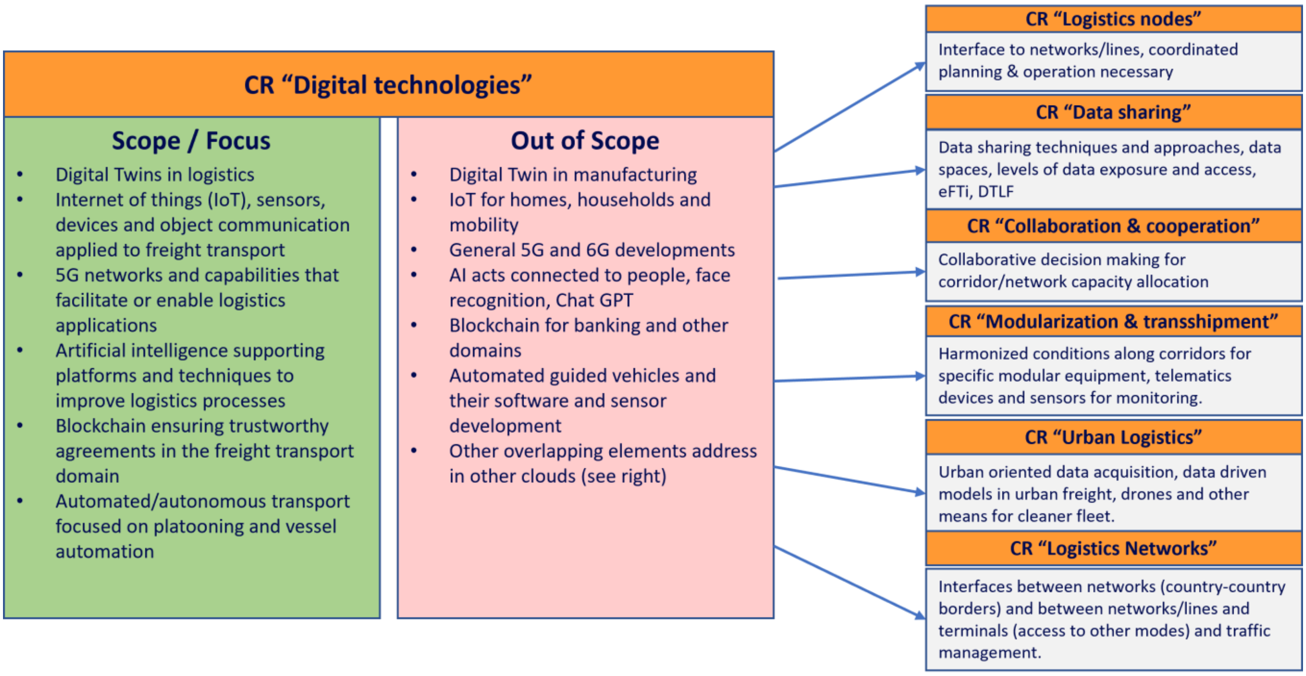

Figure 2: Scope of the "Digital Technologies" cloud and connections/overlapping elements with other clouds

As inferred from the figure, digital twin applications are retained if they are relevant for logistics purposes. The technology also proves to be the most recent one, gaining traction from 2015 and prevalent in logistics and freight transport from 2018. Although some similarities can be established between cyber-physical systems, the latter are not included in this report.

IoT systems serve as enablers for many technologies and applications (Figure 3). It has a transversal character as the IoT scope cannot be confined only to specific IoT projects. Most IoT projects also concern other enabling technologies such as 5G or AI to name a few. In this regard the cloud report conveys technologies as ecosystems rather than separate silos, especially with IoT and 5G scopes.

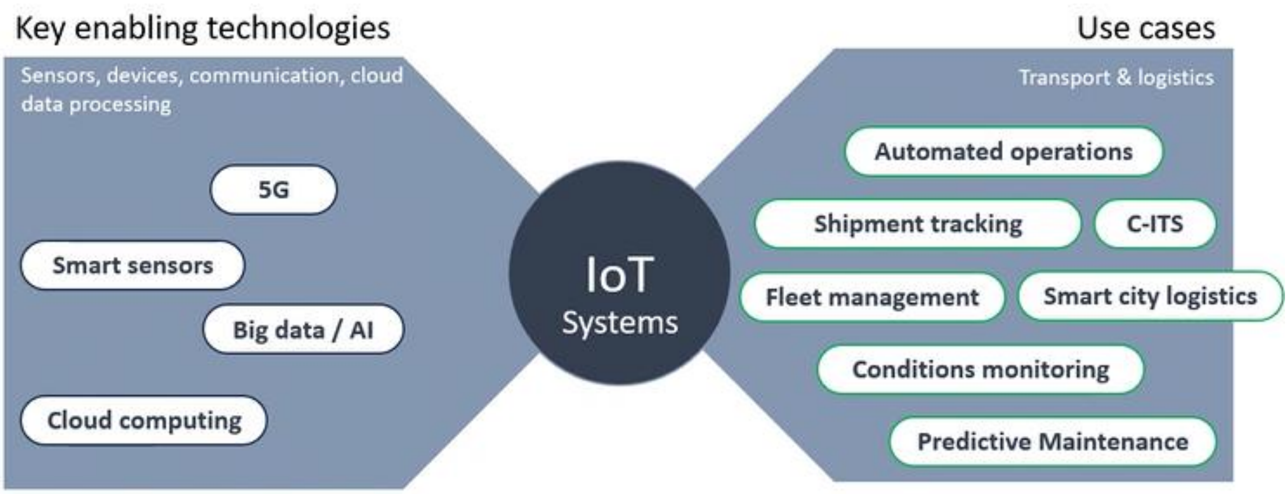

Figure 3: IoT systems and their relevance to other domains and applications. The figure is not exhaustive.

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Blockchain is a decentralized approach to data sharing and verification. The data sharing part has been covered in a different cloud (see Figure 2), but the verification and security processes are retained in this report.

Projects concerning autonomous vehicles in logistics are retained only if they demonstrate a real autonomous vehicle in a logistic use case. This means that projects focusing on demonstration of autonomous passenger transport are not in scope. Also, projects on automated guided vehicles (AGVs) that follow a predefined path and cannot differ from it, are not taken into account. This cloud report will focus on demonstrations of self-driving vehicles (SDV). The vehicle itself could be anything that is used in logistics, like a (semi) truck, yard truck, train, ship or even a forklift. It is assumed that vehicles operated from a control tower are not fully autonomous, however we understand that for this upcoming technology, a remote-control tower is necessary step in the development and demonstration of SDVs in a safe way.

1.3. Methodology of the Cloud Report

The Cloud Reports in general include a brief highlight of the main challenges, past and current specific pain points in a given cloud, key R&I results that have resulted in outcomes and key milestones achieved such as implementation cases establishing causal links between the R&I funding and innovation supporting the seamless integration and harmonization of transport modes, the more efficient management of physical, information and financial flows as well as reducing negative impacts such as decarbonization, emissions and congestion reduction, ensuring the free and seamless movement of goods and digitalization. This basic framework is provided in chapters 2 and **Error! Reference source not found.**. The reports contain clear and companies' actionable items such as cases on how to implement the outcomes or build on the implementation cases.

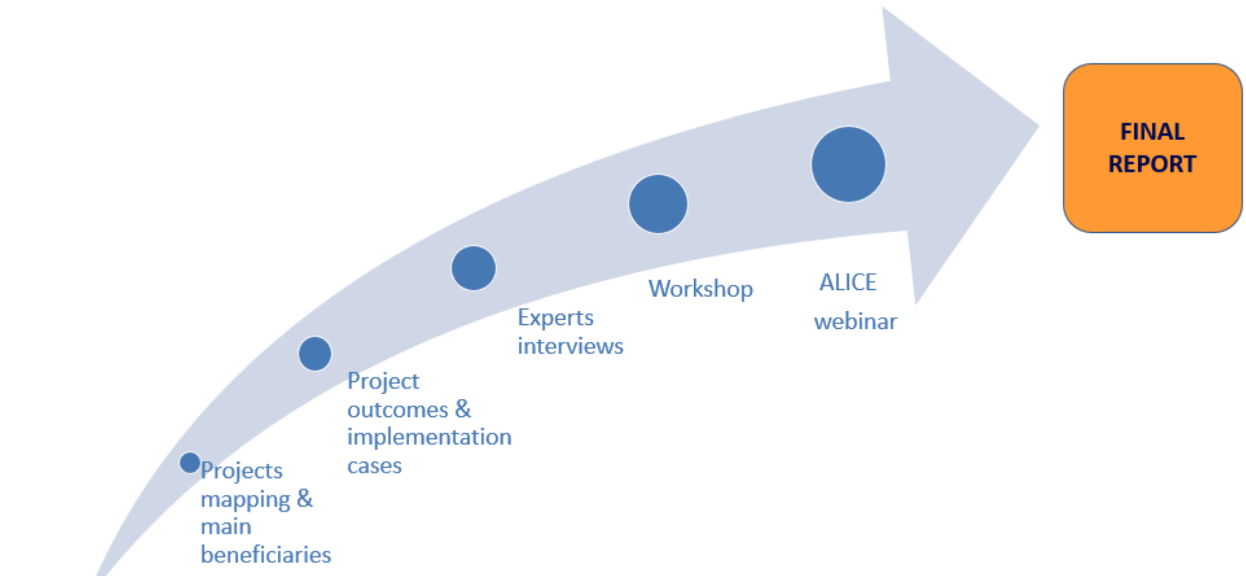

Figure 4: *Methodology for a cloud report development*

The main purpose of the Cloud Reports is to evaluate the results and outcomes from R&I projects performed since FP 5. The methodology for this core topic is shown in Figure 4. Firstly, BOOSTLOG identifies and analyses the R&I results and outcomes at cloud level (Chapter 2 and 3). The outcomes are then checked for eventual implementation after the project lifetime (Chapter 4) i.e., whether they have been implemented and adopted by the freight transport and logistics stakeholders. This investigation step is mainly performed by interviews with key experts, complemented with desk research on projects deliverables and communications. These key experts are stemming from organizations with the most prominent participation in projects for each Cloud; in addition, individual people from those organizations participating in the projects are contacted. Some are also the authors of this cloud report.

The draft report is then shared with the experts for further input and discussion through an online workshop for validation of the report. The validated report will be then presented in a webinar with ALICE members and other stakeholders through BOOSTLOG partners' networks.

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2. Digital Technologies and their role in Logistics

2.1. Introduction

The logistics and supply chain system is a multi-layer complex system with interconnections and inter-operations of its components. Digital technologies allow streamlining operations including real-time changes and unpredicted events and hence, creating systems that are more resilient. Digital Technologies have three main components which can be described in the context of freight and logistics.

Physical layer: In freight and logistics, the physical layer encompasses all the tangible components of the supply chain, such as warehouses, ports, distribution centers, transportation means (trucks, trains, ships, planes), cargo, and even inventory. It includes real-time data related to the movement of goods, tracking and tracing, inventory levels, and other physical aspects of the logistics process. Key technologies that depict the operations and characteristics of various objects are telematics and IoT devices/sensors. These devices are essential for collecting real-time data on the status of shipments, temperature, humidity, and other environmental conditions. RFID (Radio-Frequency Identification) and Barcode Scanners are technologies that help with tracking the movement of goods, from the origin to the final destination. Furthermore, GPS and Location Tracking is used to monitor the location and movement of vehicles and shipments.

Communication layer:

The communication layer is crucial for real-time tracking and data exchange in the logistics and freight industry. It involves the earlier mentioned technologies like IoT sensors on cargo and vehicles, GPS tracking, RFID, and barcode scanning. These technologies convert real-world logistics data into machine-readable formats and enable seamless communication. This layer helps in monitoring the location of shipments, tracking temperature and humidity conditions, and efficiently managing transportation routes. In this regard, the key technologies Wireless Communication Protocols such as Wi-Fi, Bluetooth, and cellular networks enable data transmission between devices and the central logistics system that can be connected via 4G and 5G networks, depending on the latency requirements. Cloud computing also plays a role to store and process data collected from sensors and devices, making it accessible for analysis and decision-making. Furthermore, data integration and middleware solutions facilitate data integration from various sources, ensuring that data is transformed into a machine-readable format. Lastly telematics systems provide real-time data on vehicle location, performance, and conditions, helping bridge the gap between the physical and digital layers for automated and autonomous transport.

Digital layer:

The digital layer plays the main role in optimizing and managing the logistics and supply chain operations. It uses computational techniques to process data from the physical layer, providing insights into route optimization, demand forecasting, and similar issues. It can simulate the impact of different scenarios on logistics operations. For example, in the digital layer, algorithms can analyze historical data to predict optimal delivery routes, consider traffic conditions, and dynamically adjust routes in response to real-time data. Some key technologies and techniques used in the digital layer are data analytics and machine learning (Artificial Intelligence). These technologies/techniques are used to process and analyze the data from the physical layer. Machine learning models can be applied for predictive analytics, demand forecasting, and route optimization.

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Considering the state of the art of the technologies mentioned above and their TRLs, the most recent Digital Twin can serve as an integrator that embodies the physical and digital processes and events. In the context of freight and logistics, Digital Twins enable companies to create digital representations of their supply chain systems. They can utilize the physical layer's data, leverage the communication layer for real-time monitoring, and harness the digital layer's analytical and simulation tools to enhance efficiency, transparency, and resilience in the complex world of shipping and logistics. This integrated approach can result in more streamlined operations, reduced costs and improved decision-making.

Table 1: *Digital Technologies and their expected impacts*

	Expected impacts								
Technology	**Increase visibility**	**Improved routing and navigability of barge, train and truck**	**Decreased cost of transport & overall logistics**	**Increase safety and security**	**Increase transport reliability**	**Data quality and communication**	**Optimize supply chains**	**Facilitate demand forecasting**	**Manage risk and adapt contingencies**
5G	X	X		X	X				
AI/ML	X	X	X		X	X	X	X	X
Autonomous transport		X	X	X	X				X
Internet of Things	X	X	X	X	X	X	X		X
Blockchain			X	X	X	X			X
Digital Twins	X	X			X	X	X	X	X

Based on the above description, the technologies are divided into 6 groups with expected impacts; Table 1 shows the allocations of these impacts to the previously defined areas with a view on the characteristics of Digital Technologies. As a matter of fact, every technology will have one of the expected impacts as a byproduct. The table thus shows the main associated impact per technology for which they are originally designed or known for. As stated before, IoT is to be considered rather as an ecosystem than a separate technology. IoT solutions are characterized by exploiting different enabling technologies such as 5G or AI. In many cases, IoT systems are combined with other digital technologies. This opens a huge variety of use cases and potential impacts in almost all areas.

2.2. Barriers, enablers and market practices

Digital technologies have experienced an increase in attention as far as EU projects are concerned. Nevertheless, the industry as such is still at its early stages since most processes are paper-based rather than paper-less (digital). To enable AI and Digital Twins, the data collection and process exchange need to be improved as it is challenging to incorporate digitalized solutions in an industry which is mostly analog. An example of this slow evolution is depicted by Figure 5 where the impact of digitalization in logistics is one of the lowest compared to media, retail and banking sectors.

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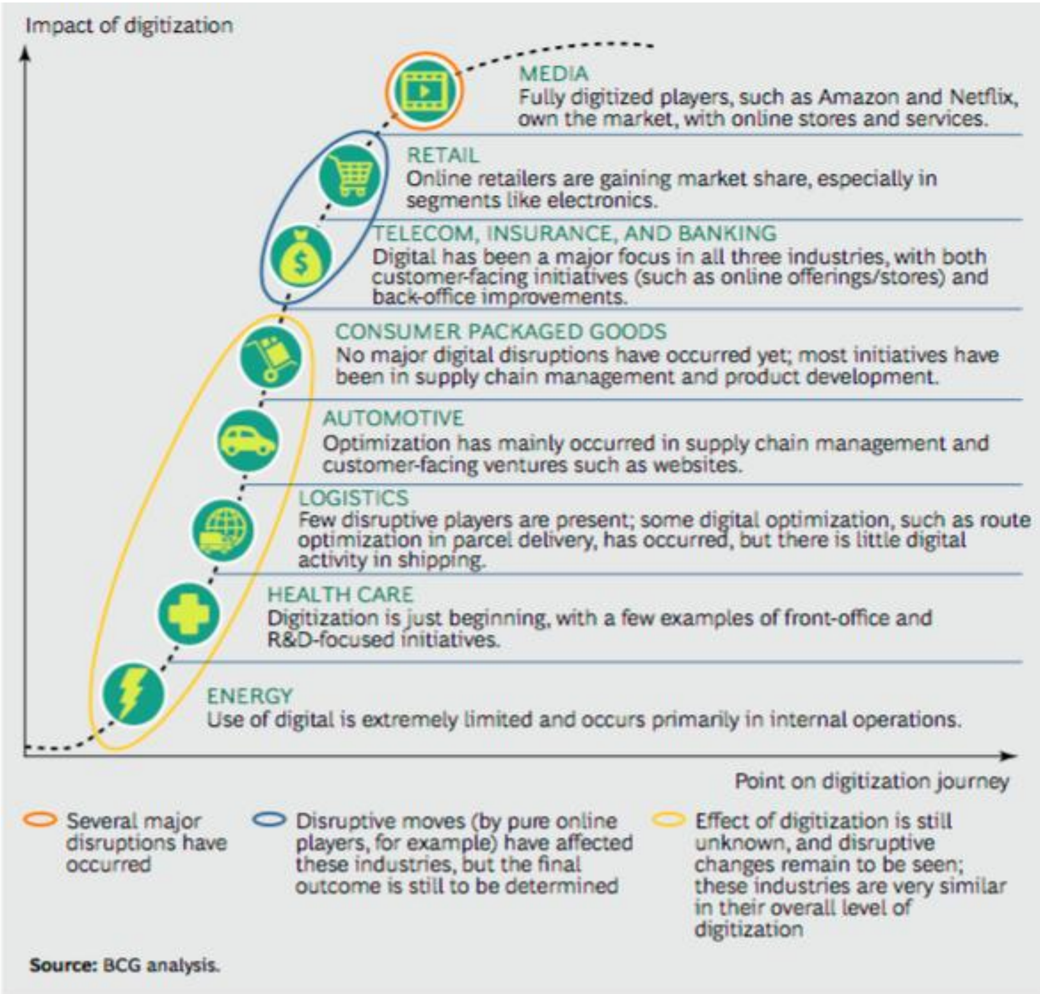

Figure 5: Logistics adoption compared to different industries and their stages (source: BCG analysis)

Therefore, one of the main barriers to the usage of digital technologies in the logistics market is the low digital maturity level that requires onboarding SMEs who have less resources and capacity to compete with larger companies. However, digital technologies can play a crucial enabling role to attract younger and technologically savvy professionals to fields such as inland waterways which experience an ageing workforce; skippers are expected live on barges and spend time away from their families. In this regard, technology can enable teleworking by remotely operating vessels from operating centers, enabled by teleoperated services, semi-automated transport and 5G connectivity for lower latency. The digital technologies have the potential to reconfigure how the industry is organized and managed.

Safety is also one of the main reasons why automated vehicles are developed since human error is the main reason behind many accidents. There are many trade-offs between the technology in the vehicle and on infrastructure that raises strategic questions in terms of automated ports, networks and transport means that roam through them; and what if not all transport means and infrastructure are not "smart" enough.

The market is being shaped by the The European Union which places a strong emphasis on tackling climate change, and recognizes the need to ensure energy security and driving sustainable economic growth. The

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European Green Deal is the blueprint for achieving these goals by committing to eliminate greenhouse gas emissions by 2050 while simultaneously fostering economic growth without depleting valuable resources[1]. For Europe to maintain its competitiveness and ensure sustainability, it should inspire supply chain actors to embrace digital transformation to meet the sustainability targets.

An enabling technology for this purpose is Digital Twinning. According to Equinix 2023 Global Tech Trends Survey (GTTS), the majority of IT leaders recognized the benefits that may be gained from this technology[2] including improved productivity and cost savings. Sustainability benefits of Digital Twins are however overlooked by many of these leaders. For instance, in the logistic sector, Digital twins can model the entire supply chain and its components, enabling logistics managers to identify inefficiency and waste. By optimizing routes, transportation modes and resource allocation, companies can reduce fuel consumption and greenhouse gas emissions. Creating, operating and maintaining a digital twin can be very complex, requiring (distributed) IT infrastructure, data collection and processing, and support real time interactions. Furthermore, AI components make some users reluctant, as most of the solutions are designed in a "black box" manner, while decision makers prefer "white box" solutions that provide more clarity on the inner workings of the algorithms.

As far as IoT solutions are concerned, they offer a wide range of application areas and benefits, from automation to improved decision-making. IoT use cases in the field of logistics include automated operations in transport and logistics, fleet management, equipment monitoring, shipment tracking as well as smart city logistics. These IoT use cases are enabled by the connection of objects and devices which can be uniquely addressed via Internet technologies (IP addresses) and capture, transmit and receive data in relation to their specific purpose. IoT is considered as an ecosystem with multiple enabling technologies, e.g. smart sensors, 4G/5G networks, big data, artificial intelligence (AI), cloud/edge computing, IoT platform software, IoT gateways etc..

Despite its recognized great potential, the implementation of IoT solutions is still in its early stages. Companies - specifically in the logistics sector - are facing various barriers in terms of its adoption and implementation. Such barriers can be broadly divided into the following areas: (1) Knowledge and strategies at company level: Many companies tend not to change established processes and switch to any new technology; one reason could be that they lack a real value proposition. Often, companies do not have sufficient knowledge of the IoT technologies and available solutions on the market; this concerns the management level potentially making the wrong decisions as well as the technical staff having the task to develop and implement the IoT solutions and to specify adapted processes. (2) High costs and required investments: IoT systems are often complex and require investments in multiple technologies. Specifically, SMEs do not have the capacities to set up comprehensive IoT systems on their own. (3) Regulatory framework: The use of IoT technologies requires many regulatory standards to be followed, transparency and clear guidelines are missing, which makes it difficult for companies to capture all regulatory requirements efficiently and at the right time of implementation. (4) Connectivity and integration: IoT systems require the connection of many devices, often combining existing ones with new technologies. Many different technologies need to be integrated; a unified standard is missing. Another challenge is related to efficiently connecting all data and processes with each other. (5) Security and safety: The use of devices that are connected to the internet also bears the risk of

[1] The European Green Deal (europa.eu).

[2] Equinix 2023 Global Tech Trends Survey | Equinix infopaper

malware. In addition, failures of IoT devices or communication chains can lead to disruptions in process chains. Due to these risks, there are often still reservations about trusting IoT-based solutions.

5G barriers relate to regulatory hurdles such as spectrum allocation. This means different countries may allocate different frequency bands for 5G, and harmonizing these allocations across borders can be a complex regulatory challenge in terms of licensing and standards, where divergent licensing requirements and standards across borders can hinder seamless 5G deployment for logistics and transport. Furthermore, interoperability to ensure that 5G-enabled devices and infrastructure are compatible across different regions is crucial for the smooth functioning of cross-border logistics operations. Data security and privacy are barriers where cross-border data transmission raises concerns about data security and privacy regulations, which may vary between countries. Ensuring compliance with these regulations is essential. Additional barriers relate to:

- Varied Infrastructure Levels: Countries have different levels of infrastructure development, and ensuring uniform 5G coverage across borders may be challenging. Remote or underdeveloped areas may have limited access to 5G networks.
- Inter-Governmental Cooperation: Effective cross-border logistics and transport operations depend on collaboration between governments. Differences in policies, priorities, and diplomatic relations can impede such collaboration.
- Reliability and Latency: Ensuring the reliability of 5G networks and minimizing latency is crucial for real-time communication in logistics and transport. Technical challenges in achieving low-latency communications can affect operations.
- Public Concerns: Concerns regarding the health effects of increased exposure to radiofrequency radiation from 5G infrastructure may impact public acceptance and support for the technology.

The main 5G enablers are faster download and upload speeds where 5G provides significantly faster data transfer speeds compared to previous generations, enabling quick and real-time exchange of large volumes of data. Near real-time communication is also ensured by 5G's low latency which brings minimal delay in data transmission. This is crucial for applications requiring near real-time communication, such as autonomous vehicles and remote monitoring. Massive Device Connectivity (MDC) is another enabler. 5G supports a high number of connected devices per square kilometer, allowing for a dense network of sensors and devices in logistics operations. The technology is also closely connected to the IoT technology discussed in this cloud report. 5G supports IoT by facilitating the seamless integration of IoT devices, enabling logistics companies to track and monitor shipments, inventory, and vehicles in real-time. Additional 5G enablers are:

- Improved Asset Tracking: With 5G, logistics providers can achieve precise and continuous tracking of assets, leading to better visibility into the supply chain and improved inventory management.
- Support for Autonomous Vehicles: 5G's low latency and high-speed connectivity are crucial for the development and deployment of autonomous vehicles and drones in logistics, reducing the need for human intervention.
- Real-Time Fleet Monitoring: Logistics companies can monitor the location, condition, and performance of vehicles in real time, optimizing routing, fuel efficiency, and maintenance schedules.
- Automated Warehousing: 5G enables the implementation of smart warehouses with connected sensors and devices, improving inventory accuracy, order fulfillment, and overall warehouse efficiency.

- AR and VR Applications: 5G's high bandwidth and low latency support the use of augmented reality and virtual reality for training, maintenance, and enhanced visualization in logistics operations.
- Advanced Analytics and Machine Learning: The increased data capacity and speed of 5G allow logistics companies to leverage advanced analytics and machine learning for predictive maintenance, demand forecasting, and route optimization.

Switching now from 5G to the analysis of automated transport, several types of vehicles are being automated such as robots, forklifts, buses, passenger cars, trucks and ships. In this Cloud Report we will focus on logistic vehicles that can be used at logistic hubs or driven on public roads autonomously. This means that projects focusing on automated public or private personal transport are not in scope. Nevertheless, we will discuss the current market status of autonomous passenger cars shortly as the CCAM technology for passenger transport and logistics are interlinked and developed for similar use cases.

We also make the difference between guided and fully automated vehicles. Automated Guided Vehicles (AGV) have been demonstrated in several projects and real-world use cases. However, they are bound to follow a predefined path and are not "smart" enough to get around barriers or reroute themselves. During the development of AGVs, some spill-over effects happened to autonomous vehicles, the so-called Self driving vehicles (SDV).

The level of automation of a vehicle can be divided into different levels. The SAE Levels of Driving automation are given in Figure 6. Almost all new vehicles, passenger cars and logistic vehicles alike, have features that can be seen as SAE level 0 to 2 implementations, which are driver-support features. Automated driving features are applicable from level 3. At this level, the vehicle can self-drive, but requires intervention when the conditions are not optimal. At level 4 the vehicle is highly autonomous, but will only work under certain conditions, the Operational Design Domain (ODD). This level is sometimes regarded as 'eyes-off'.

The applicability of level 3 and 4 vehicles is limited to a certain ODD, that defines a set of operation conditions for an automated system. These conditions could include environmental, geographical and timing constraints, together with the road characteristics. The ODD of the Level 3 and 4 vehicle will define where and when the vehicle can drive autonomously. At the highest level of autonomous driving, Level 5, the vehicle can drive itself in all conditions and this level is referred to as 'eyes and mind off'. We limited the scope of this Cloud Report to level 4 and 5 of automation, as at these levels a driver will not be required, and logistic vehicles can drive on their own.

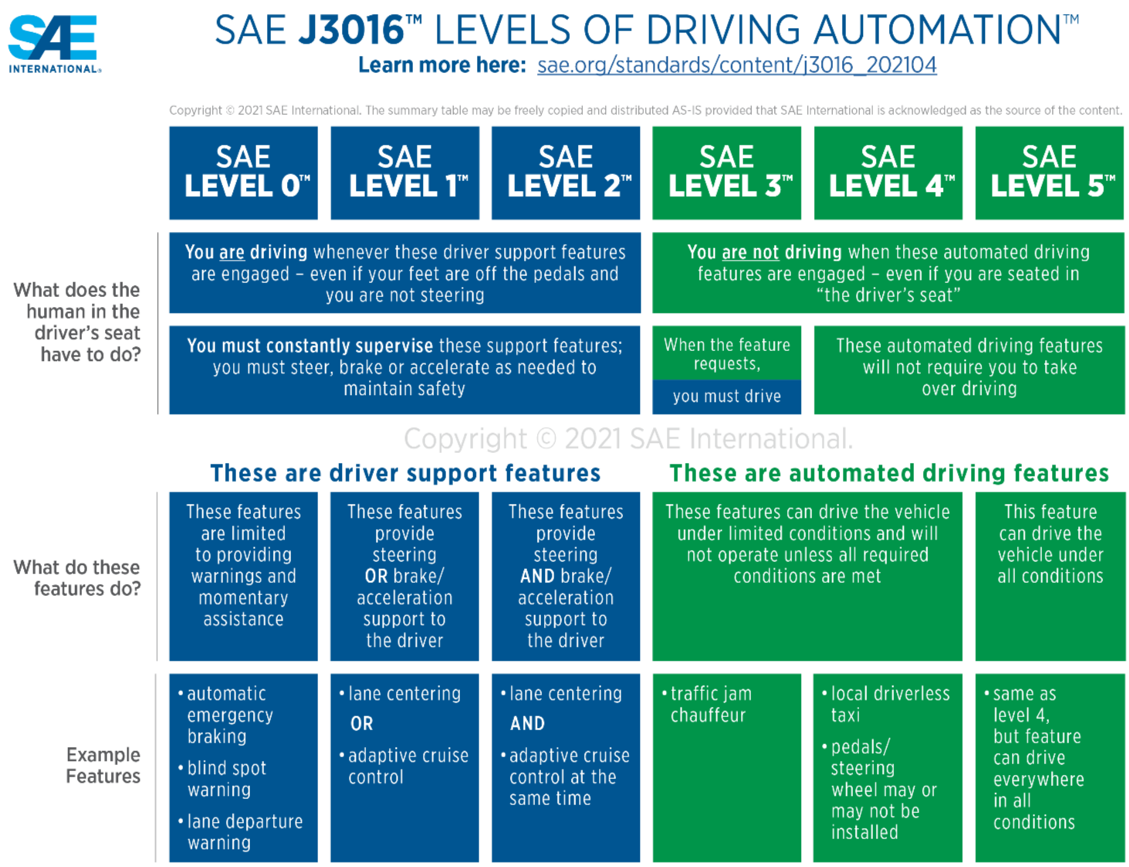

Figure 6: The SAE J3016 levels of driving automation

High levels of automation can only be achieved when the right Physical and Digital Infrastructure (PDI) is in place. With physical infrastructure is meant the road infrastructure (from junction, traffic lights to road markings). The investment in this type of infrastructure is high and the infrastructure itself has a long lifetime, both those characteristics hamper fast and wide adjustment to CCAM needs. The main general reasons to implement CCAM are (1) Safety, reducing the number of road fatalities and accidents due to human error, (2) environmental, reducing emissions and congestion by optimizing the capacity, (3) inclusiveness, ensuring access to transportation for everyone, and (4) competitiveness, strengthening the European technological leadership. From the logistics point of view two reasons can be added, CCAM can be a solution for the (5) driver shortage and the be a way to (6) further cost-optimize the logistics processes. CCAM will only be implemented in logistics when it has a viable business case.

The possible use cases for CCAM, with the focus on logistics can be divided as follows, (1) highways and corridors, (2) confined areas, like logistic hubs, ports or parking, (3) urban mixed traffic and (4) rural roads. All use cases have their specific needs and requirements, both technical and end-user oriented, so specific demonstrations should be designed for each of them. In addition, a possible, viable business case needs to be drafted. Besides the development of the infrastructure and vehicle technology itself, the acceptance and sustainability of CCAM are ongoing research topics. Social scientists try to capture the public acceptance of CCAM, as this is necessity for successful implementation. The current acceptance can vary from enthusiastic, to even hostile, since drivers and logistic workers can perceive that machines are stealing their jobs.

Sustainability is researched to assess the impact of the needed calculations on the vehicle and remotely on dedicated servers. It seems clear that the emissions linked to the energy use of necessary sensors, (onboard) computing and communication are not negligible and need to be accounted for. Another concern is the lifetime of both the software and hardware in the vehicle and the related road infrastructure. It is feared that due to the fast technology evolution, the vehicles will become obsolete prematurely. In addition, the end-users' needs and requirements should be key. Logistics end-users will only implement autonomous vehicles when business can continue, and the autonomous vehicles are capable of doing all drivers tasks ((un)loading, customs, entering gated hubs, docking to loading bay, pick up trailers…), with an acceptable availability, reliability and speed.

As far as the market status of the different use cases and concepts are concerned, platooning and automated vehicles in logistics hubs are the ones most applicable to logistics. Platooning is a form of automated driving, where a convoy of driverless vehicles (trucks) follow a first vehicle with driver. The technology was first demonstrated in the Chauffeur I[3] and II[4] projects and was improved during the ENSEMBLE project[5], where a multi-brand platoon of 6 trucks was showcased. The ENSEMBLE project provided input for the ISO standard 4272:2022 Intelligent transport systems[6]. In BOOSTLOGs Cloud Report VII the ENSEMBLE projects has already been assessed. The ISO norm is not seen as an implementation case but as outcome without implementation, since there are currently no real-life applications of platooning. Other outcomes are a collaborative AEBS system and the demonstration of the multi-brand platoon. No significant fuel consumption reduction was found during the project, despite it being expected due to drag. A possible explanation for not improving the fuel efficiency could be that the distance between the trucks was too great for positive drag effects. The distance could not be decreased during the project due to safety regulations. In the AUTOPILOT project[7], an IoT ecosystem connecting vehicles, road infrastructure and other object was demonstrated. One of the 6 use cases was platooning trucks in the Netherlands and France. In terms of the autonomous vehicles in logistic hubs, the operation of AGVs in logistic hubs, like ports, is becoming common[8]. Demonstrations with full autonomous vehicles are happening in ongoing R&I projects. The PIONEERS project is developing an electric platform that can handle container in a port environment[9],[10]. Autonomous vehicles for logistics will be demonstrated in the ePI-Node demonstrator of the ePIcenter project[11]. The Swedish technology company Einride is assessing how logistic processes can be automated by their driverless Pod. They state that logistics operations are so diverse that for each use case the implementation need to be assessed from scratch. Also,

[3] https://cordis.europa.eu/project/id/TR1009

[4] https://cordis.europa.eu/project/id/IST-1999-10448

[5] https://cordis.europa.eu/project/id/769115

[6] https://www.iso.org/standard/79853.html

[7] https://cordis.europa.eu/project/id/731993

[8] https://www.vdlautomatedvehicles.com/port-solutions; https://www.konecranes.com/port-equipment-services/container-handling-equipment/automated-guided-vehicles/agv

[9] https://pioneers-ports.eu/wp-content/uploads/2023/10/14.-Catchy-PIONEERS_-Autonomated-shuttle-solutions-for-port-operations.pdf

[10] https://cordis.europa.eu/project/id/101037564

[11] https://epicenterproject.eu/demonstrators

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commercial companies are conducting demonstrations, like NavTech with terminal tractors[12]. Nevertheless, we did not find any implementation case, where the demonstration let to an integration in daily operations (as it will be noticeable in chapter 4). An overview of CCAM research topics and finished and ongoing projects can be found at the website of the FAME project[13], the ERTRAC roadmap[14] and CCAM association[15].

Finally, this chapter concludes with blockchain and AI developments. As for the former, Blockchain technology is increasing in interest by industry in different application fields including logistics. Most of the time, it is presented as THE way to solve and diminish barriers for collaboration in "none" trusted environments. The technology has received a lot of attention in the recent years in fields connected to payments, digital identity, smart contracts. Specific logistics applications of blockchain have been carried out successfully by companies such as T-mining and various other providers. Another known application was implemented by TradeLens powered by IBM and Maers which unfortunately ceased to continue due to many reasons that will not be described in this report. In terms of cross domain applications such as blockchain combined with the use of IoT, Blockchain Market [16] state distributed legger technology raises concerns over regulations as policy makers cannot regulate the technology, but only the technological use case.

As for the latter, being AI, over the past years, artificial intelligence (AI) has become a major topic – if not the major topic – in many newspaper articles, panels of experts, forums as well as in the business community. Especially with recent developments and releases in the area of generative AI, quickly taking the market and transforming economies, for example the chatbot ChatGPT [17] by OpenAI and image generation tool Midjourney[18] by Midjouney, Inc., the discussion about the potentials of AI for all private and industrial sectors have gained a new level of attention. The EU supports the development and use of these innovative technologies by creating a regulatory framework, called EU AI Act. The goal of the AI Act is to make sure that AI systems used in the EU are safe, transparent, traceable, non-discriminatory and environmentally friendly, and to reach an agreement on the new law by the end of 2023[19]

The importance of AI is also growing rapidly in the European logistics industry, as it can help optimize processes, reduce costs, improve customer satisfaction, and increase sustainability. According to an Accenture report, 86% of COOs claim that AI is essential for achieving their growth objectives and 40% of supply chain executives participating in Accenture's Technology Vision research said AI is the second priority for scaling in a post-pandemic world, just behind the cloud[20]. Also, the 2021 MHI Annual Industry Report determined that

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[12] https://navtechradar.com/innovation-lab/port-automation/

[13] https://www.connectedautomateddriving.eu/about/fame/

[14] https://www.ertrac.org/news/new-ertrac-ccam-roadmap/

[15] https://www.ccam.eu/projects/

[16] https://www.marketsandmarkets.com/Market-Reports/blockchain-technology-market-90100890.html

[17] https://openai.com/blog/chatgpt

[18] https://www.midjourney.com/home?callbackUrl=%2Fexplore

[19] "EU AI Act: first regulation on artificial intelligence | News | European Parliament," Jun. 08, 2023. https://www.europarl.europa.eu/news/en/headlines/society/20230601STO93804/eu-ai-act-first-regulation-on-artificial-intelligence (accessed Aug. 27, 2023).

[20] J. Lagunas and P. A. Riedl, "Scaling AI in the supply chain - The next step toward intelligent, self-driving supply chains," accenture, 2022. Accessed: May 01, 2023. [Online]. Available: https://www.accenture.com/content/dam/accenture/final/a-com-migration/manual/r3/pdf/Accenture-Scaling-AI-In-The-Supply-Chain.pdf

AI is one of the technologies that have experienced the largest jump in technology adaption rate in global supply chains from 2020 to 2021, underlining the rapid growth of the importance of AI in logistics[21].

The complex decisions that control logistics processes are often made by experts and thus depend on the experience of employees. The shortage of skilled workers is a trend that will also become increasingly relevant for the logistics industry in the future, so that AI with the ability to generate and capture knowledge will become a key factor. Finally, with a contribution of 5% of the EU's gross domestic product, more than 6 million employees, and 25 % of the EU's total greenhouse gas emissions, the transport industry alone plays a significant role in the European economy and holds major potentials for optimization approaches based on AI methods[22].

The next chapter will now address EU projects that focus specifically on AI, IoT, 5G, Automated transport, blockchain and Digital Twins.

[21] MHI and Deloitte, "Innovation Driven Resilience - How technology and innovation help supply chains thrive in unprecedented times," MHI, 8, 2021.

[22] European Commission. Statistical Office of the European Union., *Key figures on European transport: 2022 edition.* LU: Publications Office, 2023. Accessed: May 01, 2023. [Online]. Available: https://data.europa.eu/doi/10.2785/322262

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3. Digital Technology projects in Logistics

Understanding the barriers, enablers and market context of the technologies forms a solid foundation to identify EU funded projects that touch upon the earlier discussed developments. This chapter contains the main identification of R&I projects and also the main entities that have a higher rate of involvement in such projects.

3.1. Identification and selection of R&I projects relevant to Digital Technologies

The mapping exercise of digital technologies in logistics led to the identification of 25 projects relevant for this Cloud Report (Figure 7). At first glance, this relatively small number might be surprising, considering the outstanding importance of digital technologies. Most projects in the short-listed R&I project ecosystem are focused on specific, and most of the time overlapping, technologies that can contribute to logistics applications and processes. This holistic operation-oriented notion of our analysis was challenging, as the implementation of technologies in R&I projects that are rather recent is difficult to analyze given that most projects recently ended, and the time from R&I to market has been very limited. Moreover, the characteristics of digital technologies in logistics also imply a high likeliness of overlapping with projects and specific outcomes tackled by other Cloud Reports. Therefore, the lower number of identified projects is understandable and plausible as some projects have been left out since they are described in detail in another cloud such as the Ensamble and Levitate projects to name a few.

Figure 7: *Selected "Digital Technologies" R&I projects and their allocation to the funding programs*

Nevertheless, setting the boundaries between the clouds is an arduous task. Clouds are interdependent with each other, and many projects affect more than one cloud, to a greater or lesser extent. This particularly applies to digital technologies, a cloud where innovations from multiple research streams are combined, and some technological areas could be even deserving of a standalone report.

Besides projects, the analysis also focused on the organizations with the highest level of involvement in the selected projects. The main selection criteria were frequency of participation in the projects as well as their role as provider of substantial results or as a project coordinator. These organizations are important for understanding and monitoring projects' outcomes as well as the implementation cases derived from them. Specifically, they form the basis for the selection of the interview partners. As depicted by Figure 8, 27 organizations were revealed as particularly involved in European research projects in the area of digital technologies.

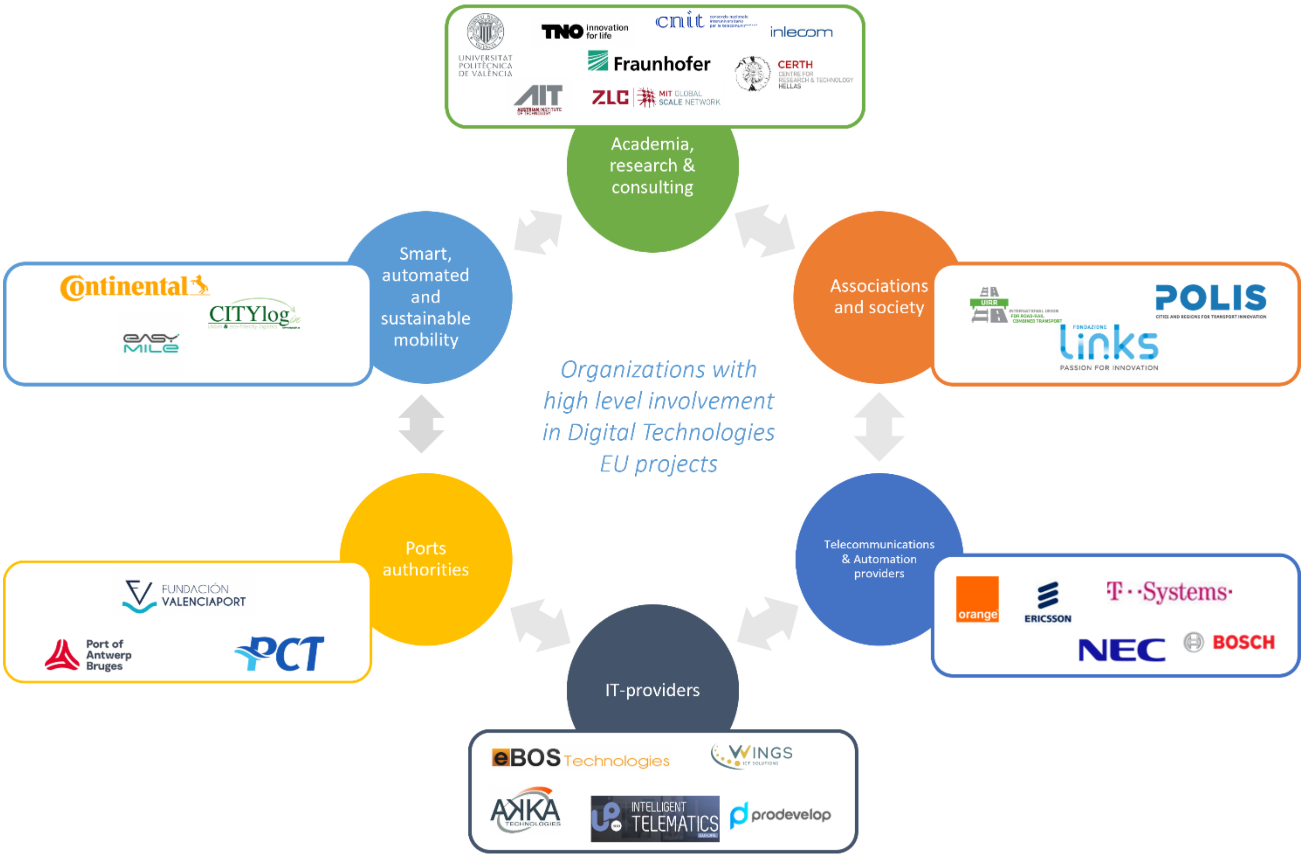

Figure 8: *Organizations with high level of involvement in "Logistics Networks" projects*

The next sub-section sheds more light on the selected projects and their main content. The projects have been divided into technological categories where we highlight the most prevalent solutions connected to AI, automated transport, blockchain, IoT, 5G, and digital twins.

3.2. Description of the selected projects

The descriptions have been retrieved and analyzed via the EU CORDIS system. Additional research, interviews and website analyses were carried out to identify the most appropriate technology focus in the given projects; as some projects cover multiple technologies. As a result, certain projects may re-appear under a different technology.

Artificial Intelligence

COG-LO (COGnitive Logistics Operations through secure, dynamic and ad-hoc collaborative networks**)**[23]

The COG-LO project introduced cognitive and collaboration features to future logistics processes. It developed a secure network environment, enabling real-time information exchange and empowering logistics actors with cognitive behavior. By revolutionizing complex event detection and decision support, COG-LO created a community of stakeholders and introduced new business models for ad-hoc collaborations. Through

[23] http://www.cog-lo.eu/

intermodal, cross country, and urban logistics pilot operations, this initiative sought to reshape the future of the industry. The COG-LO framework and tools for dynamic and ad-hoc logistics collaborations were achieved by:

- Adding cognitive behavior to all involved logistics actors (i.e. systems, vehicle, cargo)
- Developing a collaborative environment for the exchange of information through secure and trusted networks
- Improving decision making addressing ad-hoc requests and exceptions.

The main AI-features were connected to data analytics tools and APIs. This enabled complex event detection, context awareness and decision support at local and global levels. This included global reasoning, understanding and acting, while processing data and real-time streams from multi-modal sources. The tools applicable to AI were the 1) Cargo hitchhiking tool that identified collaboration in real-time along the routes by making use of IoT and advanced analytics technology and the 2) Cognitive Logistics Advisor tool that concerned deep learning techniques applied to big data the cognitive logistics object (CLO). The CLO constantly communicated with its fellow CLOs to negotiate alternatives dung various events. The pilots covered Cross-country, multi-modal and urban logistics dimensions.

COREALIS (Capacity with a positive environmental and societal footprint: ports in the future era**)**

The COREALIS project defined the future era of European ports proposing a strategic/innovative framework. It was supported by disruptive technologies, including IoT, data analytics, next generation traffic management and 5G in order to face the future capacity, traffic, efficiency and environmental challenges. As far as AI features are concerned, a machine learning tool was developed to improve the use of port assets via a predictor for asset utilization and management.

The predictor used a diversity-aware ensemble learning based algorithm, referred to as DAMVI, to deal with imbalanced binary classification tasks. Specifically, after learning base classifiers, the algorithm:

i) increased the weights of positive examples (minority class) which are "hard" to classify with uniformly weighted base classifiers;
ii) it learned weights over base classifiers by optimizing the PAC-Bayesian CBound that takes into account the accuracy and diversity between the classifiers.

The use case of PREDICTOR involves the yard trucks of Piraeus Container Terminal. The fleet involves 170 internal trucks. Its purpose was to train the developed algorithm based on historical maintenance and breakdown data in order to predict future breakdowns of yard trucks as well as the parts that will be affected and relative spare parts required for the maintenance.

The main benefits of predictive maintenance for container terminals were linked to knowing in advance the number of spare parts to be ordered (reducing administrative overhead and inventory levels). As a result, well maintained engines emitted less pollutants. The other main benefits is the avoidance of breakdowns that significantly impact the terminal processes and restructuring the whole vessel loading/unloading plan.

LOGISTAR (Enhanced data management techniques for real time logistics planning and scheduling**)**

The LOGISTAR project introduced a Decision-making tool and a real-time visualization tool for optimization and effective planning of (collaborative) freight transport. The solution consists of a collaborative route optimization by building optimal routes for collaborative freight transport using data (fleet, demands, time windows etc) as well as providing real-time supply chain visibility through dashboards, not only displaying information but also showing deviations, alerts or recommendations to take actions. Data was retrieved and harmonized, and sensors were connected to a cloud IoT platform to leverage the available data, to process it and to deliver services. The AI-related application concerns smart algorithms (Hybrid metaheuristics based on paradigms of parallel computing) for predictions, learning the preferences, optimization of the planning of operations and automated negotiation and re-optimization (based on multi-objective optimization models). Real-time dashboards provided an overview to managers of what is happening.

By collaborating and optimization in freight transport, companies could increase load factors, shorten delivery routes and create full truck load (FTL) backhaul opportunities and consolidation of less than truckload (LTL) deliveries. The solution was aimed at allowing effective planning and optimizing of transport operations in the supply chain by taking advantage of horizontal collaboration, relying on the increasingly real-time data gathered from the interconnected environment.

PIXEL (Port IoT for environmental leverage)

Given the lack of effective operational data integration and its confinement to individual entities PIXEL leveraged technological advancements to enable voluntary data exchange between ports and stakeholders.

Despite the project being an IoT-based initiative, an AI feature was presented for Maritime data analytics from vessels calls and AIS. The predictive algorithms were used for vessel calls (estimated time of arrival and estimated time of departure) visualized via a Gantt chart, and for the prediction of port congestion by monitoring port gates. The algorithms were applied in the Port of Bordeaux, Port of Monfalcone, Port of Thessaloniki and Port of Pireus for planned vessel calls, estimated time of departure and gate traffic data.

DATAPORTS (A data platform for the cognitive ports of the future

To achieve efficient collaboration and benefit from AI-based technology, a new integrating environment was needed. In that context, the DataPorts project designed an Industrial Data Platform. The Cognitive Ports Data Platform connected existing digital infrastructures of seaports and their systems, set rules on safe and reliable data sharing and trading, and offered services of data analytics. This allowed to create different smart applications according to related requirements. Before full implementation in European ports, the platform was demonstrated in two European seaports. The project extended existing machine learning platforms by delivering domain-specific AI components that empower cognitive big data applications for connected ports.
An Automatic Model Training Engine was devised to optimize business processes using machine learning techniques. It was used for two use-case applications within the project:

- Port Authority Data Sharing and Analytics Service
- Analytics Use Case for the Port if Thessaloniki to facilitate proactive and reactive actions regarding the operation of Gate Control System

KnowlEdge (Towards AI powered manufacturing services, processes, and products in an edge-to-cloud knowlEdge continuum for humans in-the-loop)

The KnowlEdge project created a solution that can optimize production sequences and improve efficiency. This includes using AI technologies to reduce human input and improve predictions of product quality parameters. This required extracting information from different data streams along the supply chain to improve coordination of production and logistics processes.

The case application focused on the production scheduling for a dairy factory. The product was to be made in accordance with market demand, while utilizing the resources efficiently. This process was constrained by many factors and required extensive knowledge to plan production. Re-scheduling in real-time needed to be undertaken when unexpected changes occurred.

The project developed a platform designed to be agile, distributed, scalable, collaborative, and standardized, with security and accountability in mind. It integrated cognitive technologies, including AI, distributed data analytics, Internet-of-Things (IoT), cyber-physical systems (CPS), edge, fog, and cloud technologies.

The platform included several elements, which addressed challenges related to decision-making, knowledge representation and storage, data integration and management, AI and analytics, and cross-platform capabilities. Distributed AI and data analytics were based on deep machine learning methods towards automatic knowledge discovery. Users could reason with the AI results and suitable interfaces allowed capturing of human domain knowledge.

Automated Transport

In this section we will discuss a project that investigates L4-level automation in logistics: AWARD. The AWARD project was the first project that focused only autonomous logistics and will be finished Q1 2024.

AWARD (All Weather Autonomous Real logistics operations and Demonstrations**)**

In the AWARD project, different types of autonomous vehicles are or will be demonstrated in 4 real-life logistic use cases. The vehicles are a forklift, a yard tractor for ports and airport and a rigid truck. As the full title of the project suggests (All Weather Autonomous Real logistics operations and Demonstrations), the vehicles will be tested under challenging weather conditions.
The yard truck in port environment was demonstrated in the port of Rotterdam by DFDS. A trailer was loaded automatically onto a ship with the yard truck. The use case also comprises moving the trailer on the site to prepare loading and the gate process, plus public road access without the trailer. Since a ship, even docked, is constantly moving the loading on a ship was more challenging than first anticipated.
The autonomous vehicle for airports is already tested in the winter of 2023 with a safety driver and will be tested in the winter of 2024 without safety driver, but with a safety vehicle that can force the autonomous vehicle to stop. In this use case the effect of snow will be tested. The demonstration is done by Avinor at the port of Oslo.
The rigid truck was demonstrated in Austria, where it transported goods from one logistic site to another one.

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A part of the use case happened over public road. Traffic signs were necessary to let the rigid trucks merge with regular traffic, as its allowed speed was significantly lower than the local speed limit.
The use case with the automated forklift will be done at the start of 2024. The autonomous forklift will load an autonomous truck, which is parked in an arbitrary position.

Blockchain

ICONET (New ICT infrastructure and reference architecture to support Operations in future PI Logistics NETworks)

The project contributed to optimizing end-to-end physical internet flow in pursuit of a new networked architecture for interconnected logistics hubs combined with IoT capabilities.
Besides other objectives, the ones applicable to blockchain were to research and investigate an experimental Cloud-based PI Control and Management Platform, appropriately transferring successful and proven Digital Internet counterparts, including Networking, Cloud, IoT and Blockchain technologies.
The project further focused on the deployment and testing of proof of concepts (PoC) in four industry-representative Living Labs with the end goal of measuring, demonstrating and quantifying business value, economic viability, innovation, deployment-related issues, and cost- benefit analyses. The project assessed key areas for future R&D which will in turn pave the way towards the first operational PI Network involving members from three leading associations – European Shippers Council, UIRR and ELUPEG.

COGLO (COGnitive Logistics Operations through secure, dynamic and ad-hoc collaborative networks)

COG-LO created a framework and tools for dynamic and ad-hoc logistics collaborations. This was achieved by: 1) Adding cognitive behavior to all involved logistics actors (i.e. systems, vehicle, cargo); 2) Developing a collaborative environment for the exchange of information through secure and trusted networks and 3) Improving decision making addressing ad-hoc requests and exceptions. The project created a vibrant community of stakeholders and introduced new business models for ad-hoc collaborations. Through intermodal, cross country, and urban logistics pilot operations, this initiative will seek to reshape the future of the industry. The solutions incorporated in the COG-LO systems and operations were aligned by design in accordance with the associate regulations, particularly with GDPR. To this end, all appropriate mechanisms of access and usage control and advanced cryptography was employed, considering data ownership, handling policies, and scalability, whereas the blockchain was used as an infrastructure to foster traceability, transparency and trust.

DATAPORTS (A Data Platform for the Cognitive Ports of the Future)

DataPorts project designed an Industrial Data Platform. The Cognitive Ports Data Platform connected existing digital infrastructures of seaports and their systems, set rules on safe and reliable data sharing and trading, and offered powerful services of data analytics. The project's goal was to provide a Data Platform in which transportation and logistics companies around a seaport would be able to manage data like any other

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company asset, to create the basis to offer cognitive services. The project was devoted to the creation of a secure data platform that allows sharing the information not only between port agents but also between other ports. Hence, this is a secure environment of data exchange in a reliable and trustworthy manner, with access permits and contracts to allow data sharing and the exploration of new Artificial Intelligence and cognitive services. The blockchain technology was used by DataPorts, together with the IDS connector technology which ensured that data owners remained in full control of their data.

Internet of things

Compared to the other technologies, the IoT domains yielded thousands of search results given its overlapping character and application fields. An additional filtering, besides "the given technology" and "logistics", had to be applied. The mapping of IoT projects has been done in 3 steps: In Step 1 (initial mapping) the project database with more than 300 entries has been screened for relevant keywords and respective synonyms in relation to IoT ecosystem (e.g. Internet of Things (IoT), Industry 4.0, Logistics 4.0), IoT key enabling technologies: (e.g. smart sensors, cloud / edge computing, connectivity, 5G, Artificial Intelligence (AI)), IoT use cases: (e.g. tracking and tracing / monitoring, inventory management, fleet management, predictive maintenance, automated driving) and general key words (e.g. smart, intelligent, collaborative, cooperative). Additionally, the project summaries were checked for these keywords. In total, 127 projects have been identified to be tackled within the next step. Step 2 (relevance and scope mapping) includes a filtering regarding relevance assessment ("high", "medium", "low") that refers to the general significance for the Cloud Reports. Only projects with the relevance assessed as "high" or „medium" were further considered; as a result 100 projects remain for the next assessment step. Step 3 (content mapping) contains a more detailed check of the project content. More specifically, the project documentations were checked regarding (1) compliance with defined focus (strong relation to IoT systems and use cases, strong focus on logistics), (2) the consideration of the project in other clusters within the Digital Technologies Cloud Report, e.g. 5G or road automation / platooning (it has been decided to rather refer to other parts of the report than duplicate project description) and (3) the consideration in one of the other Cloud Reports. Generally, this was no exclusion criterion; however, it should be ensured that the projects were properly allocated to the Cloud Reports according to their content focus.

As a result, the following projects with a strong focus to IoT systems and use cases in logistics have been selected to be presented within this report, some of them are also related to other digital technologies' domains and described thereunder: ParcelCall, FIspace, iCargo, COG-LO (described under the domain AI), COREALIS (AI), ICONET (AI), LOGISTAR (AI), PIXEL (AI), SELIS, TT, LEAD (Digital twins), MODI (AI) and I2PANEMA

ParcelCall (An Open Architecture for Intelligent Tracing Solutions in Transport and Logistics)

ParcelCall developed an open architecture for intelligent tracking and tracing in transport and logistics. New network technologies were combined with advanced sensors and innovative service engineering. The project was built on state-of-the-art technologies and developed specific answers to overcome key constraints for the realization of the objectives in an open system approach. This specifically leads to seamless integration for intermodal transport, use of active sensors, and intelligent sensor networks.

The project integrated new technologies such as RFID tags and public communication networks (Internet and GPRS) to develop the system and test the application in a realistic business environment. Mobile phones were used to obtain close to real-time information on the tracking of the entire logistics chain anytime, anywhere. The approach distinguishes three stages with increasing performance, flexibility and scalability. Firstly, the development of an open tracking and tracing architecture for the entire logistics chain. Secondly, the integration of active sensors to monitor and control the environmental conditions and quality status of the transported goods. And finally, the integration of communicating sensors that notify the owner of the goods directly if the environmental conditions deviate from their standard values.

FIspace (Future Internet Business Collaboration Networks in Agri-Food, Transport and Logistics)

Insights gained in the Future Internet Public Private Partnership (FI-PPP) research programme Phase 1 emphasize the need for novel ICT solutions that allow radical improvements for collaboration in business networks. Current ICT solutions limit this to mostly manual efforts, therewith tremendously hampering business efficiency, effectiveness & sustainability.

As a use case project in Phase 2 of the FI-PPP, FIspace aims at developing and validating novel Future-Internet-enabled solutions to address the pressing challenges arising in collaborative business networks, focusing on use cases from the agrifood, transport and logistics industries. FIspace will focus on exploiting, incorporating and validating the Generic Enablers provided by the FI-PPP Core Platform with the aim of realizing an extensible collaboration service for business networks together with a set of innovative test applications that allow for radical improvements in how networked businesses can work in the future. Those solutions will be demonstrated and tested through early trials on experimentation sites across Europe. The project results will be open to the FI-PPP program and the general public, and the proactive engagement of larger user communities and external solution providers will foster innovation and industrial uptake planned for Phase 3 of the FI-PPP.

The central features of the FIspace collaboration service (Figure 9) include integrated techniques for monitoring and tracking on the basis of data integration from the Internet of Things (IoT), including sensor systems and smart item technologies.

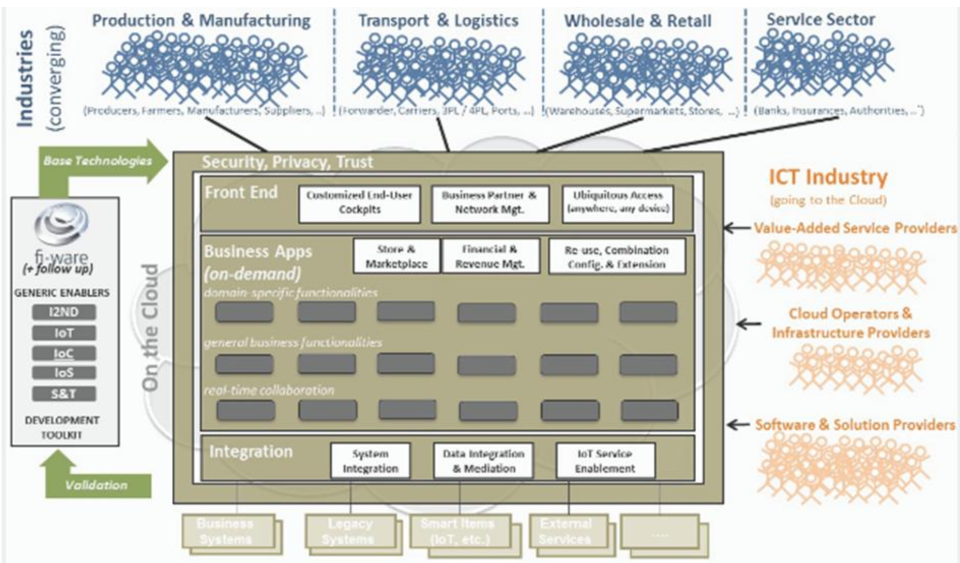

Figure 9: FIspace collaboration platform. Source: http://www.fispace.eu/project-scope.html

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iCargo (Intelligent Cargo in Efficient and Sustainable Global Logistics Operations)

iCargo has built an open affordable information architecture to allow real world objects, existing systems, and new applications to efficiently co-operate, enabling more cost effective and lower-CO2 logistics through improved synchronisation and load factors across all transport modes.

iCargo has advanced and extended the use of ICT to support new logistics services that (1) synchronise vehicle movements and logistics operations across various modes and actors to lower CO2 emissions, (2) adapt to changing conditions through dynamic planning methods involving intelligent cargo, vehicle and infrastructure systems and (3) combine services, resources and information from different stakeholders, taking part in an open freight management ecosystem.

SELIS (Towards a Shared European Logistics Intelligent Information Space)

The Shared European Logistics Intelligent Information Space is a network of logistic communities' specific shared intelligent information spaces termed SELIS Community Nodes (SCN). SELIS Community Nodes are constructed by individual logistics communities to facilitate the next generation of collaborative, responsive and agile green transportation chains. SELIS Community Nodes link with their participants' existing systems through a secure infrastructure and provide shared information and tools for data acquisition and use, according to a 'cooperation agreement'. Connected nodes, provide a distributed common communication and navigation platform for Pan European logistics applications. Each Node decides what information to publish and what information to subscribe to. The SELIS Community Node concept represents the evolution of a long line of research in this area. The fundamental principle is that it provides a 'lightweight ICT structure' to enable information sharing for collaborative sustainable logistics for all at strategic and operational levels.

The SCNs create a centralized "data lake" configured to address the needs of a logistics community, aggregating information flows in various formats, which are generated by the operational systems of the logistics participants, and also through interfaces to IoT devices and controllers, resulting near real time insights and enhanced visibility, so that the stakeholders in the logistics value chain are improving their operations, decisions, plans, policies and strategies, and their quality of services.

TT (TransformingTransport) (H2020, 2017-2019)

The Transforming Transport project has demonstrated in a realistic, measurable, and replicable way the transformations that Big Data will bring to the mobility and logistics market. To this end, TransformingTransport, has validated the technical and economic viability of Big Data to reshape transport processes and services to significantly increase operational efficiency, deliver improved customer experience, and foster new business models. TransformingTransport has performed different pilot cases; the following in the domains of major importance for the logistics sector: Smart High-ways, Sustainable Vehicle Fleets, Proactive Rail Infrastructures, Ports as Intelligent Logistics Hubs, Dynamic Supply Chains. Big Data is considered as a key enabling technology for IoT.

LEAD (Low-Emission Adaptive last mile logistics supporting on demand economy through Digital Twins)

Last mile delivery systems are facing many challenges associated with the dawn of on-demand logistics, struggling to accommodate citizen's expectations for responsive logistics systems, that deliver products at low or even zero cost. This is the case for both small and large-scale consumer platforms, pledging swift delivery times, albeit with little market economic incentives for the creation of sustainable systems.

LEAD created Digital Twins of urban logistics networks in 6 cities (Madrid, The Hague, Budapest, Lyon, Oslo and Porto), to support experimentation and decision-making with on-demand logistics operations in a public-private urban setting. Innovative solutions for city logistics were represented by a set of value case scenarios addressing the requirements of the on-demand economy while aligning competing interests and creating value for all different stakeholders. Each value case combined several measures (so-called LEAD strategies), such as innovative business models, agile freight storage and distribution, low-emission delivery vehicles and smart data-driven logistics solutions. Technology enablers for building Digital Twins include sensor technologies, IoT, and big data analytics.

I²PANEMA (Intelligent IoT based Port Artefacts Communication, Administration & Maintenance)

Ports play an important role in global supply chains. The use of IoT is considered a key feature for port operators to improve the efficiency of port operations, to be able to better manage (container goods) traffic, to empower their work forces increasing throughput and to decrease carbon emissions while making traffic safer. In addition, smart IoT solutions support automation and intelligent transport control to realize the Physical Internet.

The R&D project I²PANEMA (co-funded under EUREKA innovation cluster ITEA 3) was helping ports to become (a network of) smart ports by exploring and demonstrating the applicability of IoT technologies. With this approach, I²PANEMA aims to make ports more efficient and sustainable by introducing IoT based measures such as Active Noise Control systems and keeping pollution (like noise, dust) under control while promoting multimodal transport as part of the Physical Internet. Case studies from the project demonstrated the possibilities for developing ports in Physical Internet Nodes.

5G Applications

5G-CARMEN

5G-CARMEN project provides a cooperative, connected and automated mobility (CCAM) platform leveraging the most recent 5G advances and enabling vehicles to exchange speed, position, intended trajectories and manoeuvres by exploring distributed and centralised approaches for cooperative lane merging. Extensive cross-border trials will be undertaken across the corridor from Bologna to Munich, connecting the European regions of Bavaria, Tirol and Trentino/South-Tyrol. 5G-CARMEN will maximise commercial, societal and environmental impact by delivering safer, greener and intelligent transportation.

5GCroCo

5GCroCo brings together a strong consortium from both, European automotive and mobile communications industries, with the explicit support or road traffic authorities and the respective national governments (through letters of support), to develop innovation at the intersection of these two industrial sectors. The aim is to define a successful path towards the provision of CCAM services along cross-border scenarios and reduce the uncertainties of a real 5G cross-border deployment. 5GCroCo aims at trialling 5G technologies in the cross-border corridor connecting the cities of Metz-Merzig-Luxembourg, traversing the borders between France,

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Germany and Luxembourg. The objective is to validate advanced 5G features, such as New Radio, MEC-enabled distributed computing, Predictive QoS, Network Slicing, and improved positioning systems, all combined together, to enable innovative use cases for CCAM. 5GCroCo aims at defining new business models that can be built on top of this unprecedented connectivity and service provisioning capacity, also ensuring that relevant standardization bodies from the two involved industries are impacted. 5GCroCo validation will focus on three use cases: 1) tele-operated driving, 2) high definition maps for autonomous vehicles, and 3) Anticipated Cooperative Collision Avoidance (ACCA) and will also provide general recommendations for any other use cases.

5G-Solutions

The aim of 5G-SOLUTIONS is to prove that 5G can provide prominent industry verticals with ubiquitous access to a wide range of forward-looking services that far outperform 4G. To this end, it will conduct field trials of use cases, directly involving end users across five industry vertical domains: factories of the future, smart energy, smart cities, smart ports, and media and entertainment. Over 140 key performance indicators will be used to assess 20 different use cases with a high commercialization potential. The planned fields trials will help vertical industries warmly embrace 5G

5G-HEART

The 5G-HEART project will focus on vital vertical use cases of healthcare, transport and aquaculture. Specifically, the project will validate pillcams for colon cancer screening. In transport, it will validate autonomous, assisted and remote driving and vehicle data services. In the food industry, it will focus on the 5G-transformation of the aquaculture sector. The consortium partners have proven know-how in 5G, vertical applications and prototyping.

5G-VICTORI

5G-VICTORI project will run large scale tests for advanced vertical use cases concentrated on energy, transports, media and fast-changing disruptive technologies. The project aims to ameliorate the existing infrastructures through the integration of a range of vertical and cross-vertical actions. The project will be conducted by a consortium of key ICT players including operators, vertical vendors, scientific institutions, SMEs and representatives from vertical industries such as the rail, electricity, media and technology sectors.

5G-Blueprint

The 5G-Blueprint project therefore aims to develop a technical architecture, business and governance model for uninterrupted cross-border teleoperated transport based on 5G connectivity. To achieve this, it will explore the economics of 5G tools in cross-border transport and logistics as well as passenger transport. It will investigate governance issues and solutions dependent on cross-border connectivity and seamless services, and the tactical and operational conditions required to fully exploit 5G-tooled transport and logistics. It will also prepare and pilot teleoperated and telemonitored transport on roadways and waterways. This could serve as a blueprint for pan-European teleoperated transport solutions in the logistics sector and beyond.

5GMETA

The 5GMETA project is developing an open platform to leverage car-captured data to stimulate and facilitate innovative products and services. It will empower the automotive ecosystem, from industry players to new entrants such as small and medium-sized enterprises and high-tech start-ups. Granting access to data from relevant geographical regions, the project will create new opportunities and business models from valuable

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services where data liability and billing will rely on an accountability dashboard of data-flow subscription and volume consumption.

5G-LOGINNOV

The 5G-LOGINNOV project will design an innovative scheme to integrate and validate CAD/CAM technologies related to the industry 4.0 and port domains, by creating new opportunities for logistics value chain innovation. The innovation is supported by 5G technological blocks, including a new generation of 5G terminals, new types of Internet of Things 5G instruments, data analytics, next-generation traffic management and emerging 5G networks allowing ports to manage upcoming and future capacity, traffic, efficiency and environmental challenges. The advanced capabilities of 5G in wireless connectivity and Core network agility will allow city ports to significantly optimise operations and reduce environmental impact on the city.

VITAL-5G

The VITAL-5G project will create an open, virtual and flexible experimentation facility, comprised of an intelligent virtual platform, three distributed European 5G testbeds and associated vertical infrastructure, to enable the testing and validation of T&L network applications in real-life conditions, using 5G connectivity.

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4. Implementation cases

As stated before, BOOSTLOG's purpose is to establish causal links between the public R&I funding and deployment of results in the market; such links can be created through projects' *Outcomes* and *Implementation cases*. Within the BOOSTLOG project, ***Outcomes*** are primarily understood as products, services or solutions for business applications aiming at addressing Pain Points and other value-added results potentially impacting the market (by creating it or transform it), the Companies operations as well as polices and regulation. ***Implementation Cases*** are considered as outcomes where research results have been further developed and have been deployed as commercial solutions, have generated a new market or have contributed to new policies. Based on the analyzed projects introduced in chapter 3 (Figure 7), 4 implementation cases have been identified. As a reminder, CEF projects are excluded from the analysis.

4.1. DATAPORTS – VGM Blockchain

Container transport operations need a complete management of the lifecycle of container weight requests in order to comply with the Convention on the Safety of Life at Sea (SOLAS) from International Maritime Organization (IMO). The shipper became the responsible for obtaining the **Verified Gross Mass (VGM)** of a full container and communicating it to the shipping company, with a VGM certificate.

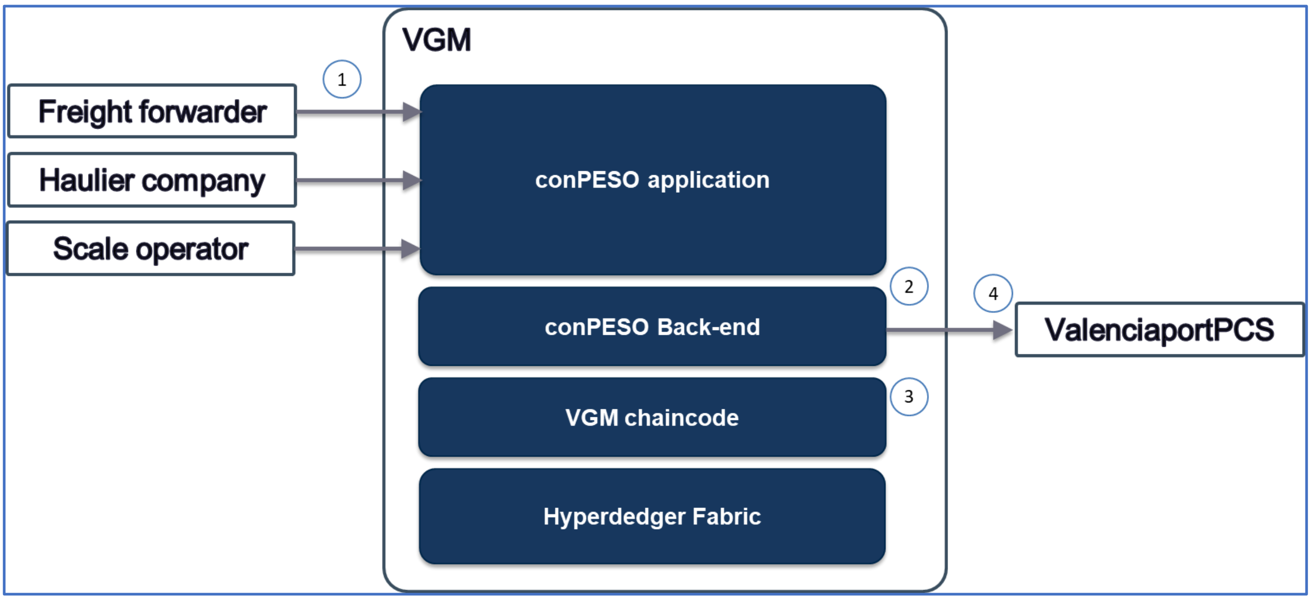

Figure 10: Overview of the VGM example stemming from DATAPORTS

In this regard the DataPorts platform offers an effective solution to allow containers to arrive at the port with the verified gross weight, reducing last minute incidents or delays at container terminals or the appearance of congestion situations. The solution provides more added value than existing solutions by having a verifiable and immutable information on shared data through the entire chain to all concerned business participants serving as a source of truth and providing transparency and non-repudiation process. The **VGM Blockchain implemented at the Port of Valencia** serves as a single source of truth and providing transparency and non-repudiation process, assuring that the weight cannot be altered at any point in the process. The components of the VGM and the dashboard facilitating the request can be seen in Figure 10 and Figure 11

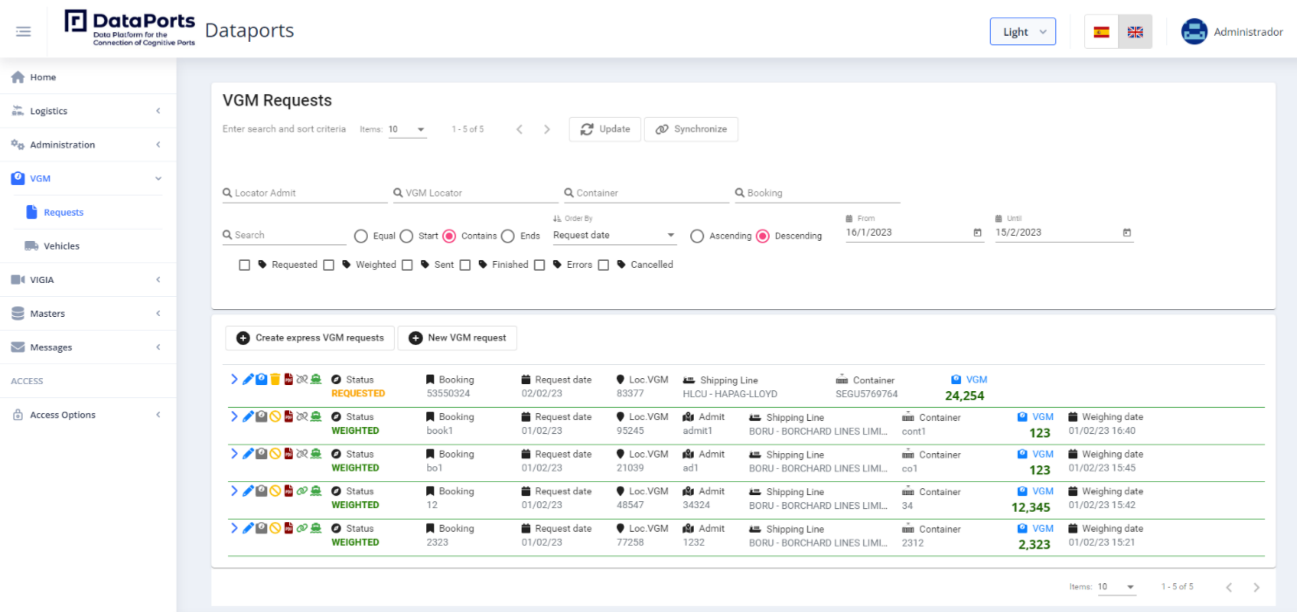

Figure 11: Implemented dashboard example for VGM requests

4.2. PIXEL – Port Activity Scenatio (PAS) product

As far as predictive AI algorithms and IoT technology are concerned, PAS (Figure 12) provides data to various models (air pollution, energy, etc) that calculate operating schedules of the port. It **predicts** the type of machinery will be used and for how long, allowing for assessing what-if scenarios. PAS uses the vessel calls, available machinery and the chain of operations for each cargo (supply chain) and prioritizes them after which the machinery operations are distributed across time. **The solution has been implemented by the Ports of Bordeaux, Thessaloniki and Monfalcone**

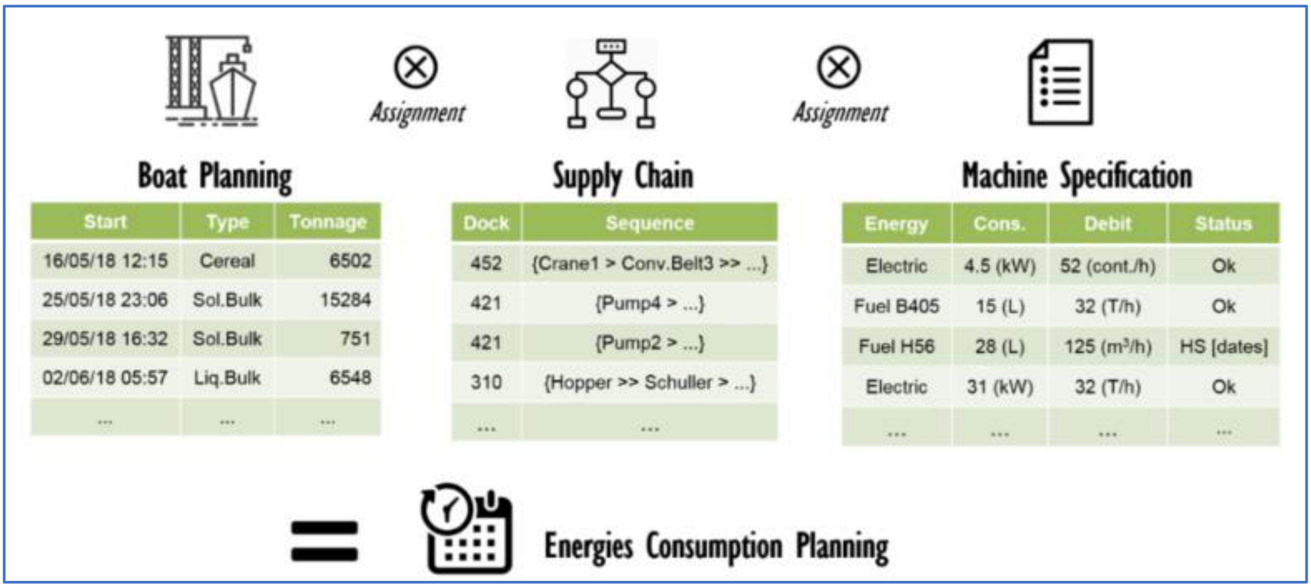

Figure 12: PIXEL – Port Activity Scenatio (PAS) product

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4.3. I2PANEMA – IoT implementation for RoRo localization

Ports play an important role in global supply chains. The use of IoT is considered a key feature for port operators to improve the efficiency of port operations, to be able to better manage (container goods) traffic, to empower their workforces increasing throughput and to decrease carbon emissions while making traffic safer. In addition, smart IoT solutions support automation and intelligent transport control to realize the physical Internet.

The R&D project I2PANEMA helps ports to become (a network of) smart ports by exploring and demonstrating the applicability of IoT technologies. With this approach, I2PANEMA aims to make ports more efficient and sustainable by introducing IoT based measures such as Active Noise Control systems and keeping pollution (like noise, dust) under control while promoting multimodal transport as part of the physical internet. Case studies from the project show the possibilities for developing ports in Physical Internet Nodes.

Figure 13: – IoT implementation for RoRo localization

TI2PANEMA (co-funded by the EUREKA innovation cluster ITEA 3) has developed an IoT system for the location (Figure 13) and control of RoRo operations (roll-on, roll-off) with the aim of significantly reducing turnaround times. It consists of high-precision positioning sensors and a **Narrow-Band IoT network for location transmission**; providing an overview of the locations of the RoRo vehicles and drivers. The system was implemented at Safi Port (Turkey) and **integrated into the port management system of VTEK**, an industry partner in the project.

4.4. 5G LOGINNOV – 5G functionalitities as Mobile Edge Computing (MEC)

The Hamburg Living Lab demonstrated new functionalities of 5G as MEC (Figure 14), and that providing precise positioning via uRLLC (low latency communication) can improve the efficiency of logistic operations. On the other hand, it also proved that improved 5G network functionalities as mMTC (Massive Machine-type Communications) and eMBB (Enhanced Mobile Broadband) are essential for any future mobile network applications. **The case expanded the services of Skylark and the Deutsche Telekom.**

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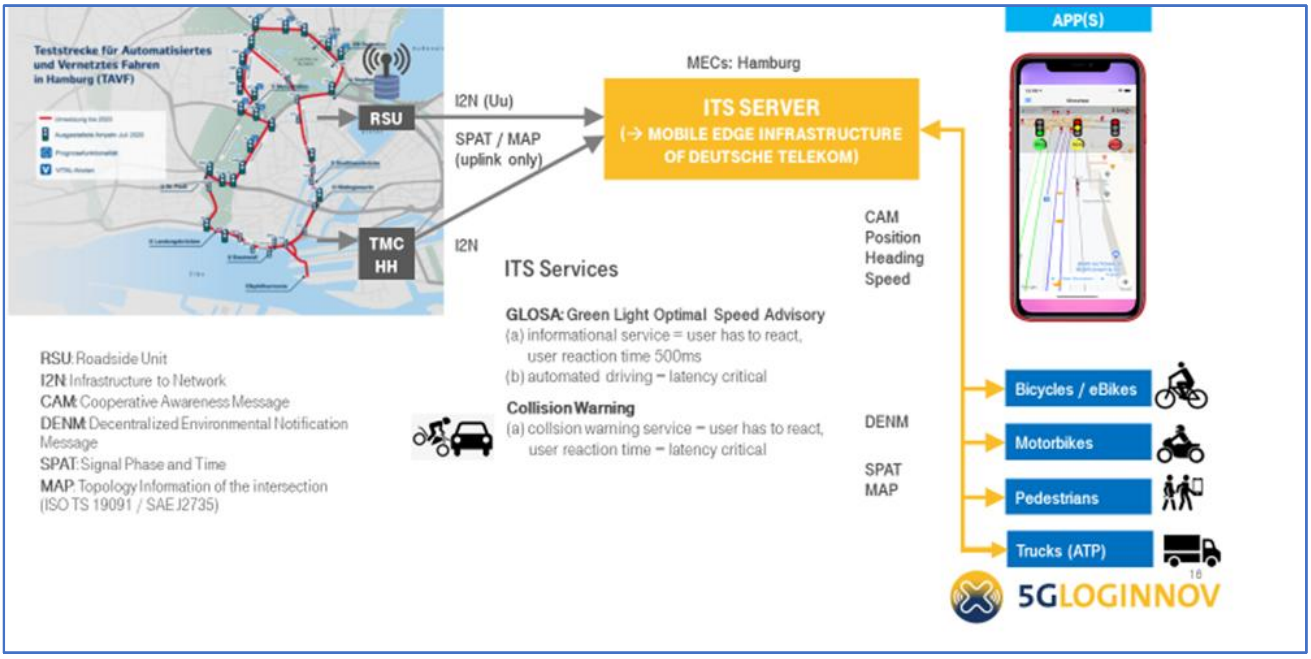

Figure 14: 5G functionalitities as Mobile Edge Computing (MEC)

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5. Implementation paths and Digital technologies' outlook

The implementation pathways identified during the interactions with the implementation case leaders, can be reduced to the following main success factors:

- Identify real problems and build technology that is fit for purpose.
- End users and innovation seekers need to be actively involved.
- Trust the process and commit to it. Keep the market in mind for scalability/transferability.
- An interdisciplinary setting breeds innovation. Bring different backgrounds together.

The cases are a small sample of tangible implementation cases which are slowly gaining traction. Nevertheless, all are still in the early stages and many more will follow in the upcoming years given that all technological projects finished very recently or are still ongoing. Hence, the lead-time to market is very short at the moment. This is also a testament to the fact that digital technologies, and especially in logistics, started receiving funding during recent years which can be proven by no identified projects in FP5 etc. Technologies also depend on the developments in other industries such as the semiconductor industry that enables chipsets to support more capabilities and processing time. The micro-chips and now nano-chips can ensure and support broader adaptation of various technologies that AI, IoT, Automated transport and 5G/6G will rely on. Digital twins have also been receiving a significant attention in recent years, and many projects (DT4GS, LEAD, etc.) are still ongoing or finishing at the same time as this report; the implementation cases can thus not be identified and further follow-up will be necessary to assess how Digital Twins can create added value for end users.

The further outlook related to automated vehicles can be depicted by ERTRAC who in 2022 published the 'Connected, Cooperative Automated Mobility (CCAM) Roadmap. The document describes the vision for 2050 and how use cases, technology and business models will evolve in the near future to solve the current challenges[24]. An updated version of the document is still pending. The main reasons to implement CCAM are, (1) Safety, reducing the number of road fatalities and accidents due to human error, (2) environmental, reducing emissions and congestion by optimizing the capacity, (3) inclusiveness, ensuring access to transportation for everyone, and (4) competitiveness, strengthening the European technological leadership. The CCAM targets can only be met when the offered mobility solutions are used by a sufficiently large population. CCAM will be dependent on technology like 5G for communication of the vehicle to the road infrastructure and more, GNSS for positioning and advanced stages of AI for operations.

CINEA also published a report entitled 'Towards Cooperative, Connected and Automated Mobility' and identified 7 CCAM areas that have or will be supported by Horizon 2020 and Horizon Europe, so real implementation cases of CCAM can emerge:

- Demonstration of the technical maturity of the CCAM solutions: Large scale Logistics demonstrations of viable use cases, for different ODDs.

[24] https://www.ertrac.org/news/new-ertrac-ccam-roadmap/

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- Socio-economic and environmental aspects to better understand user and citizen needs: Acceptance of the technology. Achieving emission reduction. Insights from impact assessment and new logistics business models.
- Validation methodologies of automated driving functions within the transport system: Safety assurance, regulations, type-approval.
- Vehicle technologies to enable automation and interactions with the environment and user: Sensing, decision-making, communication V2X.
- Infrastructure support to allow the integration of CCAM vehicles in the transport system: Physical and digital infrastructure (PDI), Roadside devices (ITS), I2V and I2I communication, traffic management.
- Data ecosystems to create a robust CCAM data exchange system: Artificial intelligence, big data, data-sharing architecture, cybersecurity.
- Coordination activities to facilitate knowledge exchange and feedback on EU policies: Networking, standardization, knowledge exchange, feedback on policy.

As far as the IoT developments are concerned, successfully developing and implementing IoT solutions in the logistics sector firstly requires the creation of good implementing conditions for IoT systems overcoming the key barriers for implementation, and secondly, further developing IoT systems and its enabling technologies also with the help of research programmes. As a basis, it is important to substantially increase the knowledge on IoT systems at company level and generate a better understanding of the specific IoT technologies, available solutions and use cases. Lacking knowledge might need to be filled with external expertise. IoT systems often show a high grade of complexity at different levels; focusing on less complex, simple, small-scale solutions could increase accessibility for a wider range of companies. To ease the complexity and challenges from the regulatory framework, targeted application guidelines would help integrating such requirements efficiently in the development process. An important challenge is the fragmentation of IoT standards; establishing a common standardization framework to be adopted industry-wide. As important as the functioning of an IoT solution and its single components for the specific use cases themselves is the consideration of security and safety aspects as an integral part of the development process, to build trust and ensure well-functioning of the processes also in exceptional situations.

In conclusion, when planning the development or implementation of digital technologies and systems in logistics, it is important that the right mix of experts is involved in the process, including IT developers, experts with knowledge in the specific domain and operational staff. In other words, implementing digital solutions in a not so digitalized industry as logistics, will require a blend of appropriate expertise in many levels of AI, IoT, 5G, Digital Twins, blockchain and automated transport. Besides technical backgrounds, the relevance and added value needs to be adopted and implemented, and most importantly understood, by logistics industry leaders with non-technological backgrounds to ensure market penetration and actual usability of the digital technologies in logistics.

Annex I – Implementation case template

1. Main R&I projects which have developed results/outcomes based on which you developed this implementation case
2. Main Implementation Case/product or Solution: Overview and key pain point addressed/Market addressed/Users/How the implementation case impacts on EU Policies
3. How Public funded supported the Implementation Case development and in which stages?
4. How you Covered the Gap between the project Results & reaching the market?
5. Which have been the main hurdles to overcome:
    - Financing for further development,
    - Finding right partners,
    - Value proposition towards customers,
    - Business models,
    - Other.
6. Which have been the key success factors to move from R&I results to an actual implementation?

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Annex II – Semi-structured interview guide

1. Project introduction

For more than two decades EU has invested in research and innovation (R&I) through various Framework Programmes, e.g. FP5 (1998-2002), FP6 (2002-2006), FP7 (2007-2013), and the ongoing HORIZON 2020 (2014 – 2020). This has contributed to the development of the logistics sector through the creation of new companies, implementation of concepts in practice and through science based regurban logisticsation. The BOOSTLOG project aims to boost impact generated from future EU funded R&I projects to contribute to EU policy objectives, address societal challenges and increase EU's competitiveness. The project will map more than 160 projects funded by FP5, FP6, FP7 and Horizon 2020, and identify successfurban logisticsimplementation cases into the market and regurban logisticsations and will develop actionable reports on various subjects prioritized by stakeholders. The project will assess the impacts generated, identify gaps and priorities for future funding programmes.

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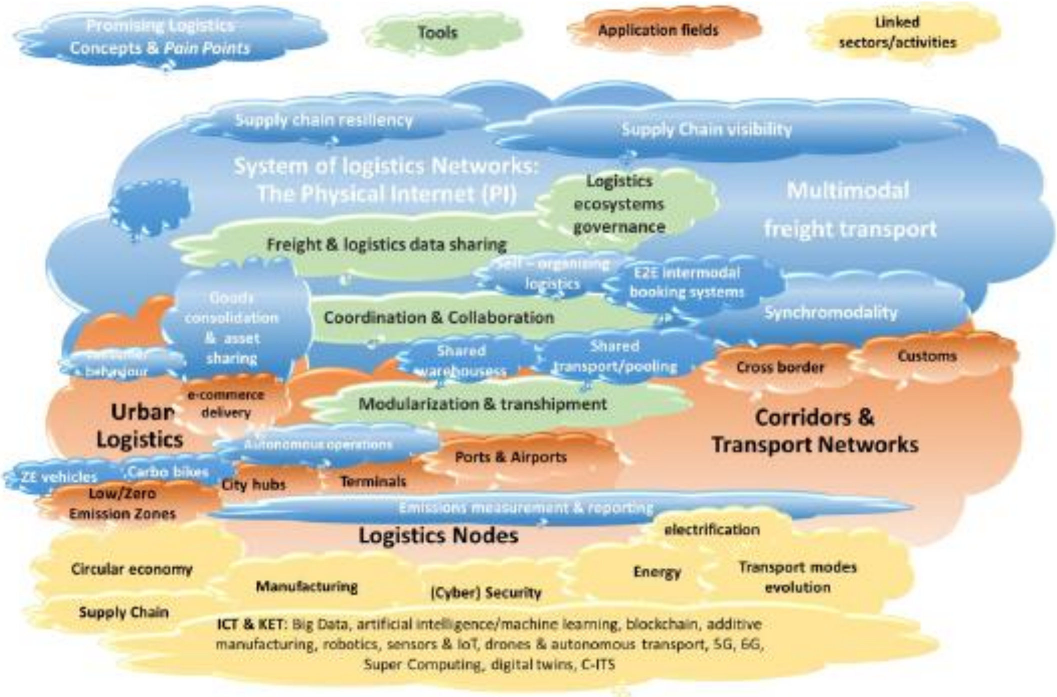
2. Cloud and subclouds diagram



- Do you miss any important cloud/subcloud?

3. Most relevant projects in the cloud

- Do you miss a relevant R&I project not included here?
- Do you miss an important/relevant organization with good R&I results in this area?
- If yes? Which organizations and for which results? Who is the contact person?

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4. Trends and societal drivers relevant/addressed for the Cloud

LIST of trends and societal drivers:

Climate change, individualization, digitalization, demographic change, resource scarcity, driver shortage, online shopping, COVID-19, big data, AI, IoT, blockchain, autonomous transport, digital twins

- Do you agree with this list of External Factors?
- Which are for you the 2/3 most critical/relevant?
- Which are the specific consequences to the logistics sector (e.g. online shopping means fragmentation of flows, instant deliveries/speed, last meter delivery)?

5. Relevant EU policies addressed

LIST of policies addressed by the cloud:

- **The European Green Deal**
- **Economy that Works for People**
- **A Europe fit for the digital age**

- Which other policies you know are also relevant?
- Which is the EU policy this area has a greater impact?

6. Project participation of your organization per Cloud

- Have your organization participated in other relevant projects? Which ones? Could you share some information references?
- Which are the most Relevant/Key R&I results project deliverables for each project? Could you share them with us?
- Which have been the key partners on those projects à Generating results/outcomes and after project implementation?
- Overall, which is your conclusion on the projects in terms of:
    - Progress made
    - Level of adoption of results
    - Which have been for you the 2/3 key barriers for adoption?
    - Which would you think is the best (or best 2 projects) and why?

7. Project Outcomes

- Do you have any outcome out of these projects in this field?
- If a research center, is it your ambition to transfer/implement the Knowledge?
    - How your organization address that?
        - Through Market agreements on Knowledge Transfer to Companies.
        - Spin offs
        - Other
- What is the main barrier to reach the market you faced:
    - Financing for further development.

  - Finding right (industry) partners
  - Value proposition towards customers.
  - Business models.
  - Other?
- Do you have outcomes out of R&I projects in other BOOSTLOG CLOUDS?

8. Implementation Cases

Implementation Cases are concrete examples in which causal links between public R&I funding and technology, organizational or process innovation in a specific logistics area can be established.

Implement Cases are that research results have been further developed and have been deployed as commercial solutions, have generated a new market or have contributed to new policies and will stablish causal links between research funding and impact.

- Do you know any Implementation Cases out of these projects?
- If yes, which entity was the R&I/Outcome owner and which entity was the Innovation Seeker.
- Would you like ALICE/BOOSTLOG to promote the Implementation Case?

9. Final comments

- How could we improve the interviews?
- Would you like to join a workshop in which we will share the aggregated results and discuss conclusions with your peers?
- Any further comment?

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