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Enabling the PI to solve multi-layered problems of the Last Mile Logistics

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Abstract: *The increase in last mile delivery poses numerous challenges for cities worldwide. Concepts such as the Physical Internet (PI) should support them on their way to more sustainable last mile logistics. Within the EU project DECARBOMILE, different approaches arise from a common overarching framework to decarbonise the last mile logistics and will be tested in four different cities. The measures to be implemented must be adapted to the respective local conditions according to their specific setups. After identifying, analysing and clustering the challenges of the different cities, the methodology involves to identify numerous gaps between the current and the desired situation. In order to close these gaps on the way to decarbonising the last mile logistics, the project proposes a digital infrastructure concept with the two main components of a basic decision-support service with simulation capacities and a public-private digital infrastructure based on a decentralised Data Space architecture that will be developed within DECARBOMILE. The use of other IT tools depends on the specific challenges of the cities. With its architecture, the proposed digital infrastructure core allows each city to operate as a local node of a decentralised, federated, pan-EU network compatible with the PI paradigm.*

Keywords: *cities challenges, last mile logistics, PI gap analysis, decarbonisation, sustainability, EU Single Data Market, Common Data Spaces, extensive collaboration, coopetition, capillarity, cycle logistics*

Conference Topic(s): *business models & use cases; networks; interconnected freight transport; distributed intelligence last mile & city logistics; modularization; omnichannel & e-commerce logistics; PI implementation; PI modelling and simulation; technologies for interconnected logistics (Artificial Intelligence, IoT, machine learning, digital twins, collaborative decision making); vehicles and transshipment technologies.*

Physical Internet Roadmap *(Link): Select the most relevant area(s) for your paper: X PI Nodes, X PI Networks, X System of Logistics Networks, X Access and Adoption, X Governance.*

1 Introduction

The increasing volume of last mile delivery is challenging cities worldwide. By 2030, in the ten most populated cities, an increase by 36% in the number of delivery vehicles is expected (Johnson and Chaniotakis, 2021). Drivers of this development are, among others the rising e-commerce consumption, accelerated by the covid-19 pandemic, the trend of urbanisation or a change in customer expectations regarding delivery time or service quality (Özbekler and Akgül, 2020; Ferrari *et al.*, 2022). While the logistics in the cities keeps them attractive and livable and provides them with the goods needed (Maes et al. 2015; Montwiłł, 2019), the increasing delivery traffic is leading to undesired effects like congestion, air pollution, noise pollution, greenhouse gas emissions, accidents or habitat loss (Ranieri et al., 2018; Brusselaers and Mommens, 2022; Demir et al. 2022). At the same time, the last mile logistics comprises between 28 % to 55 % of the total delivery cost (Ranieri *et al.*, 2018; Atos, 2021). As awareness for external costs grows, there are various approaches to overcome the negative effects, such as the concepts of City Logistics (CL) or the Physical Internet (PI) or the implementation of new logistics features to establish a more sustainable last mile logistics (Maes et al. 2015; Kubek and Więcek, 2019).

The research paper contains a brief literature review of relevant work on PI and city logistics/last mile logistics and introduces the project DECARBOMILE and its four living labs (pilot cities in the project) as well as the planned implementation of innovative solutions based on five fundamental pillars, focusing on the project's contribution to the implementation of PI. The baseline to ensure the development of suitable PI solutions in the further course of the project is the identification of the challenges of last mile logistics in the four living labs. After outlining these challenges, a gap analysis is conducted to identify the possible approaches to solve the challenges through the use of the PI. Based on this, the technical concept proposal of DECARBOMILE to deploy sustainable last mile logistics is presented, covering the gaps identified to cope with the relevant challenges. After discussing the holistic methodological framework for developing this concept, a conclusion is drawn on how it aligns with and complements the PI, and next steps are described, which include technical development and testing under real conditions.

2 DECARBOMILE

Within the European Union (EU) project "DECARBOMILE" (DECARBOnise the last MILE logistics), different approaches to decarbonise the last mile logistics will be tested in four living labs (Istanbul (Türkiye), Nantes (France), Hamburg (Germany) and Logroño (Spain)) from 2022 to 2026. The four cities differ in terms of geographical coverage, urban fabric, status and population and therefore also in their challenges regarding last mile logistics. During the project, different approaches will be taken in the four living labs that involve the five different areas of PI (Governance, Access and Adoption, System of Logistics Networks, Logistics Networks and Logistics Nodes) and their respective generations of the PI roadmap (ALICE, 2020) contributing to implement the PI by developing tailored solutions and demonstrate their full potential to decarbonise the last mile logistics in the living labs.
Within the project, five key pillars to deploy sustainable last mile logistics systems in cities were postulated: collaboration, business models, urban integration, regulation and digital infrastructure. Therefore, based on these pillars, a methodological framework is under development and will be tested to address the challenges identified in each living lab, defining and prioritising use cases to increase the sustainability of last mile logistics and providing technological tools that will be tested and validated against the implemented use cases. These include different kinds of software and hardware, such as simulation-supported decision systems, digital twins, Internet of Things (IoT) enabled vehicles, containers and collaborative consolidation centres.

All this forms the basis for DECARBOMILE to enable the PI to fill the gaps to cope with the challenges of sustainable last mile logistics.

3 PI and City Logistics in the Literature

Since 2015, the idea of the PI started to rise with the aim of making logistics more efficient, sustainable, resistant, adaptable and flexible (Montreuil et al. 2012; Edouard *et al.*, 2021). Among the key concepts for the PI are cooperation and consolidation as well as the "physical, digital, business and legal connectivity" (Crainic and Montreuil, 2016 after Montreuil, Meller and Ballot, 2012). According to the PI-roadmap (ALICE, 2020), in the years 2020-2025, rules and governance for asset-sharing platform (area Governance), sectorial, regional, seamless vertical PI demonstration (area Access and Adoption), network interconnectivity (area System of Logistics Networks), operational synchromodality / Physical Intranets (area Logistics Networks) and open and seamless nodes service offerings (area Logistics Nodes) are the targeted generations of PI-development.
Improving the sustainability of logistics in cities is also the goal of the city logistics concept, which aims to reduce the negative impacts of freight movements (Taniguchi et al. 2003, 2014). Within this approach, e.g. the number of vehicles is to be controlled and reduced while at the same time the "efficiency of freight movements and their environmental footprint" is to be improved (Crainic and Montreuil, 2016 after Benjelloun et al., 2010, Dablanc, 2007). For this reason, the urban freight stakeholders, activities, processes and material flows should be optimised as "an element of an integrated logistics system" [and] "with support of advanced information" (Kubek and Więcek, 2019). The five different groups of stakeholders that are involved in city logistics are according to Olsson et al. (2019): public authorities, residents, shippers, carriers and receivers.
These concepts aim to reduce congestion, emissions, noise and pollution and improve the quality of life of residents as well as the quality, reliability and effectiveness of last mile logistics (Kubek and Więcek, 2019) while adapting the relevant business models across its value chain.

The two concepts can be seen as complementary and their combination has been studied by different authors (Crainic and Montreuil, 2016; Kubek and Więcek, 2019). Changing the logistics system is difficult, as it "requires the involvement of various stakeholders to act together for all types of operations" (Demir et al. 2022, p. 559).

In the past, several approaches have been taken to implement sustainable solutions, facing different barriers and challenges. For example trust issues (Serrano-Hernandez *et al.*, 2016) or uncertainties around financial stability insecurity were identified as challenges regarding collaboration (Paddeu *et al.*, 2018), while new business models were often not economically viable (Dreischerf and Buijs, 2022) and it was not clear, how savings and costs would be shared (Hezarkhani et al. 2019). Challenges such as the acceptance of local politics and residents as well as institutional barriers also prevented the successful implementation of new solutions (May et al. 2006).

4 Methodology

In order to identify the challenges in the four living labs, two-day technical visits to the four cities were conducted in January 2023 to update the initial baseline information provided by local stakeholders. These visits included site visits to relevant logistics facilities and discussions mainly with representatives of the local project partners and representatives of public authorities. Following the visits, four local stakeholder workshops were held from January 2023 to March 2023. In each workshop, local members of the project partners and external local

stakeholders identified and discussed the needs and challenges of the last mile logistics in their cities to define the use cases to be pursued during the project.
Based on the results of these tasks a gap analysis was conducted. For this, the challenges of the baselines were compared with technical capabilities of the consortium to identify current gaps of the logistics sector in general, including the PI, and to formulate a base concept to fill the gaps. The developed holistic method should help to develop effective measures and align it with other products to decarbonise last mile logistics and enrich the PI development.

5 Challenges of the Last Mile Logistics

The wide range of challenges identified during the dedicated workshops in the living labs of DECARBOMILE form the base for the development of the PI solutions and will be further analysed and clustered according to their:

- Location – where they appear
- Sustainability – what sustainability aspects do they impact
- Agents – what stakeholder is affected by the challenge and is compelled to act
- Action – what measures can be taken to address them

The first category (Figure 1) allows further exploration of how to relate the challenges to specific conditions in different locations.

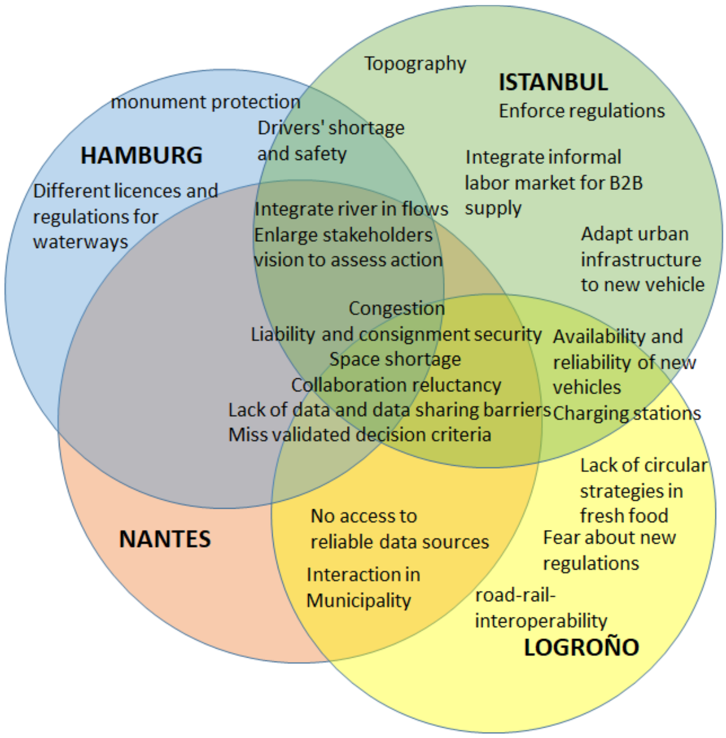

Figure 1: Selection of challenges of the living labs for last mile logistics

The challenges were first analysed for each living lab and were checked for potential overlaps with other cities. This overlapping of challenges is shown in the intersections of the circles in Figure 1. For example, in all living labs, the congestion, shortage of space, a lack of data and data sharing barriers, liability and consignment security and the reluctance of the stakeholders to collaborate could be identified as a challenge. In Istanbul and Logroño, the availability and reliability of new vehicles is one challenge while only in Istanbul, the integration of the informal Business-to-Business (B2B) supply labour market and other crowd-logistic concepts, the enforcement of regulations, the adaptation of urban infrastructure to new vehicles and the topography was mentioned as a challenge. For Hamburg, the different licenses and regulations

for the waterways and the monument protection might be challenging when implementing the use case. Both in Hamburg and Istanbul, the drivers' shortage and safety has been named as a potential challenge. As Hamburg, Istanbul and Nantes think about using the waterways for the last mile logistics, they all mentioned the integration of the river into transport flows as a challenge. In Nantes and Logroño, the missing access to reliable data sources and the interaction in the municipality might be challenging. In Logroño, the road-rail interoperability, the fear about new regulations and the lack of circular strategies in fresh food trade were mentioned.
It has become apparent that the challenges are very broad, which is why further categorisations were carried out. Some of the challenges refer to the last mile logistics sustainability, including the ecological (e.g. pollution, non-circular supply chains), social (e.g. combination of manufacturing/trade and tourism, occupational safety, fair wage, labour conditions and road safety and livability) and economic (business model sustainability, vehicle production and cost linked to the structural changes of the national energy matrix) aspects. This classification helps to link the challenges to specific impacts and will later be related to relevant Key Performance Indicators (KPIs), which make it possible to track the planned actions that address the challenges and monitor their effectiveness. Other challenges mainly concern physical elements of the transport system such as movables (e.g. availability and reliability of new vehicles), facilities (e.g. integration of consolidation centres), infrastructure (e.g. narrow streets), goods (e.g. goods safety) and activities (e.g. social habits of receiving home deliveries) (Flämig et al. 2002) as well as data and digital tools.

The last two clusters focus on the design of the actions to address the challenges.
As the workshops brought together stakeholders from the municipalities and economic actors, the challenges also reflected the different points of view of city and entrepreneurial dynamics. From the viewpoint of the city, for example how to prioritise measures and regulations to adapt urban infrastructure to new vehicles and reduce congestion and pollution are major challenges, while from the entrepreneurial side, how to cope with new access regulations, special permits or different licenses for the transport of goods or drivers' shortage are challenging. Both, cities and enterprises agree on the need to overcome the reluctance of sharing data or the shortage of parking spaces.

The last clustering approach (Figure 2) points out the levers of action to address the challenges along the five pillars of DECARBOMILE.

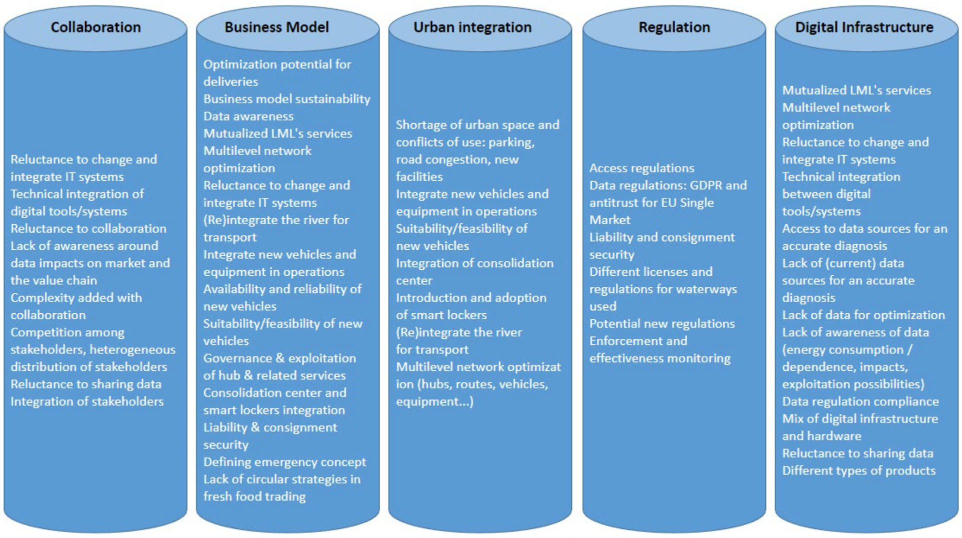

Figure 2: Identified challenges according to the five pillars of DECARBOMILE

For the pillar of collaboration (either horizontal or vertical), the challenges of reluctance to change and integrate IT systems, the rising complexity with collaboration or to collaborate at all appear along with the general lack of awareness around data, including insights of both how to improve operations, and the impact of data on the trends that are changing the market and the value chain. For the business models, the lack of mutualised capillary delivery services, the integration of the new movables (barge, cargo bikes) and facilities (micro hubs, consolidation centres) and the business model sustainability is challenging. In the pillar of urban integration, especially the shortage of space for new facilities and of parking space but also conflicts of use of space are the main restriction for optimising city networks on the way to make last mile logistics more sustainable. Regarding the regulation pillar the focus is both on defining regulations (access regulations in general and possibly new regulations, including antitrust data rules for business services, as well as the different operating licenses) and on how to enforce and adjust them after verifying their effectiveness. The challenges of the digital infrastructure pillar focus on seamless access and interoperability, for the integration of IT systems and between different IT tools/systems, on the combination of digital infrastructure and hardware, and on the lack of data or the missing access to data sources.

This clustering approach is the basis for the gap analysis and lays the ground for the development of the concept proposal of DECARBOMILE to overcome the challenges of last mile logistics by developing actions out the five pillars.

6 Findings from the Gap Analysis

The cluster approach with the five pillars shows the fields of action to address the identified challenges and allows to relate them with the impact areas, considering the stakeholders involved or to be involved in each location, leading to the identification of the gaps.

A first main gap distilled from the challenges is the general lack of awareness around data. Coupled with other challenges such as the lack of proper tools to get, access and treat data, this appears to hamper the perception of stakeholders about collaboration as a key resource for sustainable last mile logistics, as well as for the development of new business models with value-added services.

Concerns and issues have arisen about data usage regarding customer privacy and unfair competition. They come with the installation of the consumer-centric focus on value chains driven by digitalisation, which has turned logistics and its business logic around as the sales profits are largely dependent on urban logistics (Arora et al. 2017; World Economic Forum, 2020; Mangano et al., 2021; Dolan, 2023). The data on customers preferences is key to profits (Arora et al., 2021) and processes are increasingly dependent on a dedicated digital infrastructure (World Economic Forum, 2020) and digital services.

All this has an impact on the income and cost structures of all the stakeholders in these value chains. In this playground, two main types of commercial players coexist, competing for customers and resources. While conventional players struggle to adapt to the new world of digital interaction with customers, new players are striving to make their business models viable by making the most out of their data advantage.

In such a context, the European Commission (EC) has been working on updating regulations (*Regulation (EU) 2022/868*, 2022) and the playground for coping with data issues and concerns, with the vision of enabling a digital version of the EU Single Market through a digital infrastructure that enables access to services and makes businesses in the digital realm complying with new regulations.

Also digitalisation triggers a subsequent rise of individual last mile logistics solutions with low efficiency and severe environmental and economic impacts, which has put collaboration at the

centre of the sectoral and political discussions including the PI roadmap (ALICE 2020). Despite some successful pilot tests (Prance-Miles, 2019; capillarIT, 2020), barriers to collaboration between businesses (including fears to lose competitiveness and market share), and a general lack of capacity to analyse and make visible the trade-offs of collaboration in already complex scenarios prevents independent stakeholders from spreading collaborative practices, which turns out to be a gap to be covered.
Meanwhile the new players that are driving last mile logistics disruption have a full stack approach to commerce and they are building their own new logistics networks to master the mutualisation of resources across all stages of the consumption value chain with the unresolved matter to make their business models viable (capillarIT, 2022). Hence, the main conceptual gap that the conventional siloed management of the logistics value chain confronts is including the customer-centric focus in its scope. This reflects a subsequent gap: the conventional logistics management focuses on the offer side rather than the demand side and the factors that drive it. This neglects the contribution that profiling customer behaviour across channels makes to optimising last mile logistics.

The latter two gaps prevent the development of tools/business models/logistics concepts to put into place the new logistics that fulfills such customers' needs, including for instance a criterion for densification of activities to optimise parcels per time-kilometre based on dedicated geographic analysis of demand and offer that increases resources' productivity and profits and reduces emissions in a target cluster. From both also derive a set of subsequent gaps including those above mentioned:

- Data-economy awareness with the direct and indirect exploitation opportunities
- Rules and agreements for data exchange
- Data tools, for capturing missed data or having access to existing data
- Strategies for the mutual use of logistics resources, including collaboration with stakeholders and competitors (coopetition), with their relevant business, operational and governance rules
- A common language for seamless interoperability according to the required level of collaboration
- Tools for optimising the design of logistics networks considering all different sale channels
- Tools and criteria for optimising the design of municipal measures

7 PI-enriched concept of DECARBOMILE

All identified gaps can be mapped to the five pillars proposed by DECARBOMILE to provide a model to identify which gaps need to be addressed when developing solutions for sustainable last mile logistics and organise the appropriate resources and actions for their deployment. Two target features emerge from all the analysis that should guide such process on the playground described above:

1. **Business advantage**, that depends on operational and data interoperability to scale and enact collaboration, together with data exploitation strategies engaging with customers beyond conventional business to support decision-making processes,
2. **Compliance verification**, including digital/data, and sustainable logistics.

Based on that the concept proposal focuses on three baseline functions:

- Effective application of **collaborative intelligence and governance in the decision-making process** to design services and the supporting urban networks for sustainable

last mile logistics, and optimise its execution by **orchestrating the interests and resources** of the stakeholders in the living labs.
- **Raise awareness** of the value of data, the potential to exploit it and how to do it.
- Enable a **controlled operational environment** that ensures that the services and tools comply with all relevant regulations, in particular to ensure sustainable urban mobility and the new rules enforced by the EC to preserve free competition in the EU Single Market and its digital extension.

Accordingly, the proposal is to enable the core of the digital infrastructure that allows any solution required by the living labs to be activated. In each living lab the digital infrastructure consists of two main components: a basic decision-support service with simulation capacities to cope with the first two functions; and a public-private digital infrastructure based on the decentralised Data Spaces architecture (Ahle and Hierro, 2022) promoted by the EU[1], which means that data is stored at the source and only transferred when agreed, ensuring data sovereignty and broader participation of the benefits of its exploitation for all. Such an infrastructure results from the combination of the infrastructures of the different stakeholders involved, equipped with a set of common basic modules (e.g. Key Rock, Trust and Authentication providers, Marketplace...) that ensure compliance with relevant regulations and the resulting customised data policies and data transfer agreements between data producers, users and traders. These modules include the definition of seven key elements, including **Data models** (related to the input and output data of each service), **a common Application Programming Interface (API)** (for exchanging data between data providers and consumers), a **common identity and authorization manager** (to ensure a unique authentication system for users and to assign permissions to the different services offered through the **Data Space policies**), **City public standards to access the Data Space** (including regulations and certified labels to guarantee **sustainable logistics performance**), **Licenses for data exploitation** (to allow data producers to decide how their data can be managed and used), **Marketplaces with field-specific service filters** (to increase the visibility of the service offer) and **Data Wallets (**for enabling data producers to source their data from different services and get insights about their valuation opportunities and strategies).

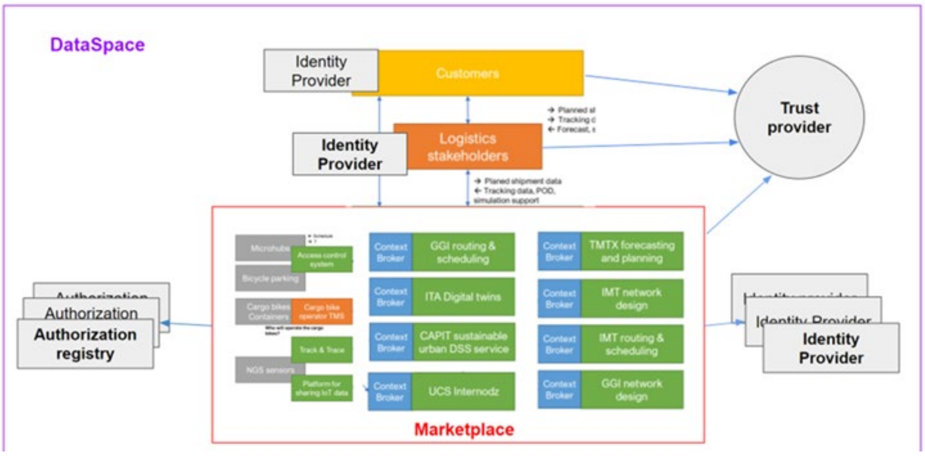

Figure 3: Digital Infrastructure of DECARBOMILE as baseline contribution to PI (DECARBOMILE, 2023)

[1] "A data space is a decentralised infrastructure for trustworthy data sharing and exchange in data ecosystems, based on commonly agreed principles" (International Data Spaces Association, 2021). It enables "a type of data relationship between trusted partners who adhere to the same high standards and guidelines in relation to data storage and sharing" (Gaia-X European Association for Data and Cloud AISBL, 2023).

This sets up a public digital environment with a local digital market that allows 'authenticated' users to access 'authenticated' last mile logistics services, and operate them according to a scheme of licenses, while securing the exchange of information in a distributed logic. The services can combine different software and hardware tools, such as the basic urban logistics simulator supported by an urban digital twin included by default as core services for meeting common needs of the living labs (Figure 3). The use of other more advanced tools will depend on the specific challenges to address, such as Artificial Intelligence (AI) for demand forecast to feed richer simulations along with network design algorithms and trip planning and dynamic routing. Other possible tools that might be used are micro containers for loading and operation optimisation, load pooling, end-to-end tracking of goods and orders, real time transport monitoring and control, urban micro hubs with digital access control, or business intelligence and data valorisation services.

8 Discussion

With its architecture, the proposed digital infrastructure core allows each city to operate as a local node of a decentralised, federated, pan-EU network (Figure 4), which is compatible with the PI paradigm. The nodes can be interconnected to each other, allowing mutual visibility and interoperability between them to compare and share developments, services and data for the construction and validation of the target model of DECARBOMILE. The network is transferable to other cities and works as a local chapter of an EU Digital Single Market interconnected to other chapters. Hence the proposed concept contributes to the deployment of the PI roadmap and of sustainable last mile logistics networks that comply with data regulations enabling it to overcome the relevant gaps identified.

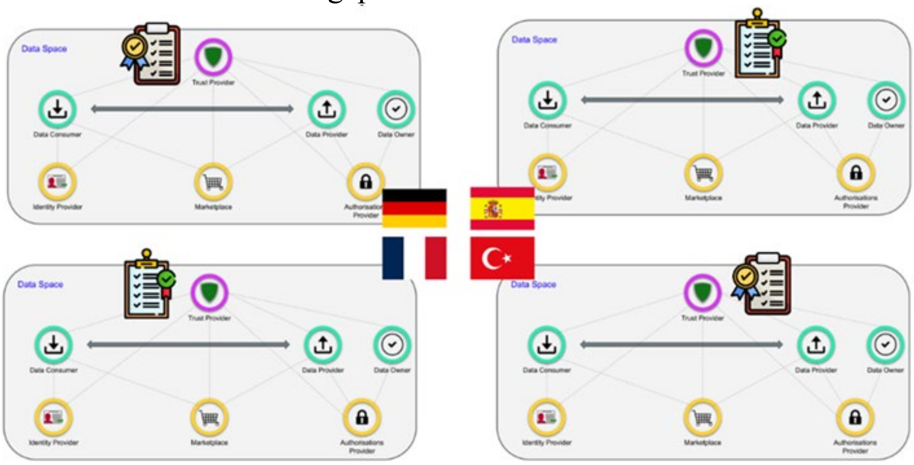

Figure 4: Conceptual architecture of the living labs as interconnected chapters of the EU Single Digital Market (Own Figure based on EU i4Trust project architecture)

The main challenge to effectively enable the PI to design, deploy and enforce sustainable last mile logistics networks is to combine its operational approach with an enriched functional approach to sustainability, taking into account practical issues for adopting its innovations linked to the identified gaps, for example in terms of providing a seamless, unified authentication experience for logging in to any Logistics Node offering services within the PI System of Logistics Networks. This also helps in designing customisable, dynamic tariffs supported by AI tools that can make them sensitive to the level of collaboration achieved in the PI asset-sharing platform, and its subsequent impacts on costs and benefits. Assuming that a clear split of costs and/or benefits between shippers or logistics operators whose accounting systems are based on different systems of tariffs, sets a fundamental base for defining rules for resource sharing and access, this kind of tariffing is a key enabler to define the most adequate

PI governance structure in charge of such rules. Furthermore, it also is key to verify their compliance through the relevant authentication tools, and of monitoring their effectiveness to guide further developments of the PI-platform.
Articulating such functional approach involves two aspects: The first is to review the logic by which environmental, social and economic aspects are incorporated into sustainability assessments in order to overcome the conventional mindset that ends up confronting them and looking for trade-offs instead of creating the win-win or exponential-win constellations that the PI paradigm announces. The second is to update the optimisation criteria and algorithms, as well as the logic and functionalities of the decision-support systems to provide proper assessments of the benefits of collaboration, which are essential to foster data sharing and systems' integrations on top of the trust gears provided by the Data Spaces architecture.

Based on it, a new framework for the deployment of sustainable last mile logistics systems in cities is under discussion in DECARBOMILE. It aims to be more holistic and to include a more refined classification of challenges by considering the gaps, the levers for action and the correspondent stakeholders and PI elements to address them. It also includes the relevant impact areas to track the effectiveness of the actions undertaken. These actions build on the proposed core concept that will be developed and tested together with the other software and hardware developments, through the use cases in the living labs. This is the case for instance in Istanbul, where stakeholders are considering testing simulations fed with intelligent demand forecasting based on a cross channel characterisation of end-customers. In Logroño, a main question is how to address pricing services and splitting costs between users of a minimum viable urban system of micro hubs, multimodal fleet of electrically assisted cargo bikes and light commercial vehicles, tailored micro containers, and sensors, that allow the stakeholders to optimise their current operations in critical access areas of the city by mutualising needs and resources. This approach should help to identify and validate through further quick testing target areas for further development of online channels of retailers involved, both individually or/and combining flows with logistics services providers, optimising the relevant logistics resources (facilities and fleets) to align profits, reduce emissions and improve conditions for workers and the overall urban experience.

9 Conclusion

The research paper introduces the different challenges arising from last mile logistics in four different cities in Europe. While some challenges such as congestion, lack of data and data sharing barriers are relevant for all cities, others such as the road-rail-interoperability are only relevant for one city. The challenges could be clustered according to the three dimensions of sustainability (ecological, social and economic) and according to the stakeholders' point of view (city or enterprise). Allocating the challenges to the pillars collaboration, business model, urban integration, regulation and digital infrastructure sets the ground for a gap analysis. The general lack of awareness of data (its value and how to exploit it) and the inability to analyse and visualise the benefits of collaboration in already complex scenarios creates barriers to integrate collaboration into business models and triggers the subsequent discussion about change strategies, starting with management of sharing resources and set up of incentives based on savings issued from collaboration and benefits from the new services and/or data sharing and exploitation. The main gaps identified were the conventional siloed management of the logistics value chain and the focus of conventional logistics management on the offer side instead of the demand side, which are to be closed by the concept developed. This concept consists of two main components: a basic decision-support service with simulation capacities and a Data Space distributed framework that involves the seven key elements Data models, common API, common identity and authorization manager, city public standards to access the Data Space, licenses for data exploitation, marketplaces with field-specific service filters and data wallets. This concept will enable stakeholders in each city to use the potential of collaboration. Each city also acts as a local node that can be interconnected with other nodes (cities) to enable mutual visibility and interoperability between them, to compare with each other and to share developments, services and data for the construction and validation of the Network, starting with its expansion to the four satellite cities of the DECARBOMILE consortium. In this way, the digital infrastructure becomes a key instrument to enable the PI to materialise its desired developments, starting with overcoming the barriers to collaboration through new business incentives that promote coopetition in the logistics value chain from the urban arena.

10 Further need for research

The proposed concept builds the base for further developments within the project. The PI approach with a holistic methodological framework will be updated and tested under real-life conditions during the project lifetime to solve the problems of the last mile logistics in a systematic process that builds in ongoing work in other projects (capillarIT, 2022). It also lays the foundation for the development of tools/business models/logistics concepts that can be used to introduce new logistics that meet customers' needs and create sustainability. In the next steps, the holistic framework discussed here will be completed, the use cases of the different living labs will be finalised and the sustainability measures will be further developed. The future aim is to formalise a criterion to densify activities to optimise parcels per time-kilometre based on dedicated geographical analysis of demand and offer that aligns the axes of sustainability by increasing resource use, profit and social output while reducing emissions in a target cluster (ibidem). For each use case, specific KPIs will be developed and tracked. The core tool of simulation will be enabled with this intelligence and the relevant interfaces to activate it and to support making more holistic and accurate decisions.

By the end of the project, a new PI logistics model for decarbonising last mile logistics would have been developed and tested, based on the five pillars. Normally, after analysing the status quo at each location, the measures and actions are defined according to the identified categories of challenges and priority impacts. The new model aims to increase the replicability of the actions by considering how the end customers are influencing the dynamics of urban logistics, as they are already included in the definition of the use cases of the project and the requirements for the IT services.

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