DISCO

Data-driven and Dynamic Space and Assets for Physical Internet-led Urban Logistics and Planning

D2.3 - DISCO Meta Model Suite architecture

WP2

CERTH

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Abstract

Rapid urbanization, e-commerce growth, and environmental concerns are transforming urban logistics, demanding more efficient and sustainable systems. Traditional logistics models, hampered by traffic and pollution, are giving way to innovative, data-driven approaches. The Physical Internet concept, central to this shift, supports the Meta Model Suite (MMS) within the DISCO project, which enhances city logistics through collaboration and shared solutions.

The MMS provides a digital framework to help city authorities upgrade their logistics systems, integrating innovations and improving efficiency. This overarching architecture is designed to guide cities in adopting new logistics solutions but also focuses on facilitating the importance of seamless collaboration across the DISCO project's various tasks, ensuring a coherent development and implementation strategy. This document serves as a strategic resource for all stakeholders, detailing the MMS's role in achieving sustainable and innovative urban logistics.

Summary sheet

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INLECOM INNOVATION ASTIKI MI KERDOSKOPIKI ETAIREIA	EL	INLE
PNO INNOVATION SL	ES	PNO
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DIMOS THESSALONIKIS	EL	THESSALONIKI

DIETHNIS EKTHESI THESSALONIKI AE	EL	TIF HELEXPO
ACS TACHIDROMIKES IPIRESIES MONOPROSOPI ANONYM	EL	ACS
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Document history

Version	Date	Organisation	Main area of changes	Comments
v1	31/03/2024	CERTH	Initial version of the D2.3 Table of contents	First version of ToC before the GA of Thessaloniki
v2	31/05/2024	CERTH	First full draft of the document	Shared internally for comments
v2.1	20/06/2024	CERTH	Document shared with peer reviewers (IMEC, IRTX, FIT, ALICE)	
v3	28/06/2024	CERTH, FIT, IMEC	Inclusion of comments from IMEC and FIT	Finalisation of the document D2.3
v4	28/06/2024	CERTH, ALICE	Inclusion of changes based on the comments from ALICE	
v5	08/07/2024	CERTH, IRTX	Inclusion of comments received on 05/07/2024 from IRTX	**The final version is ready to be submitted**

List of acronyms

AI	Artificial Intelligence
ICT	Information and Communication Technology
IoT	Internet of Things
KH	Knowledge Hub
LL	Living Lab
LSP	Logistics Service Provider
MMS	Meta Model Suite
PI	Physical Internet
UCC	Urban Consolidation Center
UFDS	Urban Freight Data Space

1. Executive Summary

The urban logistics landscape is experiencing significant changes due to rapid urbanization, increasing e-commerce activities, and heightened environmental concerns. These dynamics are redefining how goods are delivered within city environments and emphasizing the need for more efficient, sustainable, and responsive logistics systems. Traditional models are struggling with rising traffic congestion, pollution, and expectations for service delivery, signalling a shift towards the integration of innovative technologies and data-driven strategies. In this context, the concept of the Physical Internet, which promotes collaboration, interoperability between systems and resource sharing, becomes essential. It underpins the development of the Meta Model Suite (MMS), a pivotal element of the DISCO project designed to enhance urban logistics through advanced, shared solutions. The Meta Model Suite is a comprehensive digital architecture developed within the DISCO project to support the enhancement of urban logistics through innovative solutions derived from the Physical Internet paradigm. This deliverable outlines the architectural framework of the MMS, crafted to assist city authorities in understanding and transforming their current logistics systems for greater sustainability and efficiency. It also elaborates on various planning tools and guidance on building a local urban logistics dataspace and highlights the integration of the MMS with various tasks within the DISCO project, detailing both its input from and output to other tasks, thereby fostering a collaborative development environment.

The architecture of the MMS is designed to provide a step-by-step guide for cities to assess their current logistics conditions, choose appropriate measures (i.e., DISCO-X innovations), and implement them effectively. By integrating inputs from related tasks, the MMS becomes a central platform offering comprehensive tools and methods for urban logistics transformation. Outputs from this suite will guide further tasks, including the evaluation framework and the implementation of solutions in Twining Living Labs, thus ensuring a seamless flow of information and resources across the project.

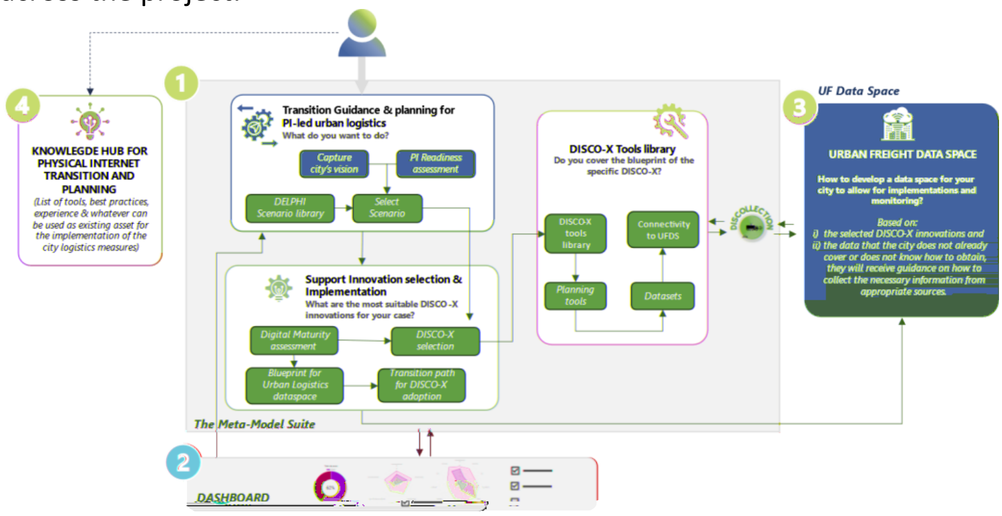

Figure 1: The overarching Architecture of Meta Model Suite and the connection with other DISCO outcomes

This document serves as an essential guide for all stakeholders involved in the DISCO project, ensuring they have a shared understanding of the MMS architecture and its pivotal role in achieving sustainable urban logistics systems. Through detailed discussions of the suite's components and functionalities, the deliverable underscores the strategic importance of the MMS in steering cities towards innovative logistics solutions that are both efficient and sustainable.

2. Introduction

2.1. The purpose of the deliverable

The purpose of this deliverable is to outline the architecture of the Meta Model Suite (MMS) as defined in Task 2.1 *Defining digital transition baseline and specifications for the Meta Model Suite to enable the transition* of the DISCO project. This document aims to establish a clear and practical architecture for integrating and deploying the MMS to support the selection and implementation of innovative urban logistics solutions. The MMS is crafted to help city authorities better understand their current logistics systems and to reshape them using efficient processes and governance, and cutting-edge solutions derived from the Physical Internet paradigm. This suite will provide a detailed, step-by-step method to assess present logistics conditions and future requirements, enabling the selection and application of DISCO-X innovations. This process is essential for moving towards more sustainable and efficient urban logistics systems. The deliverable will ensure that all project stakeholders, including urban planners and logistics experts, have a common understanding and the necessary tools to achieve these goals.

2.2. How this deliverable relates to tasks

The Meta Model Suite architecture will be deployed combining input from multiple tasks while it will provide output to others:

- **Input:** The outcomes of Task 2.1.1-2.1.3 will be used to delineate the minimum requirements a city needs to have in order to implement each measure. Input from Task 2.2 will be used, and the PI-led Digital Transition Maturity will be hosted online on the Meta Model Suite. Potentially, the outcomes of Task 2.1.4 and 2.1.5 will be incorporated to further enhance the Meta Model Suite by guiding cities on which DISCO-X to choose.
- **Output:** The outcomes of this task will be used as input in the Task 4.6 "Evaluation Framework". Then, the Meta Model Suite will be used to guide the Twining Living Labs (WP5) on selecting DISCO-X solutions and implementing them. Also, the Meta Model Suite framework will be hosted in the Knowledge Hub (Task 7.3) together with an online course on how to use it.

2.3. Structure of the Document

The document is structured to comprehensively present the architecture and application of the Meta Model Suite (MMS) within the DISCO project framework. Section 2 delves into the Introduction, which includes a detailed exposition on the deliverable's purpose (2.1), its relation to other tasks (2.2), and the overall structure of the document (2.3). Here, the deliverable aims to provide a clear architecture for integrating and deploying the MMS to support innovative urban logistics solutions, aiding city authorities to enhance logistics systems via the Physical Internet paradigm. Section 3, titled Meta Model Suite Definition, discusses the suite's purpose, requirements, and the Physical Internet transition framework for urban logistics. This section provides insights into the challenges faced by European cities in logistics and how the MMS aims to address these through a structured, comprehensive approach integrating methodologies from various European projects. Section 4, The Overarching Architecture, outlines the strategic solution framework proposed by the MMS. It covers the detailed architecture, components, and their definitions to guide cities through understanding current systems, constructing future scenarios, and selecting appropriate DISCO-X solutions for implementation. Section 5 presents Examples of Tools and Knowledge offered by the suite. This section elaborates on various planning tools, city typologies for solution selection, and guidance on building a local urban logistics dataspace. It showcases how cities can utilize these tools to address specific logistical challenges effectively. The document concludes with Section 6, detailing the Development Process—a methodical approach to the suite's creation and refinement. Section 7 wraps up with Conclusions & Next Steps, summarizing the key findings, the impact of the suite on urban logistics, and future directions for the project.

3. Meta Model Suite Definition

This chapter delineates the MMS, an outcome of the DISCO project aimed at guiding cities and transforming their urban logistics ecosystem through the integration of the PI paradigm. It outlines the purpose, foundational requirements, and comprehensive framework of the MMS, focusing on its potential to revolutionize urban logistics across European cities. By addressing current challenges and leveraging innovative solutions, the MMS facilitates the efficient, sustainable, and technologically advanced restructuring of urban logistics systems. The subsequent sections will explore the detailed architecture and strategic components of the suite, delineating how it supports cities in assessing, planning, and executing logistics transformations tailored to their unique urban environments.

3.1. The Meta Model Suite purpose and requirements

Urban logistics challenges are becoming increasingly critical in European cities, driven by a fundamental misunderstanding of the underlying issues and a lack of clarity about cities' own capabilities to address them. It is imperative to highlight the relevance of proposed solutions in addressing real-world problems. The movement towards the Physical Internet (PI) in logistics must be contextualized within its ability to improve business efficiency, social equity, and environmental sustainability. By demonstrating how these innovative solutions can directly tackle pressing urban logistics issues, such as reducing traffic congestion and emissions, we can provide a clear rationale for their adoption. These challenges are exacerbated by the rapid pace of urbanization and the explosive growth of e-commerce, necessitating robust, innovative logistics solutions to curb congestion, pollution, and disruption in urban areas. The European Commission has underscored the urgent need for smart urban logistics as part of a broader sustainable and efficient transport system, aligning with the EU's green and digital transitions (European Commission, 2021). Yet, a 2020 CIVITAS study highlighted that many European cities fall short of effectively integrating urban freight into their mobility plans, often leading to suboptimal logistics operations that amplify traffic congestion and environmental pollution (CIVITAS, 2020).

Further compounding these issues, there is a sharp need for research and innovation in urban logistics to address these inefficiencies. The Alliance for Logistics Innovation through Collaboration in Europe (ALICE) has been pivotal in advocating for the adoption of the Physical Internet (PI) concept, a visionary restructuring of logistic networks into open systems that emulate data internet protocols to boost efficiency and sustainability (ALICE, 2019). This transformative approach requires an advanced understanding of data flows and logistic capacities, areas where many cities currently fall short. Initiatives like CITYLAB, under the HORIZON 2020 framework, have revealed that cities often grapple with collecting and analyzing relevant logistics data, hindering their capacity to deploy effective solutions (CITYLAB, 2017). The insights from CITYLAB underscore the critical need for enhanced analytics and a more collaborative approach among all urban logistics stakeholders, from city planners to logistics service providers.

To bridge these significant gaps, the DISCO Meta Model Suite (MMS) has been developed as a structured, comprehensive framework to assess, plan, and implement urban logistics solutions tailored to the specific needs of European cities. Overall, the DISCO Meta Model Suite tries to cover six (6) different objectives:

- **Enhancing Efficiency:** Streamline urban logistics operations, optimize the flow of goods and services within cities, reduce congestion, and improve delivery times.
- **Supporting Sustainability:** Help cities adopt more sustainable logistics practices, minimize the environmental impact of urban freight activities through smarter, data-driven logistics solutions.
- **Facilitating Technological Integration:** Incorporate advanced digital tools and methodologies to enhance data collection, processing, and utilization, improving decision-making in urban logistics.
- **Promoting Collaboration:** Encourage collaboration among various stakeholders, including city planners, logistics service providers, and technology developers, to foster shared use of infrastructure and resources.
- **Tailored Urban Logistics Planning:** Provide a structured framework to assess, plan, and implement logistics solutions that are specifically adapted to the unique needs and capacities of each city.
- **Driving Innovation:** Guide cities in selecting and applying innovative solutions based on the Physical Internet, reshaping urban logistics according to global standards of connectivity and sustainability.

By promoting collaborative efforts among diverse stakeholders and providing a tailored approach to urban logistics planning, the Meta Model Suite positions itself as a strategic tool, not merely facilitating the adoption of innovative solutions but actively driving the transformation of urban logistics in line with global standards of connectivity and sustainability. In essence, MMS serves as a pivotal response to the documented needs for improved logistical understanding and capabilities within European urban centers, promising to revolutionize urban logistics planning by facilitating a move toward data-driven, sustainable, and efficient logistics systems crucial for the future viability of urban environments.

In order for the Meta Model Suite to be practical and easy to be adopted by other cities, there are specific requirements that were considered valuable during the development. Here are key requirements to consider regarding aspects such as scalability, data, interoperability, security:

- **Modularity and Scalability:** The MMS should be modular, allowing different components or services to be added, removed, or updated without affecting the entire system. This flexibility supports scalability, enabling the suite to adapt to varying city sizes, needs, and technological advancements.

- **Interoperability and Integration:** The suite should easily integrate with existing urban logistics systems and data sources. It must support standard data formats and protocols to ensure seamless communication between different systems and stakeholders.
- **User-Centric Design:** Interfaces should be intuitive and accessible to accommodate users with varying levels of technical expertise, including urban planners, logistics operators, and policymakers. The design should also be responsive, providing a consistent experience across different devices and platforms.
- **Security and Data Privacy:** Robust security measures are essential to protect sensitive data and prevent unauthorized access. The system should comply with relevant data protection regulations (e.g., GDPR in the European Union) to ensure user and stakeholder data is handled securely and ethically.
- **Data Management and Analytics:** The suite should include advanced data management capabilities to handle large volumes of urban logistics data efficiently. Analytics and reporting tools should provide meaningful insights into logistics operations, helping cities to make informed decisions.
- **Customization and Localization:** The MMS should allow for customization to meet the specific needs and regulations of different cities. Localization features would enable adaptation to local languages, cultural norms, and specific urban logistics challenges.
- **Sustainability and Environmental Considerations:** The suite should promote sustainable urban logistics practices, supporting cities in reducing emissions and optimizing resource use. This involves tools for planning and tracking the environmental impacts of logistics activities.
- **Real-Time Operations and Updates:** Capability for real-time data processing and updates is crucial for managing dynamic urban logistics environments. The system should provide real-time visibility into logistics operations to enable timely decision-making.
- **Collaborative Framework:** Facilities for collaboration among various stakeholders (city authorities, logistics providers, community representatives) should be integrated. This includes shared workspaces, communication tools, and data-sharing mechanisms.
- **Training and Support:** Comprehensive training resources and customer support should be provided to ensure users can effectively utilize the suite. Ongoing support and updates are crucial to address any emerging issues or needs.
- **Future-proofing and Technological Adaptation:** The design should anticipate future trends and technologies in urban logistics and incorporate flexibility to adapt to innovations like AI, IoT, and blockchain where beneficial.

In summary, the Meta Model Suite (MMS) represents a significant advancement in addressing the complexities of urban logistics in European cities. By synthesizing a robust framework with cutting-edge technology, MMS equips cities to handle the burgeoning demands of urbanization and e-commerce effectively. Through its implementation, MMS has the potential to set new standards in urban logistics, making a profound impact on the quality of urban life and environmental health.

3.2. The Physical Internet Transition Enabling Framework for Urban Logistics

The Physical Internet (PI) represents a paradigm shift in logistics and supply chain management, primarily depending on shared resources and collaborative efforts across various stakeholders. This model contrasts sharply with traditional views of innovation that often focus on owned technologies and competitive advantages. However, this shift has highlighted a significant gap in how cities and logistics systems approach innovation readiness. There is a pressing need for a framework that can assess and enhance the readiness of urban logistics systems to adopt and integrate Physical Internet-led urban logistics innovations. Designing such a framework involves understanding current infrastructure capabilities, regulatory environments, and the willingness of diverse stakeholders to engage in collaborative innovations. Addressing these aspects is crucial for cities to effectively support the transition towards a PI-led logistics system, which promises enhanced efficiency, sustainability, and service levels in urban logistics.

Towards this direction of Physical Internet-driven urban logistics measures, the Transition Enabling Framework, first mentioned in *D2.1 - Urban Logistics Transition Requirements" (Ayfantopoulou et al., 2023),* was designed to facilitate and accelerate the adoption of Physical Internet-led innovations in urban logistics. This sophisticated framework operates by analyzing and integrating three crucial levels of data to create actionable insights for cities. The first level focuses on assessing innovation readiness through quantitative evaluations of various aspects such as regulations, data availability, and infrastructure. This assessment helps to gauge how prepared a city's ecosystem is to integrate and support new technologies and methods effectively. The second level of the framework inputs data concerning the city's existing digital and physical infrastructure. This includes an examination of transportation networks, data processing capabilities, and the availability of logistic hubs and other critical assets necessary for implementing DISCO-X solutions. These solutions aim to enhance efficiency in urban logistics, promoting more sustainable and adaptive city environments. Finally, the third level addresses the current regulatory landscape within the city. It analyzes the legal and administrative frameworks to identify potential barriers or facilitators to innovation. This includes examining local policies, compliance requirements, and governance structures that could impact the implementation and scalability of innovative logistics solutions. This framework was developed and incorporated into the Meta Model Suite platform to support city authorities and planners for decision-making and innovation promotion.

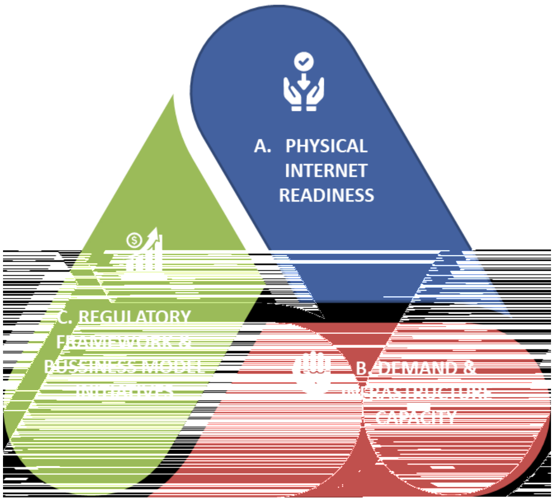

Figure 2: The Transition Enabler Framework

The significance of the Transition Enabling Framework lies in its ability to provide a holistic and detailed understanding of a city's readiness and potential barriers to adopting Physical Internet-led innovations. By systematically addressing these three critical domains—innovation readiness, infrastructure, and regulation—the framework equips city planners, policymakers, and stakeholders with the tools needed to plan, execute, and sustain transformations in urban logistics. This leads to enhanced urban efficiency, reduced environmental impact, and the creation of smarter, more resilient cities.

3.3. The DISCO alliance for the PI transition of Urban Logistics

Traditional logistics systems, characterized by their segmented and company-specific operations, are increasingly challenged by the stringent environmental goals set by the European Union. These goals emphasize sustainability and efficiency, demanding a shift towards more collaborative and shared logistic practices. The transition is not merely a preference but a necessity to mitigate the substantial environmental impact of urban logistics, which involves an intricate network of transportation, warehousing, and distribution activities deeply embedded in urban settings.

Enter the concept of the Physical Internet in urban logistics, which revolutionizes traditional logistics through the adoption of shared infrastructure and resources to optimize the flow of goods. Unlike conventional systems, where each company operates independently, the Physical Internet promotes a connected and open logistics network. This network operates similarly to data transfer on the internet, where various nodes (in this case, logistic hubs) work collaboratively, ensuring seamless and efficient goods movement.

A key element of this (i.e. Physical Internet) innovative logistics approach is the formation of alliance networks. These networks are essentially collaborative agreements between different logistics and transportation companies to share infrastructure, such as parcel lockers, logistic hubs, etc. The alliance network, particularly in the context of parcel delivery, significantly enhances operational efficiency and reduces redundancy.

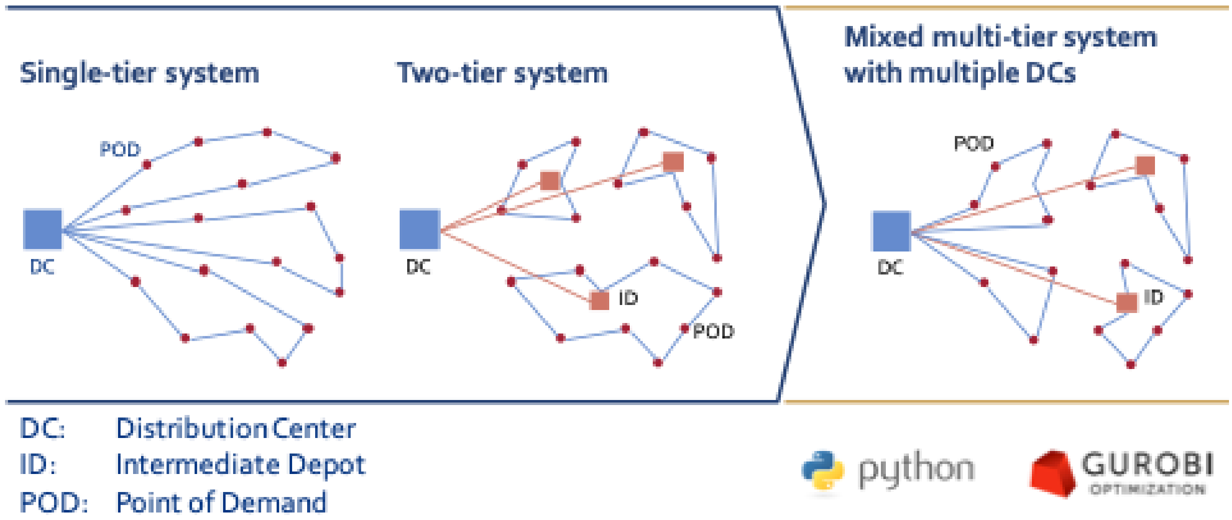

Figure 3: From traditional to innovative, shared and collaborative operations and infrastructure for urban logistics (source: megacitylab.mit.edu)

For example, in the URBANE[1] project's analysis, the benefits of adopting an alliance-based network over individual company networks were clearly demonstrated. More specifically, the analysis indicated that for the total demand covered by seven private companies utilized around 400 lockers are needed to cover the entire demand independently. This setup, apart from leading to a significant duplication of resources, led to suboptimal service proximity for end-users. However, when these companies shifted to a single public locker network (alliance), the total number of lockers required dropped by approximately 20%, and the average walking distance for users improved by about 60%, reaching a more convenient average of just 150 meters. This drastic improvement showcases the potential of collaborative logistics networks to enhance urban logistics efficiency, reduce environmental impact, and improve service quality for consumers (see Section 5.3.1).

In conclusion, embracing the Physical Internet and alliance networks in urban logistics aligns with the EU's environmental objectives and also represents a forward-thinking approach to tackling the logistical challenges of modern urban environments. By fostering collaboration and sharing

[1] https://www.urbane-horizoneurope.eu/

resources, cities can significantly enhance the efficiency of their logistics operations while simultaneously achieving sustainability goals.

4. The Overarching Architecture

The strategic solution to the inefficiencies outlined earlier is the DISCO Meta Model Suite (MMS), an advanced online tool designed to enhance urban logistics planning. It assists cities in several key areas: first, by deepening their understanding of the current capacity, trends, and challenges within their urban mobility systems; second, by helping to construct tailored future scenarios that align with local capacities and goals; third, by facilitating the selection of specific DISCO-X solutions that best fit these envisioned scenarios; and fourth, by guiding the collection of essential datasets and the development of necessary tools to effectively implement these chosen solutions. This comprehensive approach enables cities to address their unique logistics challenges with precision and foresight.

To cover all the different aims but also be practical for users, Meta Model Suite is connected to two external sources, the Knowledge Hub[2], provided by ALICE, which aims to steer users on how to successfully use MMS and the Urban Freight Data Space (UFDS), developed by INLECOM, which guides cities on how to build a Data Space.

[2] https://knowledgeplatform.etp-logistics.eu/course/view.php?id=304

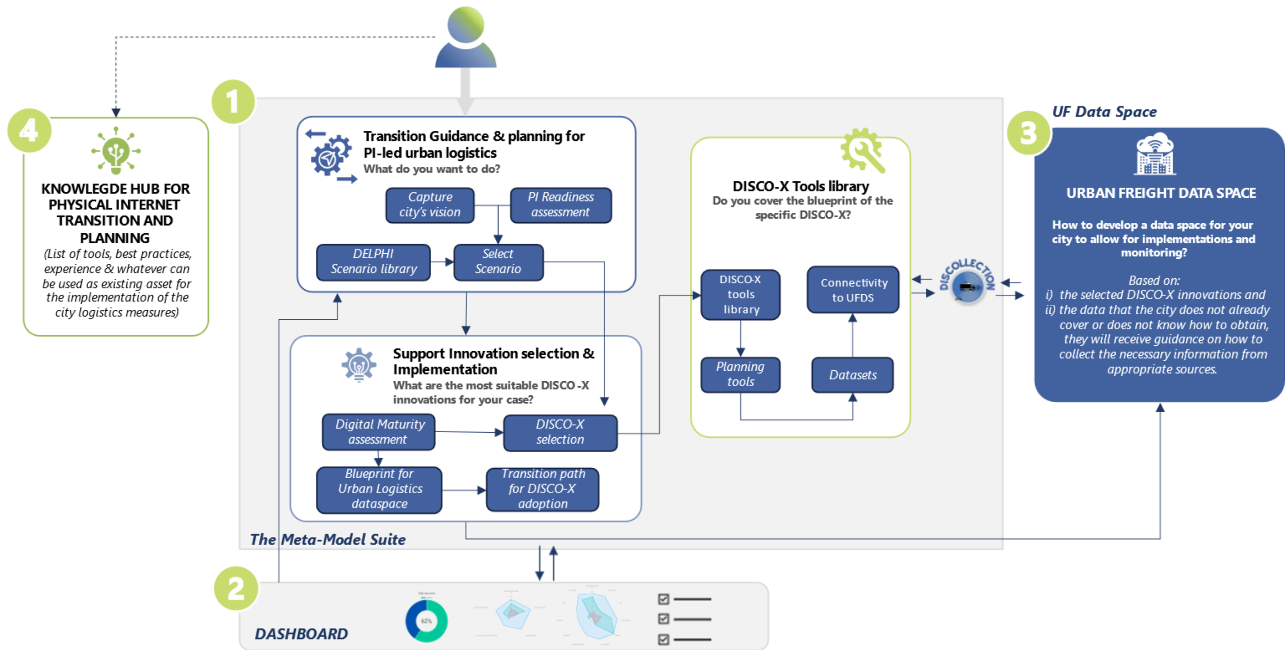

Figure 4: The overarching Architecture of Meta Model Suite and the connection with other DISCO outcomes

The architecture outlines a comprehensive procedure for transitioning to Physical Internet (PI)-led urban logistics, emphasising a structured and integrated approach. The process begins with capturing the city's vision and conducting a PI readiness assessment to establish a foundational understanding. Utilising the DELPHI[3] Scenario Library, the city can select an appropriate scenario that aligns with its goals. Following this, a digital maturity assessment will evaluate the city's technological capabilities, so that digital performance across LLs can be compared, and DISCO cities can associate promising data-driven solutions to their environment typology with transition success in other cities. Subsequently, the focus shifts to the DISCO-X Innovation selection, where the most suitable innovations are identified based on the city's specific needs. A clear transition path for the adoption of these innovations will then be outlined. The DISCO-X Tools Library will play a crucial role at this stage, providing essential planning tools and ensuring connectivity to the Urban Freight Data Space (UFDS). The UFDS will be instrumental in guiding the development of a robust data infrastructure, offering guidance on data collection, and ensuring comprehensive implementation and monitoring frameworks are in place. To support this transition, the Knowledge Hub offers a repository of tools, best practices, and resources, serving as an existing asset for implementing city logistics measures. Throughout the process, the Dashboard provides a dynamic interface to visualize data and metrics, facilitating real-time decision-making and monitoring progress. This entire procedure is encapsulated in the Meta-Model Suite, ensuring a seamless and efficient flow from initial vision to full implementation, thereby driving sustainable and effective urban logistics solutions.

To sum up, the overarching architecture consists of four elements, where the Meta Model Suite is the central node. Following, the conceptual approach which will be integrated into the Meta

Model Suite together with the connection of MMS with external nodes will be described and defined.

4.1. Architecture principles

Building on the comprehensive architecture outlined in the previous section, the DISCO Meta Model Suite integrates a set of foundational principles that drive its design and functionality. It was important from the beginning of the design process that the principles should not just be theoretical underpinnings but also essential for ensuring that the approach of the tool effectively addresses the complex needs of urban logistics ecosystems. As cities increasingly seek to harness technological advancements to optimize their logistics and mobility strategies, the Meta Model Suite provides a framework to facilitate this transition. These principles guide the development of the suite's components and their interactions, ensuring that the architecture supports the aforementioned logistics requirements but is also adaptable to future challenges and technological evolutions[3]:

1. **Data-Driven Decision-Making & Integration with External Systems:** Urban logistics are complex, influenced by multiple variables including traffic patterns, economic activities, and environmental considerations. Data-driven decision-making allows for empirical analysis and informed strategy development. By integrating and analyzing diverse data sets, the Meta Model Suite supports cities in understanding current dynamics and forecasting future scenarios, thereby facilitating more effective and strategic urban planning decisions. The suite is linked with the Urban Freight Data Space (UFDS) as it was presented on Figure 4, which collects, stores, and showcases urban logistics data. This centralized data handling approach enables the suite to provide insights and recommendations based on real-time data analytics, thus enhancing decision accuracy and timeliness.
2. **Modularity:** Modularity in system architecture offers flexibility, easier maintenance, and scalability. By designing the Meta Model Suite with distinct but interconnected modules, the system can adapt to different city needs and technologies without requiring complete redesigns, thereby saving resources and allowing cities to tailor the system to their specific urban logistics challenges. The suite's structure includes various components like the Knowledge Hub, DELPHI Scenario Library, and DISCO-X Tools Library. Each can be updated independently, allowing for specific enhancements or changes without impacting the overall functionality of the suite.
3. **Holistic Thinking:** In full harmony with the DISCO project’s objectives and approach, the MMS considers the entire urban logistics ecosystem, including interactions between

[3] https://www.sciencedirect.com/topics/social-sciences/delphi-method
[4] http://sysarch.pbworks.com/w/page/7241231/FrontPage

different transportation modes, the impact of logistics on urban spaces, and the interdependencies between logistics and other urban systems. Ensures that the suite's solutions are comprehensive and sustainable, addressing not just the immediate urban logistics needs but also their long-term impacts on urban development, environmental sustainability, and social dynamics.

4. **Robust Functionality and Essential Complexity:** Focuses on creating solutions that provide robust functionality without unnecessary complexity, ensuring that the system remains efficient and user-friendly. Balances the need for sophisticated functionalities required to handle complex urban logistics challenges with the necessity for simplicity to ensure ease of use, maintainability, and reliability.
5. **Iterative Development:** Supports the continuous improvement of the system through iterative testing, feedback, and refinement. Allows the MMS to evolve in response to changing needs and challenges in urban logistics, ensuring that the system remains relevant and effective over time.
6. **User-Centric Design:** Focuses on the needs and experiences of the end-users, including city planners, logistics operators, and the general public, ensuring that the system is accessible, intuitive, and responsive. Promotes wider adoption and effective use of the MMS by making it more approachable and tailored to the specific needs and constraints of its users.

The DISCO Meta Model Suite embodies a transformational approach to urban logistics, establishing an architectural blueprint that is both robust and responsive to the evolving demands of modern cities. By adhering to the principles above, the MMS is well-equipped to support cities in navigating the complexities of urban logistics, optimizing operational efficiencies, and enhancing sustainability. In conclusion, the MMS, guided by its core architectural principles aims to work as a pivotal instrument for cities aiming to achieve their urban logistics ecosystem optimisation goals. This alignment with both current needs and future advancements underscores the suite's role as an essential facilitator of urban transformation, embodying the innovative spirit of the DISCO project and providing a scalable model for global urban logistics solutions.

4.2. Components and definition

The Meta Model Suite consists of multiple components to support and guide city stakeholders to select and successfully adopt Physical Internet-led urban logistics innovations. This section analyses these parts and their connections with each other.

4.2.1. Transition Guidance for PI-led urban logistics

Initially, the Transition Guidance for PI-led Urban Logistics represents the fundamental component designed to guide city authorities and policymakers in enhancing their urban mobility systems. At the core of this guidance is a scenario selection process that employs detailed datasets to evaluate the city’s current logistics capabilities and readiness for innovative transformations. By utilizing expert insights and the DELPHI methodology, the guidance aims to provide a clear and actionable roadmap for cities to align their logistics strategies with broader urban development goals. This structured approach ensures that the transition to a more efficient and sustainable urban logistics system is both strategic and tailored to the specific needs of each city.

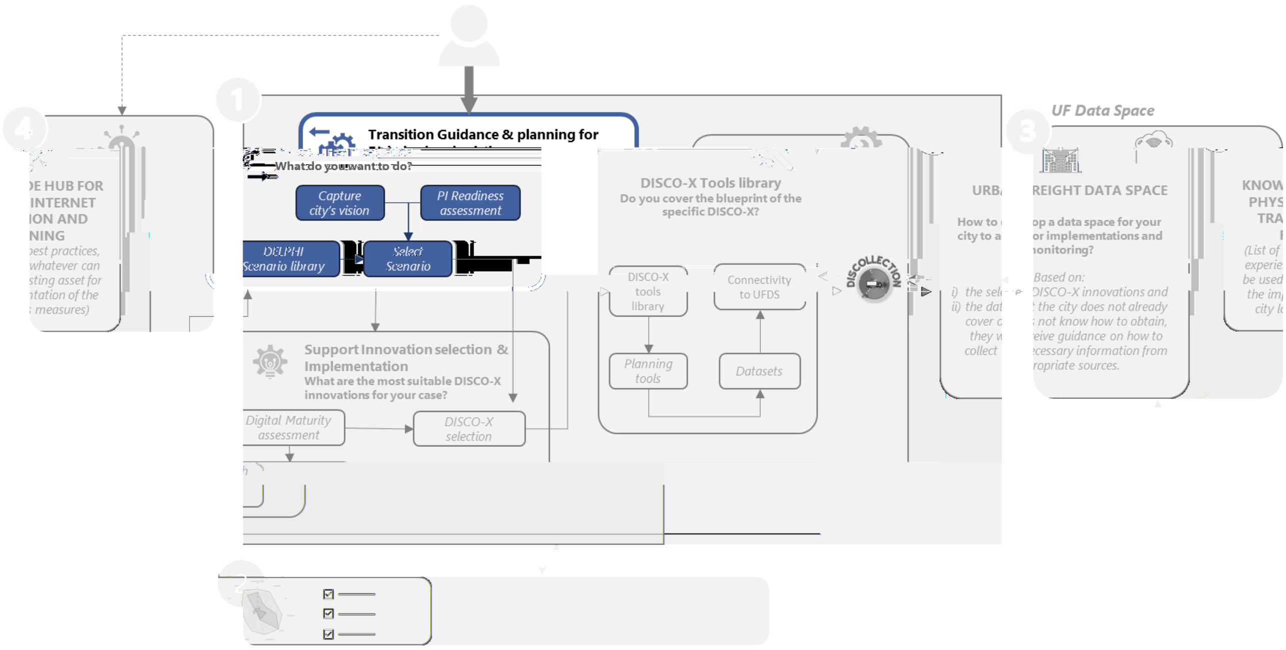

Figure 5: Transition Guidance for PI-led urban logistics

This component initiates with a scenario selection process that utilizes two distinct datasets: a catalogue of potential Physical Internet (PI)-led urban logistics scenarios and a comprehensive assessment of the city's vision to address challenges and its readiness to embrace PI-led innovations. During this conception, it was crucial to engage with sector experts from academia and industry by applying the DELPHI methodology to achieve consensus. This approach was considered the most suitable to pinpoint the factors that empirically drive the successful implementation of the project's PI-led innovations. These factors are then integrated with projections and trends within both the mobility and logistics sectors to construct a series of future scenarios.

Subsequently, the factors identified through the DELPHI methodology are synergized with an extensive literature review to create a qualitative assessment using a 5-point descriptive scale. This scale measures a city's readiness to adopt PI-led innovations, providing a structured and detailed evaluation framework.

At the initiation of this component, users are prompted to articulate their vision and primary objectives for their urban logistics system by completing a checklist of simple statements. Following this initial input, they will engage with the Physical Internet-led Innovation Readiness Self-

Assessment Tool. This tool analyzes the input data and recommends relevant future scenarios derived from the DELPHI outcomes. Users are then given the opportunity to review, validate, and, if necessary, modify the suggested scenarios to ensure they align with the city's specific logistics and mobility goals.

4.2.2. Support innovation selection and implementation

This component is designed to integrate inputs from various sources and provide strategic outputs for urban planning and digital transformation. It primarily takes two major inputs: the selected scenario from the previous module and the Digital Transition Assessment developed by KLU in the context of D2.2 (Rod et al., 2024). The selected scenario provides a contextual framework based on predefined scenarios that guide the digital transformation process. The Digital Transition Assessment is a comprehensive framework designed to evaluate an organization's maturity in digital transformation.

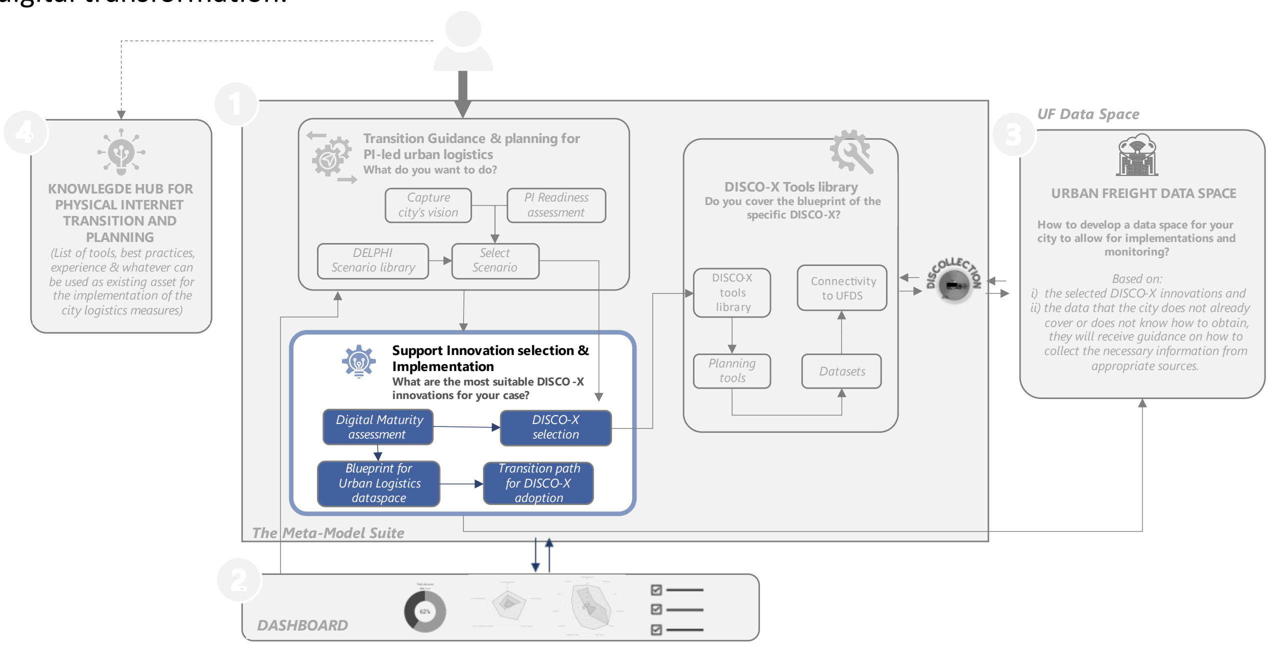

Figure 6: Support innovation selection and implementation

The Digital Transition Assessment Tool is essential for evaluating an organization's (i.e., a city authority) digital transformation maturity. It guides users through a structured assessment process that involves several phases. It focuses on identifying key performance indicators (KPIs) that are crucial for measuring digital transformation while it also involves the practical application of the developed assessment tool to evaluate the digital transition maturity of an organization. Based on the assessment results, the tool provides tailored recommendations for improvement. By leveraging this tool, organizations can gain a deep understanding of their current digital capabilities, identify areas needing enhancement, and develop a strategic roadmap for successful digital transformation. Specifically, the authoritative organization can use this tool to gain valuable insights into their digital readiness and take informed steps towards achieving their digital transformation goals.

The outcomes of the Digital Transition Assessment Tool highlight those areas where a city is considered strong and where it needs improvement. These results, combined with the PI-led innovation readiness, classify cities into a specific typology. The city typology, along with the selected scenario, assists city planners in selecting the most suitable DISCO-X(s). This component results in two significant outcomes: the selection of DISCO-X(s) and the blueprint of the urban logistics dataspace. Based on the city's vision and capacity, the most appropriate DISCO-X(s) is suggested to cities which validate the selection. Additionally, the blueprint will outline the necessary steps and infrastructure required for the city to develop its urban logistics dataspace.

The blueprint also defines the transition path for the city to implement the selected DISCO-X(s). This includes a detailed plan on how to achieve the digital transformation goals, considering the city's current capabilities and future aspirations. The transition path, as established in "D2.1 - Urban Logistics Transition Requirements" by CERTH (Ayfantopoulou et al., 2023) is a strategic roadmap that outlines the steps needed to move from the current state to the desired digital future.

In summary, this component integrates critical inputs from the selected scenario and the Digital Transition Assessment Tool to provide strategic outcomes for city planners. By selecting the appropriate DISCO-X(s) and developing a comprehensive blueprint for the urban logistics dataspace, cities can effectively navigate their digital transformation journey.

4.2.3. DISCO-X tools library

The DISCO-X Tools Library is a crucial component designed to ensure that cities have the necessary tools, data, and infrastructure to successfully implement a DISCO-X. This component builds upon the foundations established in "D2.1 - Urban Logistics Transition Requirements" by CERTH (Ayfantopoulou et al., 2023), which defined the minimum requirements for a DISCO-X implementation.

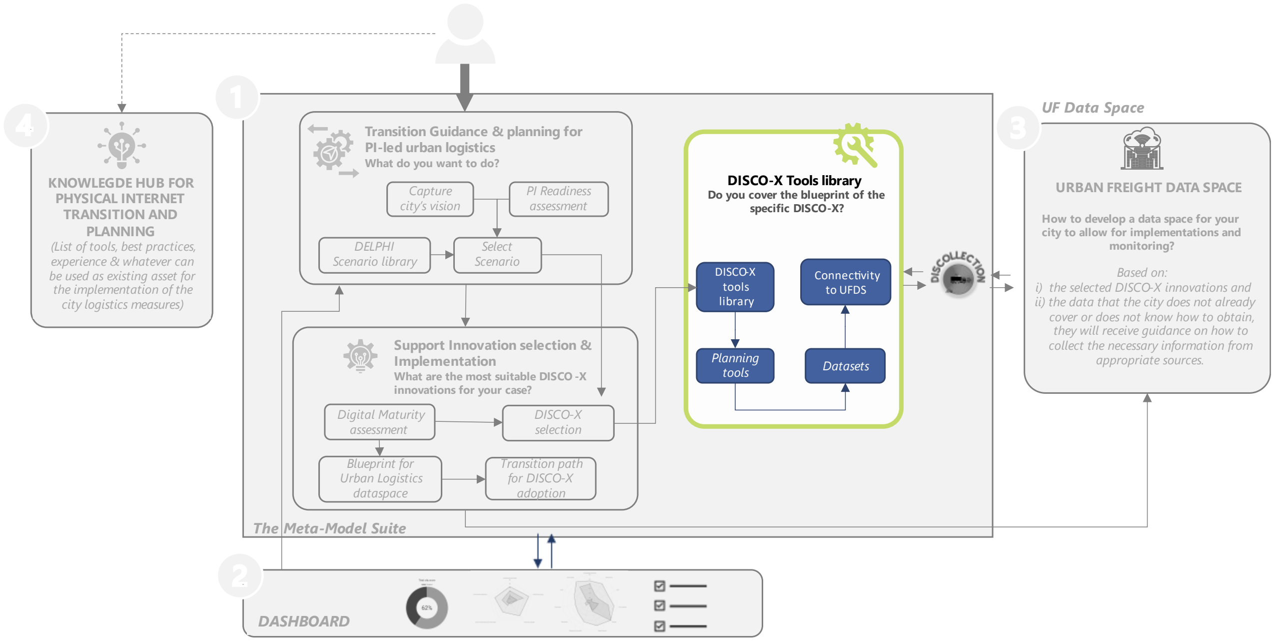

Figure 7: DISCO-X tools library

In this component, the selection of DISCO-X for each city is followed by an assessment to determine if the city meets the minimum required datasets, tools, and infrastructure. The assessment process includes a detailed description of each dataset, covering aspects such as the data included, its source, what it represents, its frequency, spatial resolution, and other relevant characteristics.

Regarding tools, the component will provide detailed descriptions of the necessary tools, including the purpose of each tool, the reasons for its necessity the domain that it covers within the cities' logistics ecosystems, and the expected inputs and outputs. Additionally, the component will suggest useful physical infrastructure necessary for the successful implementation of DISCO-X. This might include hardware, network infrastructure, and other physical resources that support digital transformation efforts.

Apart from the guidance for setting up the city-related data space using dedicated tools and datasets, some planning tools are included to assist policymakers in designing specific innovative urban logistics solutions. These planning tools support decision-making processes by offering data-driven insights and scenario analysis, enabling the development of effective and sustainable urban logistics strategies. Important aspect here is to thoroughly assess and describe the datasets, tools, and infrastructure, the DISCO-X Tools Library component ensures that cities are well-prepared to implement their selected DISCO-X.

4.3. Meta Model Suite Use Cases

Following, the varied use cases of the Meta Model Suite (MMS), demonstrating its applicability and value in optimizing urban logistics through the integration of the Physical Internet (PI) are presented. Each use case illustrates distinct scenarios and strategies, providing stakeholders with actionable insights and methodologies to enhance their logistics operations. This section serves as a practical guide to understanding and implementing the PI concept in urban environments, offering tools and innovations that address specific needs within the logistics framework. From educational resources on PI-led logistics planning to strategic tools for implementing DISCO-X innovations, these use cases highlight the suite's versatility in tackling the complexities of urban logistics management. Through these examples, users will find structured approaches to develop sustainable, efficient, and connected urban logistics systems, ensuring that the suite meets the diverse needs and challenges of modern cities.

4.3.1. Use Case 1: Learn More About Physical Internet-led Urban Logistics Planning and Implementation

The first use case of the Meta Model Suite focuses on providing comprehensive knowledge about the Physical Internet (PI) and its application in urban logistics (UL) planning and implementation.

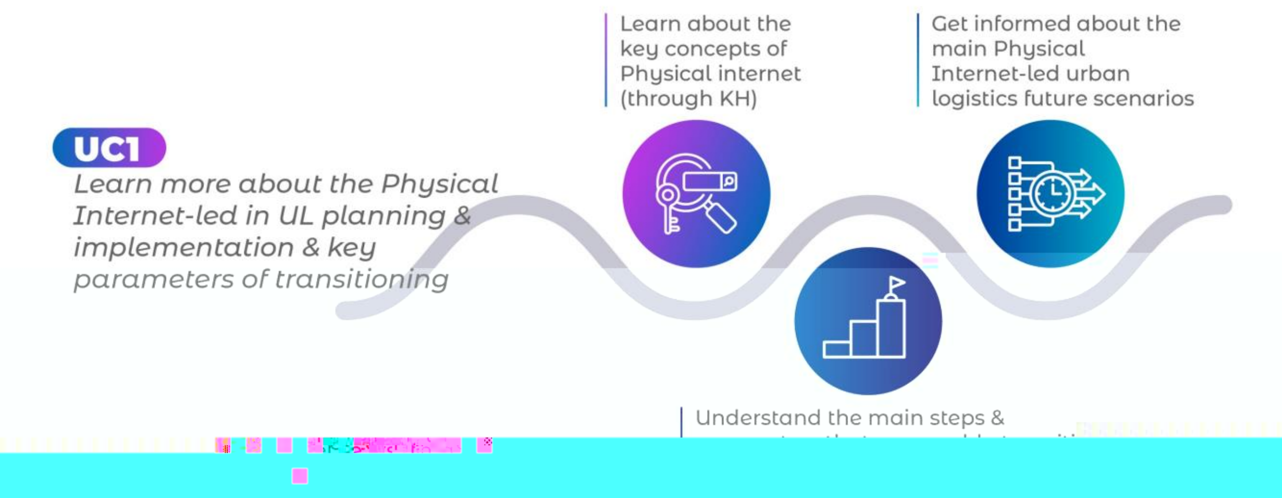

Figure 8: Description and main functionalities of MMS for UC1

This use case serves as an educational and informational resource, explaining what the Physical Internet is and the concept of a PI-led transition. Users will gain insights into key parameters of transitioning to PI-led UL, such as connectivity, standardization, and optimization of logistics networks. This foundational knowledge is crucial for stakeholders involved in urban logistics, as it sets the stage for understanding how to effectively plan and implement a PI-led transition. The information is directly connected with insights and methodologies developed in section 7.3, ensuring that users have access to detailed, structured, and actionable knowledge about PI principles and their practical application in urban logistics.

4.3.2. Use Case 2: Create Vision and Select a Scenario for Developing a Physical Internet in Urban Logistics

Many cities around Europe have not yet developed a sustainable urban logistics plan (SULP), although definition of PI is well described from ALICE, the PI approach is not part of the planning process of cities and companies. This use case of the meta model suite aims exactly to help city stakeholders to develop a strategy for the PI development and scenarios of each implementation in each city.

The second use case enables users to define a vision and select a scenario for developing a Physical Internet in urban logistics.

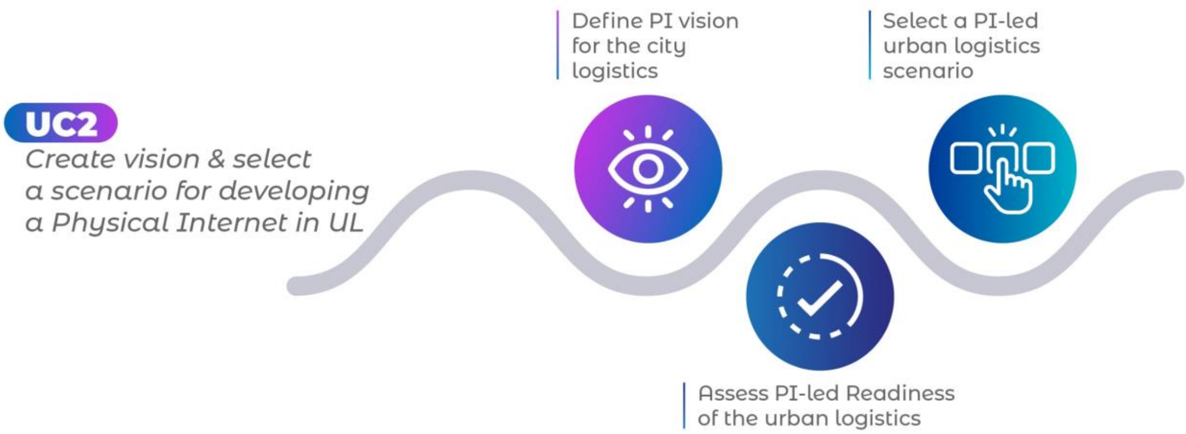

Figure 9: Description and main functionalities of MMS for UC2

This use case guides city planners and stakeholders through the process of defining a PI vision tailored to the specific needs and goals of their city logistics. It includes assessing the PI readiness of the urban logistics ecosystem, considering factors such as current digital capabilities, existing infrastructure, and stakeholder engagement. Based on this assessment, users can propose a PI-led scenario that aligns with the city's strategic objectives and logistical challenges. This use case provides a structured framework for creating a clear and actionable vision for PI integration, ensuring that cities can effectively plan their transition to more efficient, sustainable, and connected urban logistics systems.

4.3.3. Use Case 3: Select DISCO-X Innovation for Accelerating Transition to Physical Internet in Urban Logistics

The third use case focuses on selecting the appropriate DISCO-X innovation to accelerate the transition to the Physical Internet in urban logistics.

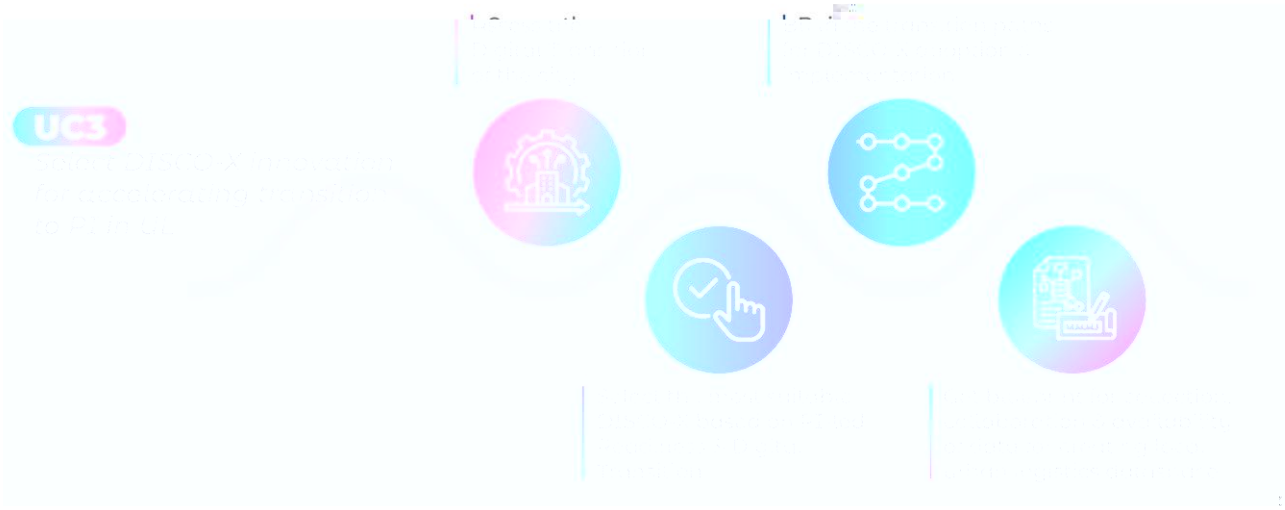

Figure 10: Description and main functionalities of MMS for UC3

This involves checking the digital maturity and available infrastructure of the city to determine its readiness for adopting DISCO-X solutions. Users will receive guidance on identifying suitable transition paths for DISCO-X adoption and implementation, considering the city's unique logistics landscape and digital capabilities.

Additionally, this use case provides detailed instructions on estimating resource requirements, fostering collaboration among stakeholders, and ensuring the availability of data necessary for creating a local urban logistics dataspace. By following this use case, cities can strategically select and implement DISCO-X innovations that drive their digital transformation and enhance urban logistics efficiency.

4.3.4. Use Case 4: Use Tools for DISCO-X Implementation

The fourth use case outlines the practical application of tools necessary for DISCO-X implementation.

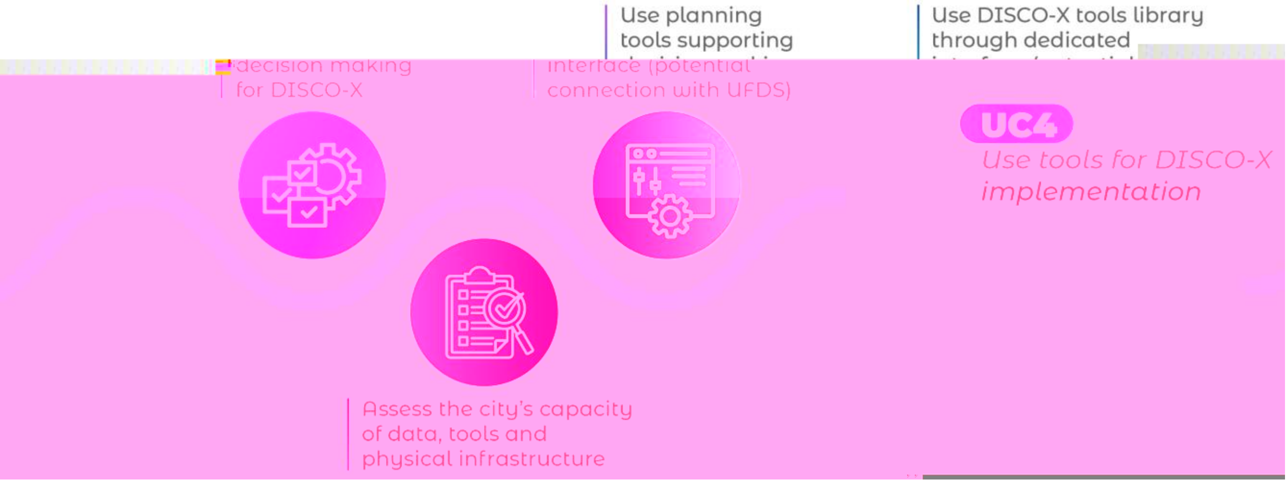

Figure 11: Description and main functionalities of MMS for UC4

It includes guidance on tool connectivity and data requirements, ensuring that users understand how to integrate various tools within their existing infrastructure. This use case also emphasizes the importance of planning tools that support decision-making processes related to DISCO-X implementation. Users will learn how to interface with the DISCO-X Tools Library, accessing a repository of tools and resources tailored to their specific needs.

This use case seamlessly integrates the Meta-Model Suite with the Urban Freight Data Space, a key component of the Federated Data Space within the DISCO Project. It initiates with the introduction of the DISCO-X solution to cities and Living Labs, where a detailed blueprint for its implementation is shared. The main component in this implementation strategy is the DISCO-X Tools Library "App Store" within the DISCO Urban Freight Data Space, which serves as a hub for all relevant DISCO-X tools. This digital storefront allows for browsing and downloading tools from the Open Software Repository -as outlined in D3.1 by INLECOM- or provides manuals on integrating tools that need a commercial license. Each tool is accompanied by a concise description of its functionalities, aiding users in selecting the most appropriate resources for their specific requirements.

The use case extends beyond mere tool selection, offering comprehensive guidance on tool connectivity and data integration. It focuses on the strategic use of planning tools that enhance decision-making processes critical to the successful implementation of DISCO-X solutions. Users are guided on how to effectively interact with the DISCO-X Tools Library, accessing a repository filled with resources tailored to meet their distinct operational needs.

Ultimately, the outcome of this use case through the Meta-Model Suite is to identify and promote tools that are precisely suited for specific purposes, thereby defining clear next steps for utilizing these tools within the proposed-by-the-Meta-Model Suite DISCO-X framework.

5. Examples of tools and knowledge to be offered

This chapter delves into the diverse array of tools and knowledge provided by the Meta Model Suite, specifically designed to facilitate the transition to a Physical Internet (PI)-led urban logistics framework. It outlines an extensive suite of strategic planning resources, innovative assessment tools, and practical implementation guides that collectively aim to optimize the integration of digital and physical infrastructure within urban logistics. From capacity-building tools that enhance city stakeholders' understanding of their logistics ecosystems to advanced operational tools that support real-time logistics management, the offerings are meticulously designed to address the complexities of modern urban logistics. These tools aid cities in assessing their readiness for PI adoption, planning for digital maturity, selecting appropriate innovations, and implementing effective logistics solutions. Additionally, the chapter highlights the development of a city-specific urban logistics dataspace and a sophisticated dashboard that integrates all components, providing stakeholders with a holistic view of urban logistics planning and execution. This strategic compilation of resources serves as a cornerstone for cities aiming to enhance their logistics efficiency, sustainability, and connectivity, ultimately leading to a transformative impact on urban logistics systems worldwide.

5.1. PI urban logistics transition guidance and planning tools

The first layer of tools contains Capacity Building tools which use qualitative data from a city's ecosystem (e.g. city authorities, LCVs, technology providers, disruptors) to get insights about critical aspects of a city's ecosystem such as infrastructure, data collection, governance, digital competence, etc. These tools are informative, and it is suggested to be used by city authorities and city planners to gain insights on where to strengthen their ecosystem in order to easily adopt innovative urban logistics solutions.

The Physical Internet is a concept that aims to transform the global logistics system into an efficient and sustainable network of interconnected logistics networks, similar to how the Internet connects computers and information networks. In the context of city logistics, the concept of Physical Internet seeks to optimize the movement of goods and services within urban areas by building a seamless, synchronized and hyperconnected logistics network. More specifically, it envisions a smart, open and interconnected logistics network where a multitude and diverse network of actors is closely cooperating for ensuring the consolidation and standardization of the goods flows which will result in higher sustainability performance of the whole system.

In addition to that, the use of advanced technologies and IoT platforms is a fundamental component of this new system for easing the data/information sharing among the multiple parties involved, providing the appropriate transparency and safety in the multiple transactions taking place, enhancing the visibility of the goods/information flow across the chain, and thus strengthening the trust among the participants involved.

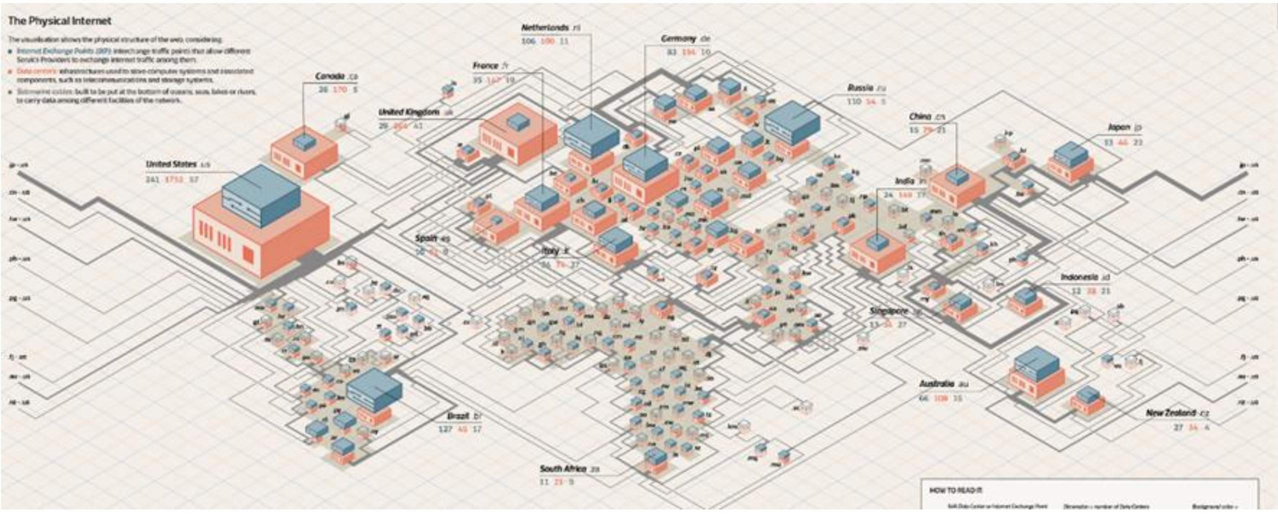

Figure 12: The Physical structure of the web: Internet Exchange Points, the Data centers and the Submarine cables

In order, though this concept to become real and be viable requires the appropriate support by the city itself. The existing urban layout together with how the urban space is allocated, the current physical and digital infrastructure for city logistics as well as the existing or to-be-planned regulatory framework impacts significantly the performance and viability of such innovative concepts.

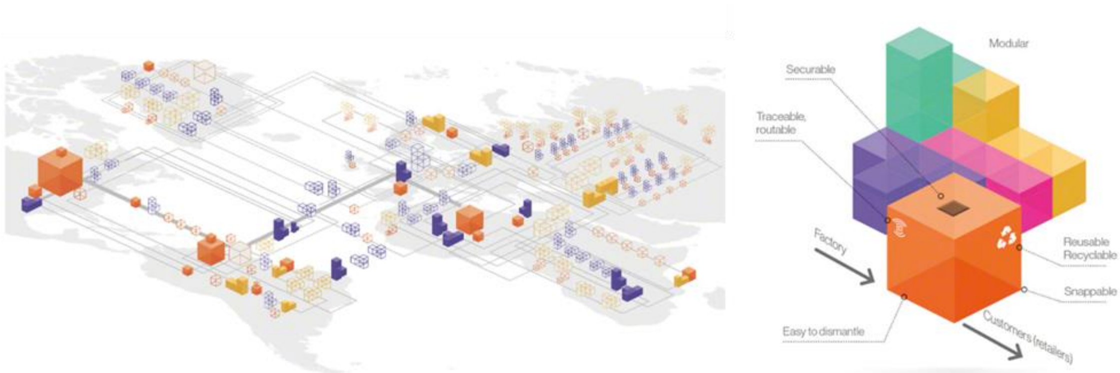

Figure 13: PI & π containers

The city plays a significant role in fostering collaboration among parties with conflicting interests, supporting the development and growth of entrepreneurship and start-ups in the field, supporting the research and development in the field and securing the innovation adoption from the public. This means that the city itself can be either a great facilitator or a great obstacle towards change. However, little is known so far on how to identify the level of PI-led maturity of the current city logistics system and the level of readiness of a city in harnessing such innovations. Cities often overlook the importance of introspection, resulting in a limited understanding of their system's strengths and weaknesses. In addition, the common issue of limited knowledge of the city logistics systems' main operational needs, characteristics and influencing factors, makes the cities not know where to start any changes to be able to support the sector.

5.1.1. PI Readiness Assessment tool for UL

The concept of Innovation Readiness was first introduced in H2020 SPROUT in the context of urban mobility and logistics and then, it was further developed in HORIZON EUROPE URBANE focusing on urban logistics. At this point, the third level of innovation readiness is being developed to assess the maturity of a city to adopt Physical Internet-led urban logistics solutions.

Figure 14: The evolution of Innovation Readiness concept

This new assessment aims to further specialize the previous innovation readiness assessments towards the collaboration and shared aspect for urban logistics. These two aspects are incorporated in the Physical Internet concept and the new qualitative assessment has the two major objectives:

- **Obj. 1:** *What shall a city authority do to come closer to a PI-led city logistics system?*
- **Obj. 2:** *How ready and mature a city logistics system is in introducing this concept and how can this be measured and assessed eventually?*

In literature, the term "ecosystem" is often extended beyond its biological roots to describe a network of interdependent components that collectively function to support a complex system. This concept has been effectively utilized in URBANE to outline the structure of an innovative urban logistics ecosystem. Here, the ecosystem framework identifies critical elements essential for enhancing urban logistics operations, including safety, infrastructure, stakeholders, and governance. Each component is integral to the ecosystem's overall functionality, mirroring the interconnectedness observed in natural ecosystems. This approach underlines the necessity of holistic integration and coordination among all parts to ensure efficient, sustainable urban logistics solutions.

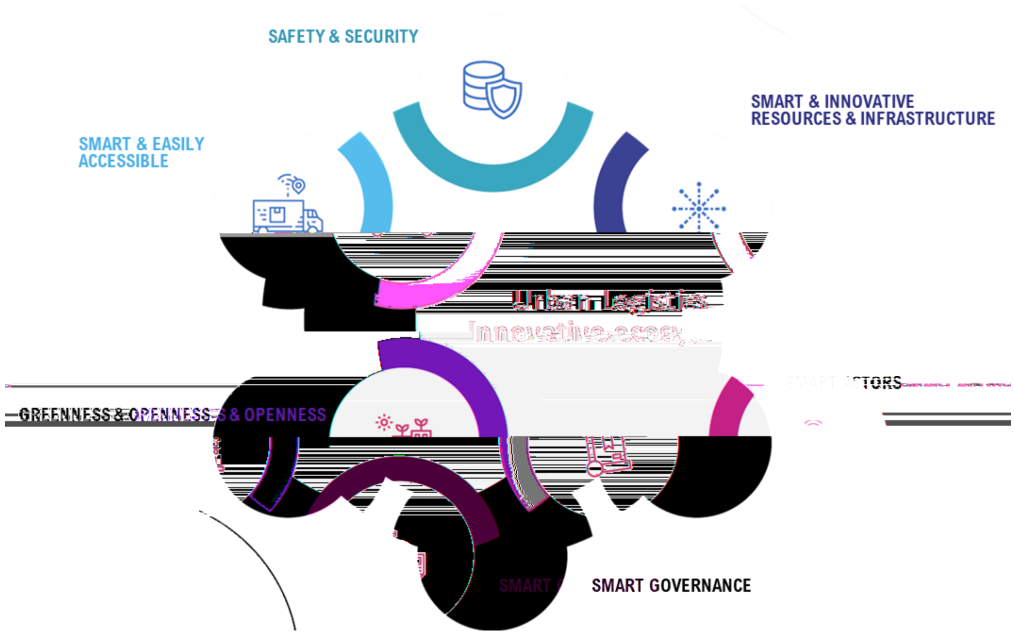

Figure 15: The elements of the Urban Logistics Innovative ecosystem developed in URBANE

Specifically, this ecosystem consists of six (6) different sub-elements; their name and a brief description for each of them are provided in the following table (Table 1). Building on this approach, the Physical Internet Readiness survey will develop questions to capture a city's capacity to adopt PI-led urban logistics solutions.

Table 1: The Urban Logistics Innovative Ecosystem

Element	Description
SMART GOVERNANCE	Smart Governance acts as the strategic and operational framework that shapes the urban logistics ecosystem. It involves advanced planning and policy development, coupled with proactive stakeholder collaboration. This governance ensures the ecosystem is steered by a comprehensive vision and robust, adaptable regulations, all backed by data-driven decision-making. This dynamic approach allows the ecosystem to effectively respond to technological innovations, environmental pressures, and the changing needs of urban areas.
SMART & INNOVATIVE RESOURCES & INFRASTRUCTURE	This element forms the core physical and digital infrastructure critical for fostering innovative logistics solutions. It encompasses the implementation of smart technologies, supportive regulatory environments, and the integration of cutting-edge technologies like the Internet of Things (IoT) and Artificial Intelligence (AI). These resources and

Element	Description
	infrastructures are vital for sustaining efficient, sustainable urban logistics and adapting to emergent logistics models.
SMART ACTORS	Smart Actors are central to driving innovation and fostering collaboration within the urban logistics ecosystem. This group includes logistics service providers, city planners, technology developers, and community members, all collaborating to enhance and implement smart logistics solutions. Their collective expertise and technological acumen promote a culture of continuous improvement, essential for the ecosystem's growth and adaptation.
GREENNESS & EFFICIENCY	This aspect emphasizes sustainable environmental management and low-carbon operations within the logistics ecosystem. It evaluates the commitment to reducing environmental impact through the adoption of clean technologies, like electric vehicles and renewable energy, and through strategies aimed at minimizing emissions in urban logistics. Greenness & Efficiency also strive to boost operational effectiveness, reducing waste in time and resources, thereby supporting a sustainable and efficient logistics practice.
SMART & EASILY ACCESSIBLE CITY LOGISTICS NETWORKS	Focused on enhancing the connectivity and accessibility of urban logistics, this element highlights the importance of developing comprehensive multimodal transportation networks, facilitating standardized data exchanges, and promoting cooperative platforms. These networks ensure that the logistics system remains adaptable, resilient, and capable of meeting both current and future urban demands efficiently.
SAFETY & SECURITY	Safety and security are paramount in maintaining the integrity and sustainability of the urban logistics ecosystem. This element involves setting strict standards, employing advanced tracking and security technologies, and adapting regulatory frameworks to address new challenges.

To construct this survey, it was critical to garner insights from a diverse group of experts on the future of urban logistics systems in cities and to identify key factors that support the Physical Internet concept. For this purpose, we employed the DELPHI methodology, engaging logistics professionals across academia, industry, and public authorities from various regions. This approach facilitated the development of future scenarios, each defined by factors critical to assessing readiness for the Physical Internet.

The resulting Physical Internet-led self-assessment tool represents the initial phase of the Meta Model Suite deployment. This tool will provide city authorities with valuable insights into the logistics ecosystem's maturity and readiness to embrace Physical Internet-led innovations.

Specifically, it identifies areas of weakness within the ecosystem at the element, sub-element, and question levels. The insights gained from this survey can assist cities in two primary ways: in the short term, they can determine which logistics operations are most feasible based on existing competencies; and in the long term, they provide strategic direction on where investments should be made to enhance the urban logistics ecosystem.

5.1.2. PI-led Digital Maturity assessment tool for PI-led solutions implementation

The Digital Transition Assessment Tool is a resource designed to help organizations evaluate their readiness and progress in transitioning to digital technologies and processes. It typically consists of a series of questions, metrics, and frameworks that allow businesses to assess their current digital maturity level, identify areas for improvement, and develop a roadmap for digital transformation.

This tool covers various aspects of digital transition, such as technology adoption, digital skills, organizational culture, data management, customer engagement, and more. By using the assessment tool, organizations can gain a better understanding of where they stand in their digital journey and make informed decisions to enhance their digital capabilities. The tool may provide a structured approach to assessing digital maturity, offering insights into strengths and weaknesses, benchmarking against industry standards, and providing recommendations for achieving digital transformation goals. Ultimately, the Digital Transition Assessment Tool serves as a valuable resource for organizations looking to navigate the complexities of digital transition and stay competitive in the digital age.

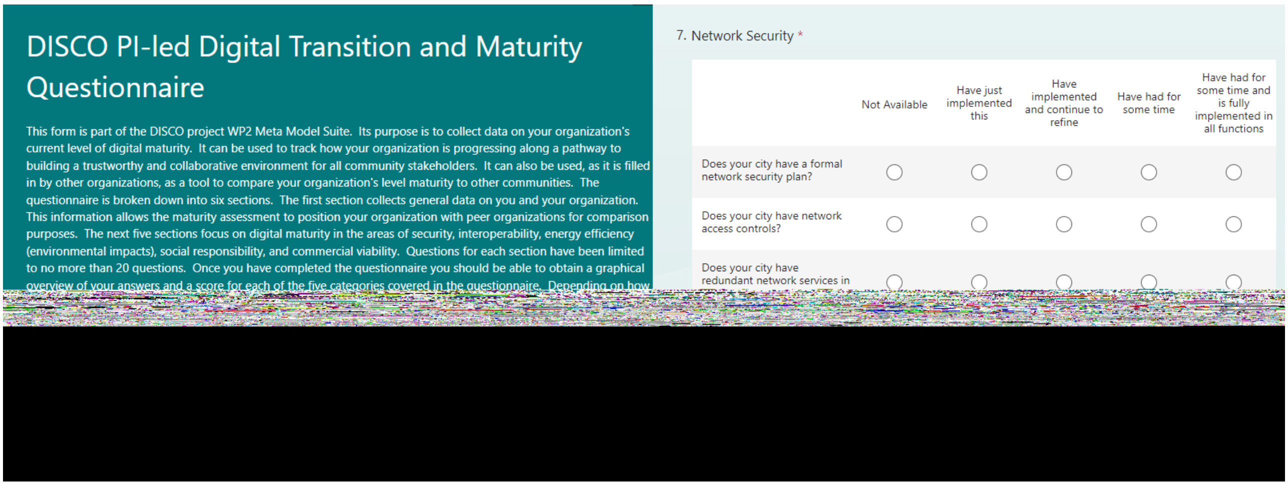

Figure 16: The DISCO PI-led Digital Transition and Maturity Tool

The questionnaire is structured with a series of questions categorized into the following sections:

- **Digital Services,**
- **Security,**
- **Interoperability,**
- **Energy Use and Environmental Impacts,**

- **Social Responsibility, and**
- **Commercial Viability.**

Each section contains a set of questions that prompt the respondent to assess the maturity level of their city's practices and initiatives in that particular domain area. The questions are framed in a way that allows for a nuanced evaluation, with response options ranging from *"Not Available"* to *"Have had for a long time and is fully implemented in all functions."* This scale enables cities to gauge the extent to which they have implemented digital solutions and strategies in various domains.

The tool covers a wide range of topics, including data security, digital services accessibility, interoperability, energy efficiency, social responsibility, and commercial viability. By addressing these key areas, cities can gain insights into their strengths and areas for improvement in leveraging digital technologies to enhance governance, service delivery, sustainability, and economic development.

5.1.3. PI planning scenarios library and scenario selection guidance

To investigate the potential transformation of urban logistics systems through collaborative and shared business models, a Delphi methodology will be employed, engaging experts from city authorities, academia, and companies. This method begins by clearly defining the study's objectives and recruiting a diverse expert panel to ensure a wide range of insights. An initial questionnaire will be circulated to establish a baseline understanding of current urban logistics scenarios and perceptions regarding the feasibility and impact of collaborative models. In the first round, experts will suggest potential scenarios, which will be synthesized into a cohesive set for further refinement. The second round involves distributing these scenarios back to the panel for detailed feedback, focusing on realism, feasibility, and impact, which will be used to refine and clarify the scenarios further. The third round seeks to prioritize these scenarios through expert ranking, aiming to identify the most likely and desirable outcomes. This process culminates in a final report that outlines the agreed-upon scenarios and provides actionable recommendations for various stakeholders, including city planners and logistics companies. The report will guide strategic planning and the development of tools to aid the implementation of collaborative logistics models, ensuring the study's findings are practical and actionable.

Each scenario within the library will be comprehensively detailed, emphasizing the transformative impacts of collaboration and synergies that promote the concept of the Physical Internet in urban logistics. Key elements such as the increase in e-commerce, fleet electrification, and the implementation of collaborative business models will be thoroughly described. These descriptions will highlight how shared infrastructure and interconnected logistics operations can enhance the efficiency and sustainability of urban supply chains. For each scenario, the expected impacts on specific Key Performance Indicators (KPIs) such as traffic reduction, emissions levels, operational efficiency, and economic viability will be detailed. Additionally, the scenarios will explore the enhancement of collaborative networks which are central to the Physical Internet concept. This includes detailing changes in urban space utilization due to the optimized use of shared logistics hubs, changes in consumer behavior favoring online commerce, and the impact of regulatory environments conducive to open logistics platforms. To deepen the utility of the scenario library, further areas will be included for each scenario, emphasizing the synergies and collaborative efforts required to implement the Physical Internet. This will involve an analysis of technological advancements, such as IoT and blockchain, that facilitate transparent and efficient data sharing across the logistics network. Also, the implications for workforce development and the necessary shifts in governance to support an ecosystem where different stakeholders operate under a cooperative model will be outlined.

This methodology will end up in a library of PI planning scenarios, afterwards, cities will have the opportunity to select the scenarios which are more suitable for their city and that can be applied to. Cities will select the most preferable future scenarios for their urban logistics systems based on an analysis of their current circumstances and strategic objectives. This selection process will be informed by the outcomes of the Delphi methodology, which identifies and refines potential scenarios through expert consensus. Once cities have chosen their preferred scenarios, these will serve as critical inputs in a broader analytical framework that also integrates assessments of Physical Internet (PI) digital maturity and PI-led innovation readiness. This comprehensive assessment framework will enable a tailored approach to suggest specific DISCO (Digital, Interconnected Supply Chain Operations) innovations to each city. The selected DISCO innovations will be aligned with the city's current digital and innovation capabilities but also with their desired future state as defined by their chosen logistics scenarios. This method ensures that the recommendations are both practical and aligned with each city's unique developmental trajectory and logistics challenges.

5.2. Support PI innovation selection and implementation

The second layer of tools is dedicated to enhancing urban logistics planning, a crucial element in optimizing delivery processes within urban areas. This need has become increasingly relative to the increase of e-commerce and the corresponding logistics demands it generates. By incorporating these planning tools into the Meta Model Suite platform, cities can input essential data such as area and demand forecasts to effectively address common urban design challenges, including optimal locker placements. This integration facilitates better management of the complexities in modern delivery systems and bolsters the sustainability of urban logistics operations.

This approach categorizes cities into distinct typologies based on their urban logistics transition capabilities and guides them in selecting the most appropriate DISCO-X solutions. By leveraging the PI-led Innovation Readiness and Digital Maturity assessments, cities are equipped to choose solutions that align with their vision and capacities. This strategic framework is essential for understanding a city's current position in the urban logistics landscape and determining the most effective steps forward, ensuring a tailored and efficient approach towards urban logistics innovation and sustainability.

5.2.1. City typology and DISCO-X(s) selection

At this point, the input from the PI-led Innovation Readiness and the PI-led Digital Maturity will be used to guide cities to select the most suitable DISCO-X solution(s) based on their vision and their capacities.

The city typology clustering is an integral part of the urban logistics transformation process, employing a systematic grid methodology that categorises respondent cities based on their Urban Logistics (UL) transition capabilities. Specifically, the categorization is derived from the combined results of the PI-led Digital Maturity and the PI-led Innovation Readiness assessments. By analyzing these assessments, cities are classified into four distinct typologies, each representing a city's readiness and approach towards adopting innovative logistics solutions:

- **UL Transition Inspired City:** These cities are in the earlier stages of their transition journey. While they may lack some of the advanced infrastructure and governance frameworks of more prepared cities, they are inspired and motivated to transform. For these cities, the typology highlights the need for foundational improvements and strategic planning to foster a conducive environment for urban logistics innovation.
- **UL Transition Acceleration City:** Cities falling into this category are characterized by robust digital capabilities and innovative practices that are not yet fully optimized but show significant potential for rapid development. The focus for these cities is on accelerating their existing capabilities and resources to quickly move towards comprehensive urban logistics solutions.
- **UL Transition Ready City:** This typology identifies cities that have both the necessary infrastructure and a progressive governance framework which together facilitate immediate implementation of advanced urban logistics solutions. These cities exhibit a high level of preparedness in their digital and innovative capacities, making them prime candidates for leading the charge in logistics transformation.
- **UL Transition Partnership City:** This typology is for cities that recognize the importance of collaboration and partnerships to enhance their urban logistics systems. These cities may need to leverage external expertise and enter strategic partnerships to build the necessary capabilities and infrastructure required for a successful transition.

Each city typology is not just a label, but a strategic framework that guides city planners and authorities in understanding their current position in the urban logistics landscape and identifying the most effective steps forward. The assessment fosters a tailored approach, allowing cities to align their strategies with their specific needs and capabilities, thus facilitating more targeted and effective interventions in their urban logistics systems. By applying this grid methodology, stakeholders can more accurately gauge the strategic interventions needed, enabling a more focused and efficient allocation of resources towards urban logistics innovation and sustainability.

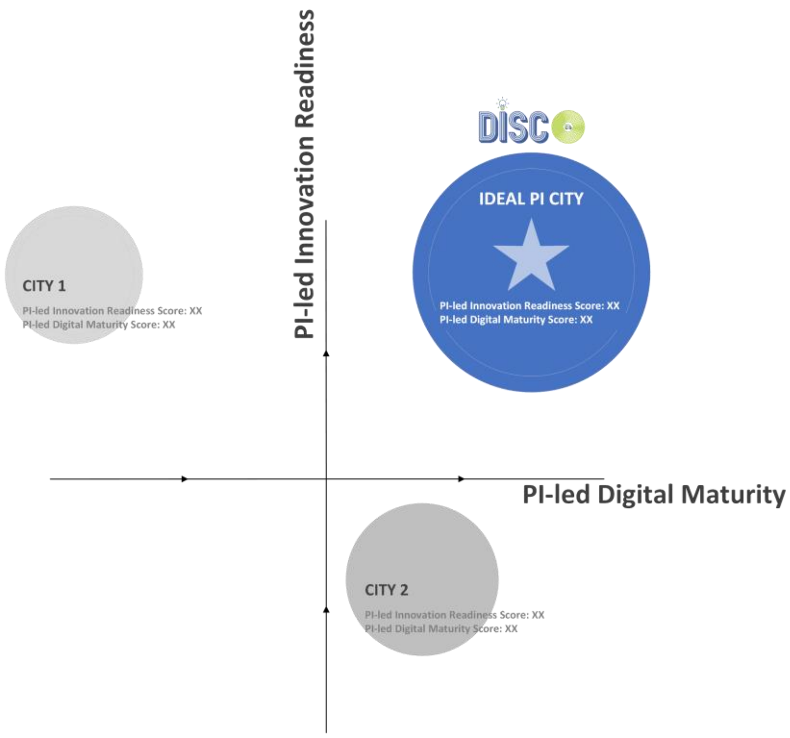

Figure 17: The DISCO PI-led Digital Maturity and Innovation Readiness typology grid

On the other hand, the final step is the DISCO-X(s) selection for each city based on its vision and capabilities. The DISCO-X(s) selection approach is a sophisticated methodology that integrates expert opinions, pilot project outcomes, and PI-related assessment outcomes. This process begins with the definition of DISCO measure packages based on successful experiences and expert insights, where each package includes one or more specific DISCO-X solutions (e.g. package 1: DISCO-CURB & DISCOLLECTION). The methodology incorporates an analytical framework, starting with the collection of the results from the PI-led innovation readiness and digital maturity from all participating DISCO cities. This data is crucial as it reflects the preparedness of each city to implement advanced logistics solutions.

To analyze this multifaceted data effectively, a dimension reduction technique such as Principal Component Analysis[5] (PCA) was employed. PCA simplifies the complexity of the data by focusing on the most significant variables, thus enhancing the robustness and interpretability of subsequent analyses. Following this, a logistic regression model was applied. This statistical model uses the reduced data to ascertain the relationship between a city's digital and innovation metrics and their chosen DISCO-X solutions, providing predictive insights into the effectiveness of each logistics solution package.

[5]https://www.sciencedirect.com/topics/earth-and-planetary-sciences/principal-component-analysis

The final component of the methodology involves integrating these analytical tools into the Meta Model Suite. As new cities join and input their respective data into the Suite, the system utilizes the pre-configured logistic regression model to advise on the most suitable DISCO measure package for them. This predictive guidance helps cities make data-driven decisions to optimize their urban logistics, thereby enhancing efficiency and sustainability.

5.2.2. Selected DISCO-X implementation guidance

Each DISCO-X solution, as a vital component of the Meta Model Suite (MMS), is designed to address specific urban logistics challenges through the deployment of innovative technologies and data-driven strategies. For effective implementation, each DISCO-X necessitates a foundational set of data, digital services, and infrastructure, tailored to meet the unique demands of different urban environments. In addition to this, the existence of specific regulations could support the successful implementation and operation of the selected DISCO-X urban logistics solutions. This comprehensive approach ensures that cities can optimize their logistics systems efficiently and sustainably. To facilitate the adoption of selected DISCO-X solutions, the MMS provides an analytical framework that specifies the minimum requirements for data, digital services, and infrastructure necessary for each solution. This framework serves as a guide for cities to assess their current capabilities and identify gaps that need bridging to effectively implement the chosen DISCO-X solutions.

- **Data Requirements:** Each DISCO-X demands specific data types to function optimally, such as traffic flow data, environmental impact data, or real-time logistics performance data. The MMS outlines these requirements in detail, specifying the characteristics of each data type (e.g., granularity, frequency, and format). For cities lacking in specific data categories, the MMS provides guidance on engaging relevant stakeholders such as local government bodies, private data providers, and community organizations to acquire the necessary data.
- **Digital Services:** Digital services facilitate the processing and analysis of data, supporting decision-making and operational efficiencies in urban logistics. These may include AI-powered analytics platforms, real-time monitoring systems, or digital twins of urban areas. For each DISCO-X, the MMS details the digital services required and assists cities in assessing their existing digital infrastructure. If a city does not possess the necessary digital services, the MMS advises on the development or acquisition of these services, often recommending collaboration with technology providers and academic institutions.
- **Infrastructure Requirements:** Effective implementation of DISCO-X solutions also depends on appropriate physical and digital infrastructure, such as sensor networks, data centers, and logistics hubs. The MMS describes the necessary infrastructure components in detail, helping cities to understand and evaluate their current infrastructure against the requirements. For infrastructure deficiencies, the MMS suggests strategies for infrastructure development, which may involve public-private partnerships, investment in new technologies, or upgrading existing facilities.

- **Regulatory Compliance and Policy Integration:** For each DISCO-X solution, the MMS will also assess and suggest necessary regulatory adjustments or the development of new policies to facilitate the seamless integration of these solutions within the urban logistics system. This involves examining the current regulatory environment of each city to identify legal and policy constraints that could hinder the adoption of innovative technologies and strategies. The MMS would provide a detailed analysis of existing laws, zoning regulations, and urban planning policies that need to be amended or introduced. This might include suggestions for creating supportive legal frameworks for autonomous vehicle operations, data privacy laws tailored to protect personal information while allowing data sharing for logistics optimization, or specific environmental regulations to mitigate the impact of increased logistics activities. The MMS could also advise on the formulation of incentives or subsidies to encourage private sector participation in these solutions.

To ensure that each city can meet these requirements, the MMS identifies i) what is lacking and ii) provides a roadmap for acquisition and development. This includes identifying potential partners for collaboration, specifying the types of agreements needed, and outlining the steps to integrate new data and services into the existing urban logistics framework. By doing so, the MMS supports cities in crafting a tailored approach to logistics innovation, ensuring that each city can leverage its unique strengths and opportunities to foster a more efficient and sustainable urban logistics system.

5.2.3. A blueprint for building a local urban logistics dataspace

The city-specific local logistics dataspace, as outlined in the blueprint produced by the Meta-Model Suite, will not store data directly but will instead guide users to where necessary data for urban logistics planning and operations can be found.

The development of a local logistics dataspace is a planning initiative driven by the Meta-Model Suite's comprehensive assessment of the city's logistics needs. This digital infrastructure needs to be designed to function as a decentralized, trustworthy environment. The dataspaces as a concept focus on facilitating access to and the exchange of crucial logistics data among the immediate stakeholders, rather than storing the data themselves (Curry, 2019). This approach strengthens data sovereignty and security, ensuring that city planners, logistics companies, and regulatory bodies can share data transparently and efficiently. The resulting blueprint for a local logistics dataspace will provide a detailed plan for using city-wide data to improve urban logistics management in line with EU regulations and modern data-sharing practices. This strategic document will guide cities in developing and implementing an integrated data space that enhances data management and supports the transformation of city logistics through the Physical Internet approach.

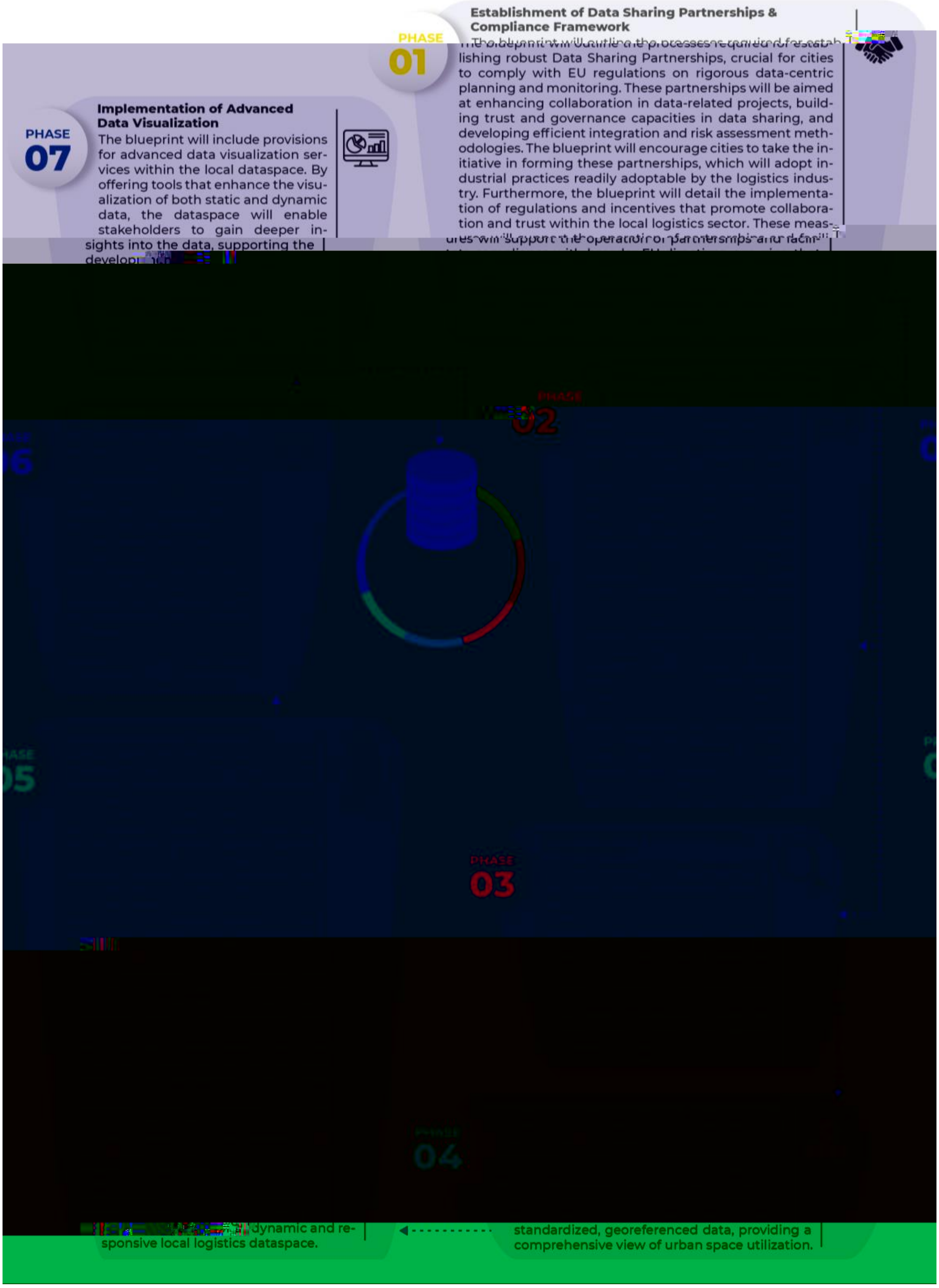

Figure 18: Foundational guide for cities to develop and operationalize an integrated dataspace

The blueprint will commence by establishing robust Data Sharing Partnerships to support rigorous, data-centric planning and monitoring by cities. These partnerships will emphasize stakeholder collaboration in data-related projects, build confidence through improved data governance, and develop efficient data integration and tracking methodologies. To foster active participation, cities will incentivize industrial partners with easily adoptable practices and implement regulations that promote trust within the local logistics sector. This includes granting access to essential data like geospatial and traffic management information crucial for strategic planning. Furthermore, the blueprint will guide cities to gather operational data from businesses under incentive-aligned frameworks to maintain a steady data flow for DISCO-X implementations. It will also outline strategies to secure data discovery within municipal and public domains and integrate existing city service platforms into the dataspace for seamless access. Additionally, the blueprint will focus on interoperability, ensuring that various DISCO-X solutions can integrate and function cohesively within the dataspace, enhancing their collective impact and ensuring compliance with existing standards for sustainable expansion.

5.3. Physical Internet-led DISCO tools library

In practical terms, Physical Internet builds on a multi-zone and multimodal web architecture where the physical resources such as logistics hubs, (micro) consolidation centres or freight hotels are open and shared among the actors involved in the supply chain and multimodal pathways are available for carrying the goods from one point to another inside or outside the city’s borders. The role of physical interconnectivity and the seamless flow of goods through the multiple nodes requires the further generalization of standards and protocols (π container packages that will be environmentally sustainable, traceable, smart and secure). The use of data-driven optimization tools is the main facilitator towards this process by optimizing the tactical and operational coordination of the goods movement.

Thus, a PI-led logistics system expects to have a significant impact on the efficiency and sustainability of the sector which means lower operational logistics costs for the operators, higher service levels for the customers and lower environmental externalities for the overall society and the city. The following figure provides a visualization of the position of PI-led DISCO tools in city logistics setup.

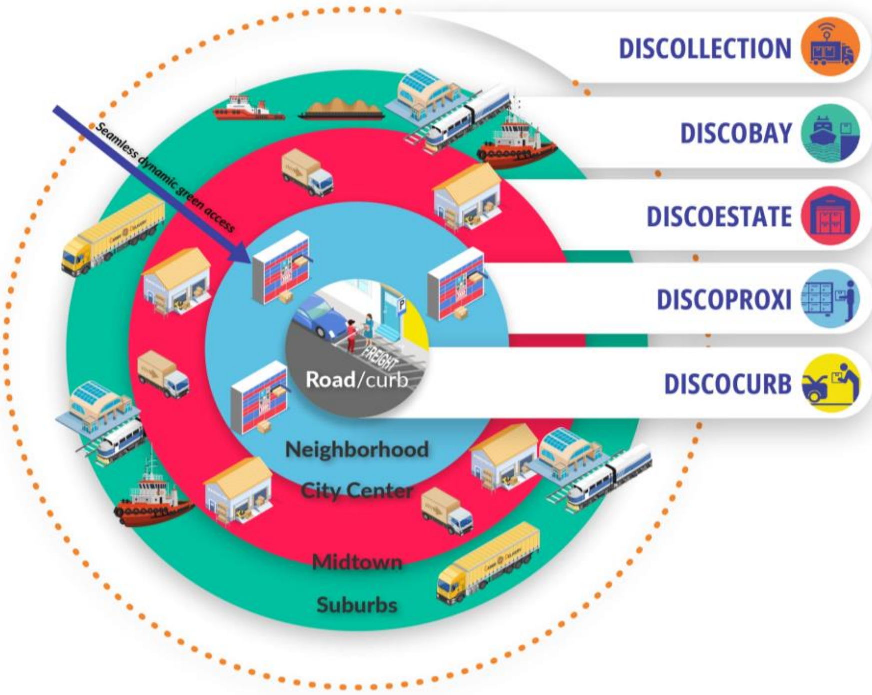

Figure 19: A Spatial Perspective of DISCO-X Innovations within the Physical Internet paradigm of Urban nodes

The third layer of tools within the urban logistics framework is categorized under Operational Tools. These tools are essential for the elaboration of specific strategies, planning, and the real-time management and optimization of logistics operations within urban environments. These tools integrate advanced technologies to streamline processes and improve integration with broader logistics and real estate systems, thus supporting more sustainable and efficient urban logistics operations.

5.3.1. Planning tools

The advent of e-commerce has transformed urban logistics, making the effective distribution of goods in city centres a crucial planning challenge. DISCOPROXI, as defined in D2.1, leverages collaborative logistics and shared resources to address the inefficiencies in last-mile delivery—a segment particularly strained by the rapid growth of online shopping. Central to this approach is the strategic deployment of parcel lockers, utilized as micro-hubs within dense urban areas. These lockers facilitate the transition of goods from larger distribution centres to their final urban destinations, reducing the need for traditional delivery vehicle interventions and promoting the use of environmentally friendly transport methods like cargo bikes and electric vehicles.

The optimization of delivery times occurs by minimizing travel distances and also by significantly reducing traffic congestion and CO2 emissions. Furthermore, it enhances customer convenience, providing secure and accessible points for package collection. The integration of smart network management systems further refines the delivery process, enabling precise planning and efficient grouping of parcels. This model illustrates the potential of modern urban logistics solutions to align with environmental sustainability goals while maintaining the robustness required by today's consumer-driven market. The planning tools section, particularly focusing on the optimal number of lockers, plays a vital role in quantifying the needs and capacities essential for this logistic framework to function effectively within various urban contexts.

Optimal number of lockers

At its core, DISCOPROXI addresses the challenges of last-mile delivery in dense urban areas, where traditional logistics methods struggle to meet the demands of modern e-commerce and online shopping trends. By focusing on collaborative logistics approaches and shared resources, DISCOPROXI aims to streamline delivery operations, reduce costs, emissions, and alleviate congestion in urban centers.

One of the key elements driving the success of DISCOPROXI is the strategic utilization of parcel lockers as micro-hubs within urban environments. These parcel lockers serve as essential nodes in the last-mile delivery process, acting as mini warehouses that receive goods from larger distribution centers. By strategically locating these micro-hubs on the periphery of bustling neighborhoods, DISCOPROXI optimizes the final leg of the delivery journey. Once goods are transferred to these micro-hubs, eco-friendly modes of transportation such as cargo bikes and electric vehicles take over, navigating through the city with precision and efficiency.

Parcel lockers play a crucial role in supporting the DISCOPROXI concept by enhancing accessibility, safety, and convenience for customers. The lockers are integrated with smart network management systems, allowing for efficient planning and grouping of deliveries. This integration streamlines the delivery process and significantly improves the overall effectiveness of urban logistics systems. By reducing the need for multiple trips and minimizing missed deliveries, parcel lockers as micro-hubs contribute to a more sustainable and customer-centric approach to urban logistics.

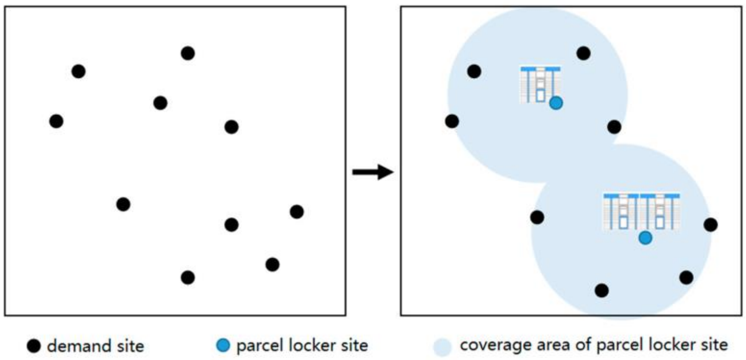

Figure 20: The concept of parcel locker network in the context of DISCOPROXI (Wang et al. 2022)

In this context, a model was developed to estimate the optimal number of lockers based on the delivery demand in the city and the CO_2 reduction goal. Specifically, a continuous approximation modeling approach was employed to determine the optimal number of parcel lockers to be installed within a specified area. This model evaluates two main types of costs associated with urban logistics operations for e-commerce:

1. Company operational costs, including transportation, city depot, and handling expenses. These costs are determined by factors such as total kilometers driven, duration of unloading and delivery processes, and the average number of parcels each vehicle delivers on a unique route.
2. External costs to society, encompassing environmental impact, congestion, air pollution, and CO_2 emissions measured in kilograms. These costs are crucial for establishing objectives towards greener and more sustainable urban logistics practices.

The implementation of parcel lockers aims to reduce the kilometers driven by vehicles, consolidating deliveries and enabling customers to retrieve their final products by walking. The optimal number of locker modules is calculated based on the estimated quantity necessary to meet the sustainability goals of individual cities.

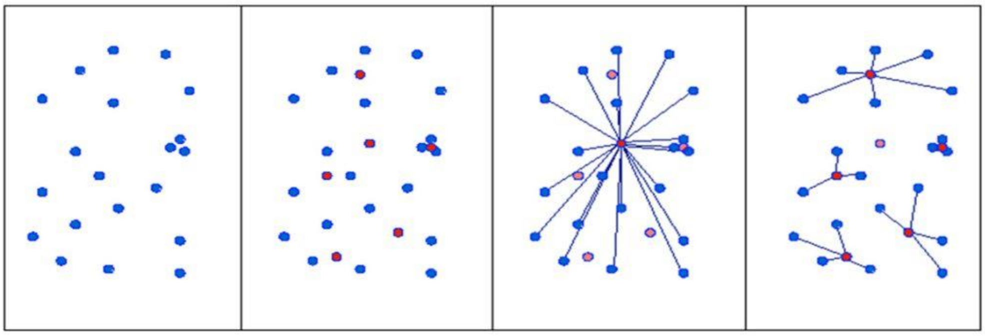

Figure 21: The optimal number of lockers to serve the whole city's demand (source: www.oga.ai)

Customer arrivals at these lockers are treated as a stochastic process, characterized by an arrival rate (λ) and a processing rate (μ) according to the M/M/c/c queueing model. These rates are influenced by the proximity of lockers to customers' delivery locations. The model's output provides the number of lockers required to achieve specific sustainability objectives, tailored to each city's goals.

This methodology was further enhanced to highlight the impact of replacing the private parcel lockers networks with a shared one and provide evidence to city authorities and policy makers in order to promote shared and collaborative logistics operation in the context of Physical Internet paradigm.

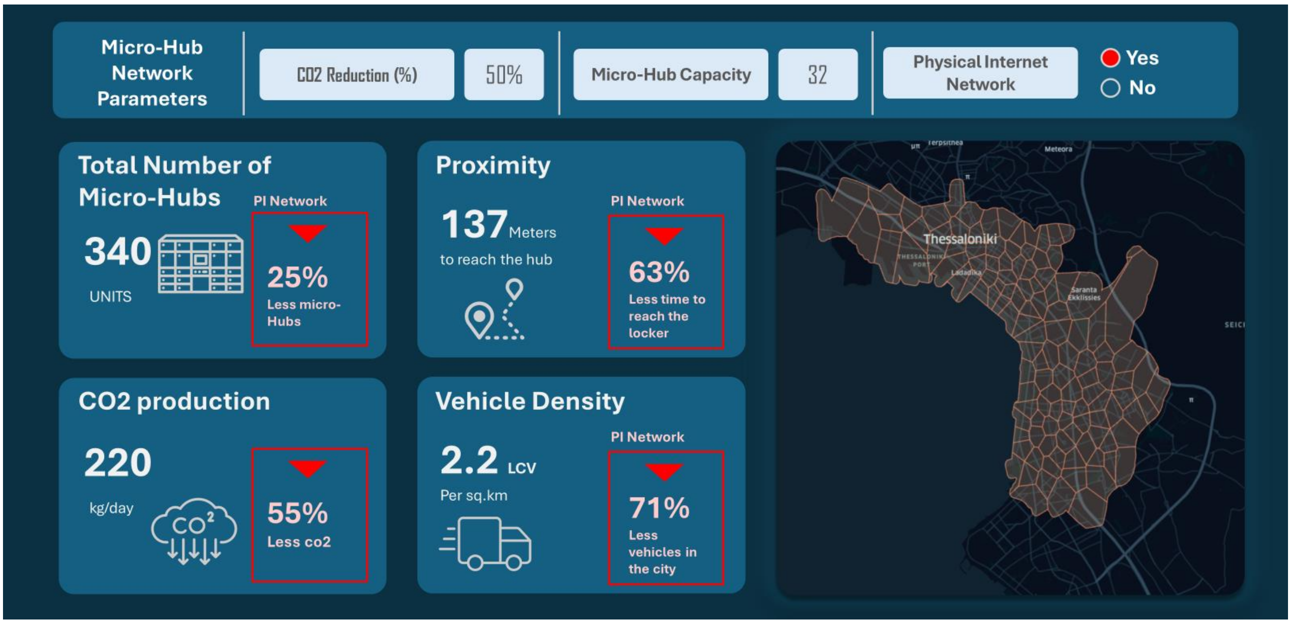

Figure 22: The case of replacing the private parcel locker networks with a shared one and the expected impacts (the area of Thessaloniki)

Except for the change in the total number of lockers, also the average distance of each user to a locker (proximity), the production of CO2 per day and the required number of vehicles in the city for logistics operations will be assessed through the tool.

Optimal number of urban consolidation centers (UCC)

DISCOESTATE, a dynamic model which focuses on optimizing underutilized buildings for last-mile logistics operations, particularly through the concept of urban consolidation centers (UCCs). This innovative approach involves the strategic repurposing of temporary, multistorey, and multipurpose buildings to serve as hubs for efficient and sustainable urban logistics activities. By leveraging underused spaces within urban areas, DISCOESTATE aims to maximize the utilization of available land and infrastructure, promoting a more resource-efficient and environmentally friendly logistics ecosystem.

Urban consolidation centers (UCCs) play a vital role in supporting the DISCOESTATE concept by serving as key nodes for the aggregation, sorting, and distribution of goods within urban environments. These centers act as strategic points where goods from various suppliers are consolidated before being dispatched for last-mile delivery. By centralizing these operations in UCCs, DISCOESTATE optimizes the flow of goods, reduces the number of individual delivery vehicles on the road, and minimizes the environmental impact associated with urban freight transport.

Furthermore, UCCs within the DISCOESTATE framework facilitate collaboration among multiple stakeholders in the logistics chain, promoting shared use of facilities and resources to enhance operational efficiency. By providing a centralized location for goods “bundling” and distribution, UCCs enable more effective route planning, vehicle utilization, and overall logistics coordination. In essence, with this collaborative approach, UCCs serve as essential components of the DISCOESTATE model, driving the transition towards a smarter, more sustainable urban logistics system.

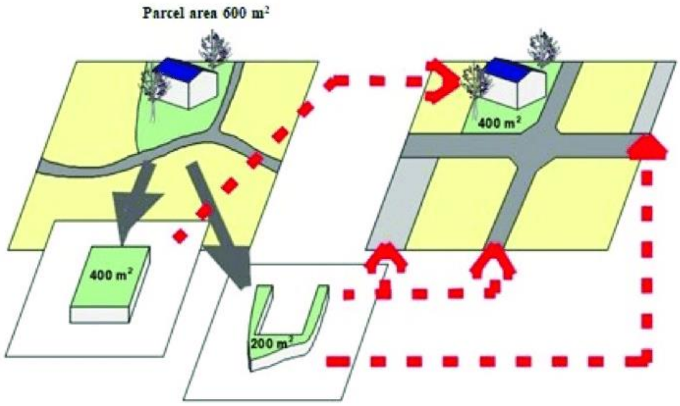

Figure 23: The optimal number of consolidation centers in the context of DISCOESTATE (Pamuković et al. 2020)

Similarly to optimal number of parcel lockers, this is also a continuous approximation model which estimates the optimal number of Urban Consolidation Centers (UCCs) needed to fulfill city's logistics demand but also are necessary for city to reach the CO2 emission goals. Specifically, this model evaluates the operational costs associated with urban logistics, specifically in the context of Urban Consolidation Centers (UCCs). The primary adjustment is the recognition that although the direct handling expenses at these centers are lower, the process of consolidating goods from multiple logistics service providers (LSPs) into fewer delivery routes leads to an increase in transshipment durations. This factor must be carefully balanced to ensure that the time-sensitive nature of e-commerce deliveries is not adversely affected.

Furthermore, the model emphasizes the reduction in external costs as a significant benefit of employing UCCs. By streamlining the delivery process, there is a notable decrease in environmental impacts, including reduced congestion, air pollution, and lower CO2 emissions. These improvements stem from the optimized routing and reduced frequency of delivery vehicles traversing urban areas, which is a direct result of the consolidation process.

The core objective of this approach is to harness the efficiencies gained through the consolidation of parcels with a main focus on minimizing operational and handling costs and significantly mitigating the societal and environmental impacts of urban logistics. This strategic consolidation serves as a foundational element in the pursuit of more sustainable urban logistics systems.

The calculation of the optimal operation scale for UCCs, similar to the locker model, considers customer accessibility and the stochastic nature of demand, characterized by specific arrival and processing rates. The expected outcome of this model is a detailed understanding of how UCCs can be effectively integrated into the urban logistics framework to achieve sustainability goals while balancing the time-sensitive requirements of e-commerce deliveries.

5.3.2. Tools for DISCO-X implementation

This section presents the set of tools and methodologies designed to support the practical application of DISCO-X innovations in urban logistics. These tools are engineered to facilitate the transition of urban centres towards smarter, more sustainable logistics solutions by harnessing the capabilities of the Physical Internet paradigm. The section delves into the specifics of various innovative tools such as the WareM&O platform, Urban Access Control, and Dynamic Curb Management applications. Each tool is optimized to address distinct aspects of urban logistics challenges, ranging from underutilized storage space management to enhancing curb space efficiency. The set of tools streamlines the deployment of DISCO-X innovations by making sure that city planners and logistics managers are equipped with the necessary resources to effectively translate strategic visions into operational realities, ultimately fostering more connected and efficient urban environments.

WareM&O by DISCOESTATE

In Thessaloniki, the WareM&O platform is essentially a virtual freight centre developed as part of the WareM&O project, which focuses on the utilization and upgrading of underutilized storage spaces in urban areas. The platform aims to address the following goals and objectives:

1. **Utilization of Underutilized Storage Spaces:** The primary goal of the WareM&O platform is to maximize the use of underutilized storage spaces in urban centres. By connecting users in need of storage with available spaces, the platform helps optimize the use of existing storage facilities.
2. **Ensuring Fair Pricing System:** The platform deploys fair pricing algorithms that can ensure that both storage owner and user comply with the agreed price.
3. **Enhancement of Storage Efficiency:** One of the key objectives of the platform is to improve the efficiency of storage operations. By streamlining the process of finding, booking, and managing storage spaces, the platform helps users save time and resources in their storage activities.
4. **Creation of a Collaborative Environment:** The platform seeks to create a collaborative environment where users can interact, share resources, and find storage solutions that meet their needs. By facilitating communication and cooperation among users, the platform aims to enhance the overall storage experience.

The platform was further enhanced to be adopted in the DISCOESTATE innovation of DISCO towards specific directions:

1. **Standardization and Enrichment of Data Model:** The platform's data model was standardized and enriched to comply with the specific requirements of DISCOESTATE. This involved modifying the data structures and formats used within the platform to ensure they could effectively integrate and interact with other systems in the DISCOESTATE ecosystem. This standardization helps in maintaining consistency and reliability in data handling across different systems.
    - FM Logistic Dataset Alignment: The platform was enhanced to align with the FM Logistic dataset. This means that the data used and generated by FM Logistic—a

key player in logistics and supply chain services—could be seamlessly integrated with the WareM&O platform. This alignment ensures that data related to logistics operations is accurately reflected and utilized within the platform, enhancing its utility and effectiveness.

- TIF Real Estate System Alignment: The enhancement also included the alignment with the TIF Real Estate system. This likely involved adapting the platform to accommodate and interact with data and processes specific to TIF's real estate management systems, ensuring that real estate and storage aspects are well-coordinated.

2. **Proof of Concept for Logistics Facility Owner/Tenant Electronic Agreement:** Part of the enhancements involved developing a proof of concept for an electronic agreement system between logistics facility owners and tenants. This digital solution aims to simplify and streamline the process of signing and managing contracts, reducing paperwork and increasing efficiency.
3. **Interface with Thessaloniki's UL Dataspace:** Finally, the platform was enhanced to interface with Thessaloniki's Urban Logistics (UL) Dataspace. This integration aims to facilitate the sharing and utilization of urban logistics data specific to Thessaloniki, enhancing the platform's functionality and its ability to support urban storage and logistics solutions in the city.

These enhancements were designed and integrated to broaden the functional scope of the WareM&O platform and improve its integration and utility within broader urban logistics and real estate systems, to better fit in the context of the DISCOESTATE implementation requirements.

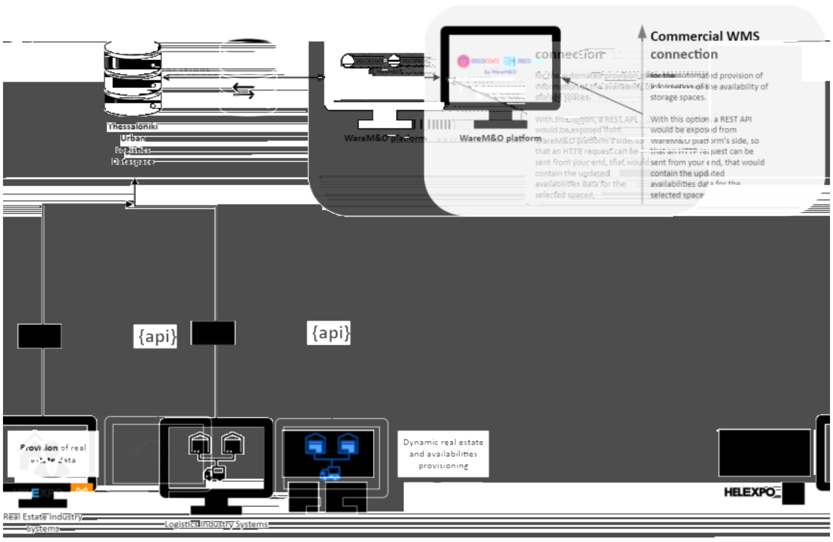

Figure 24: Architectural structure of WareM&O by DISCOESTATE platform

The architecture depicted in the diagram provides a comprehensive system for real-time management and updating of real estate data through a series of interconnected components. At the core is a database that stores detailed information on real estate, which is accessed through APIs labeled for different types of properties, such as residential homes and commercial warehouses. These APIs interface with the WareM&O Platform, a central hub that utilizes blockchain technology to ensure the security, transparency, and immutability of data transactions. This integration is crucial for maintaining trust and accuracy in the data provided. To the right of the platform, a commercial WMS (Warehouse Management System) connection highlights the system's capability to communicate directly with logistical and storage operations, providing automated updates on space availability via a REST API. This allows external systems to query the platform effectively, ensuring that space utilization is optimized, and information is up-to-date.

The platform provides multiple use cases for space owners and users. On the one hand, space owners can list their storage spaces on the platform, detailing the size, features, pricing, and availability. They can manage their listings effectively, including updating information and communicating with potential renters. The platform allows space owners to define compartments within their storage spaces, making it possible to partition larger areas into smaller units tailored to user needs. They can handle booking requests, reviewing and approving or rejecting them based on criteria such as availability and suitability, streamlining the booking process. Space owners also have access to performance metrics and analytics, including key performance indicators (KPIs) that track storage utilization, booking trends, and operational efficiency, enabling them to optimize their storage operations and make informed decisions. On the other hand, the platform offers a tailored search and booking experience, allowing users to find storage spaces that meet specific criteria such as size, location, amenities, and rental duration. Once a suitable space is identified, users can directly book through the platform. The reservation management system provides users with the ability to view upcoming bookings, amend reservation details, or cancel bookings, offering flexibility in managing storage requirements and confirm their agreement with an e-signature document. Additionally, the platform supports collaborative storage solutions by facilitating communication and coordination among users interested in sharing storage spaces to reduce costs and optimize capacity. Users can also provide feedback and rate their storage experiences, enhancing transparency and trust within the community by aiding others in making well-informed decisions.

Urban Access Control (UAC)

The Urban Access Control (UAC) represents an innovative approach to urban mobility and access management. It aims to enhance urban transport systems' efficiency, safety, and environmental sustainability. The UAC focuses on leveraging digitized data to streamline urban access and transportation, addressing various urban challenges, including traffic congestion and pollution reduction.

The primary objectives of the UAC innovation are to increase the visibility of city access regulations and to promote environmentally friendly last-mile delivery options. This is achieved through sophisticated data-sharing strategies among municipalities, logistic service providers, and green last-mile delivery services. UAC aims to optimize these interactions at three critical stages of urban mobility: pre-trip planning, during-trip transport guidance, and post-trip strategic optimization.

These objectives are instrumental in fostering a more sustainable and efficient urban transport environment, which aligns with broader goals of reducing emissions and enhancing the overall quality of urban life.

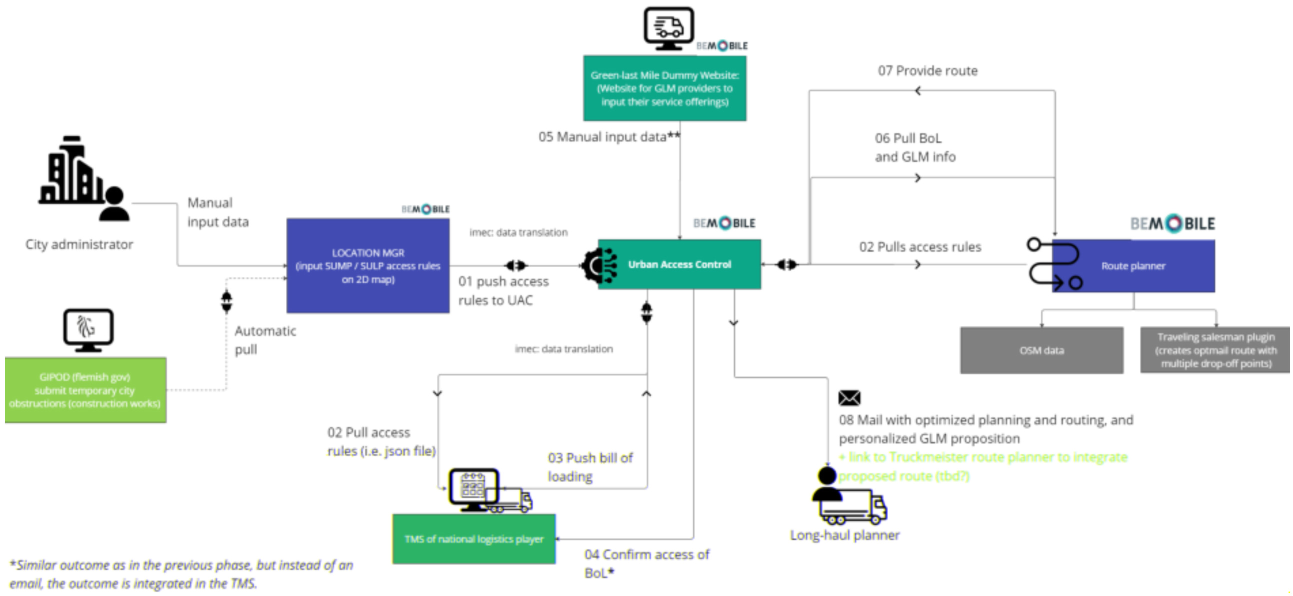

Figure 25: Architectural structure of Urban Access Control (UAC) platform for the case of Ghent

For the case of Ghent, where the Urban Access Control (UAC) system implemented, encapsulates a comprehensive and advanced architectural framework designed to refine urban mobility and enhance logistic efficiencies within the city. Central to its operations is the UAC System which acts as the operational hub, integrating various functional components like the Location Manager and the Transport Management System (TMS). The Location Manager, managed by Be-Mobile, is instrumental in integrating Sustainable Urban Mobility Plan (SUMP) and Sustainable Urban Logistics Plan (SULP) rules into a dynamic 2D mapping interface. This functionality facilitates manual data input by city administrators and also automatically pulls data from external sources such as GIPOD, which tracks temporary urban obstructions. Concurrently, the TMS interfaces seamlessly with the UAC, enabling Logistics Service Providers (LSPs) to comply with the city's access regulations by managing detailed freight data, including bills of loading that encapsulate essential information about freight origins and destinations. Furthermore, the Route Planner, a sophisticated component also operated by Be-Mobile, leverages OpenStreetMap data and incorporates a “traveling salesman” plugin to calculate optimal delivery routes considering multiple drop-offs, real-time obstructions, and urban access rules. At the core, the UAC system synthesizes and enforces these inputs to align freight movement with Ghent’s urban policies and infrastructure capacities. Additionally, the system's architecture is enhanced by the integration of Green Last Mile service offerings, which will serve both Ghent’s DISCOPROXI and DISCOBAY measures, and the Urban Freight Data System (UFDS), promoting sustainable delivery options and enabling continuous route optimization and data feedback mechanisms.

Dynamic Curb management app by DISCOCURB

The concept of DISCOCURB centers on the dynamic management of curb spaces to enhance urban environments by optimizing the use of public spaces, improving mobility, and boosting logistics efficiency. This approach enables cities to better understand, plan, and utilize curb space to benefit residents and businesses alike. Currently, the SPRO app efficiently manages the loading and unloading zones for urban goods distribution. Building on this foundation, a new computer vision application under DISCO will be developed to work alongside the SPRO app. This upcoming app will assess the effectiveness of the SPRO application and continuously monitor curbside activities, further refining the management of urban spaces.

SPRO Application

SPRO is an innovative mobile application designed to revolutionize the management of loading and unloading zones in urban environments, aligning closely with the objectives of improving curb space utilization, enhancing urban mobility, and streamlining logistics operations. Central to the SPRO platform is its ability to offer a comprehensive view of designated spaces for urban distribution of goods (DUM), initially available in Barcelona and its neighbouring municipalities. By integrating digital capabilities such as real-time geolocation, occupancy forecasts, and personalized notifications, SPRO provides city managers and professionals with critical insights into curb usage, facilitating efficient planning and execution of urban logistics.

Within the SPRO ecosystem, the user interface plays a pivotal role. It simplifies the process of finding and booking DUM spaces by allowing users to enter a DUM code visible on street signs, granting access to up to 30 minutes of free parking—extendable by another 30 minutes for zero-emission vehicles in Barcelona.

Figure 26: Street signs for entering DUM

Complementing the user-focused features, SPRO includes advanced administrative capabilities that cater to businesses, enabling the creation of company accounts with multiple user access, overseen by a designated administrator. This function enhances coordination within companies, providing them a tailored experience that supports their specific operational needs.

Figure 27: SPRO User Interface showing real-time availability

Together, the user interface and administrative capabilities of SPRO create a holistic solution that addresses the needs of individual professionals and businesses alike, contributing to more organized and accessible urban environments. By leveraging SPRO, cities can achieve better curb space management, adapt to the evolving demands of urban logistics, and promote more sustainable mobility practices, all while enhancing the overall quality of urban life.

Computer Vision algorithm

The Computer Vision application under development for DISCOCURB represents a significant advancement in the management of urban curb spaces. Leveraging cutting-edge technology, this app is designed to provide an integrated solution for curb space management. The primary function of the Computer Vision app will be to continuously monitor and analyze curbside activities in real-time while, it results will be also used to cross-validate the existing SPRO application.

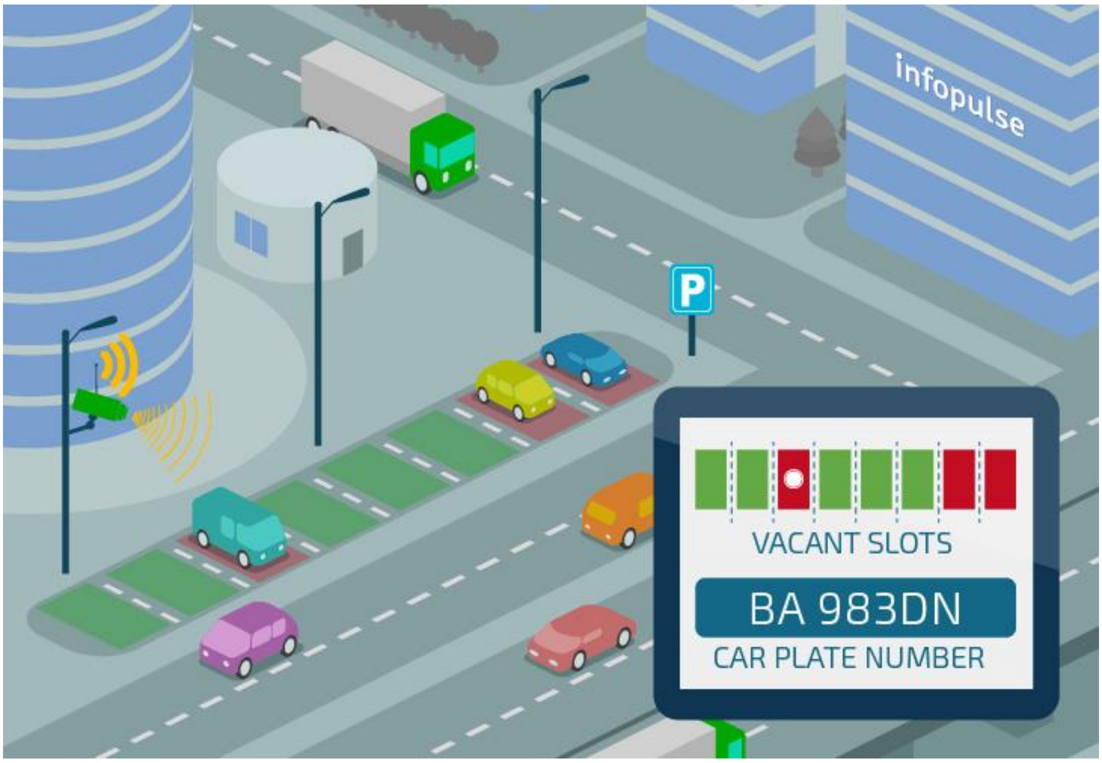

Figure 28: Curbside app for monitoring parking slots

By utilizing advanced image recognition and machine learning algorithms, the app will be able to detect vehicle types, assess compliance with loading and unloading regulations, and monitor traffic flow and parking patterns (Figure 28). Ultimately, the integration of this computer vision technology into DISCOCURB's framework aims to create a more dynamic, responsive, and sustainable urban environment.

5.4. External Interfaces

The aforementioned library of DISCO-X tools contains tools with defined data requirements. For a city to connect to the Meta Model Suite and use these tools for optimizing its logistics operations and planning, a connection with the DISCO Urban Freight Dataspace is necessary. The data used by these tools must be sufficient in quantity and meet the required quality based on the respective tools' specifications. To facilitate this, one of the DISCO-X tools, DISCOLLECTION, addresses this need. DISCOLLECTION, through a Smart Data Platform developed by the DISCO-X owner IMEC, operates as an intermediary system to serve this purpose.

5.4.1. Smart Data Platform (DISCOLLECTION platform)

In terms of architecture, the Smart Data Platform fits within the Meta-Model-Suite but is connected to the UF Data Space, serving as a go-between for the connected and non-connected actors in the

UF Data Space. This platform enables all onboarded data sets to be part of the broader Data Space Catalog. Consequently, DISCOLLECTION offers a temporary solution to make access to the UF Data Space's content more widely available for consumption within the rest of the DISCO-X solutions. It will gather data from the living labs and transform the data when ingested towards the chosen data model. The Smart Data Platform will be connected with a dataspace connector and become a provider to the UFDS. Figure 29 shows how the LL will provide an easy-to-use API that can be used to retrieve data over the web as suggested by the Meta-Model Suite DISCO-X innovation.

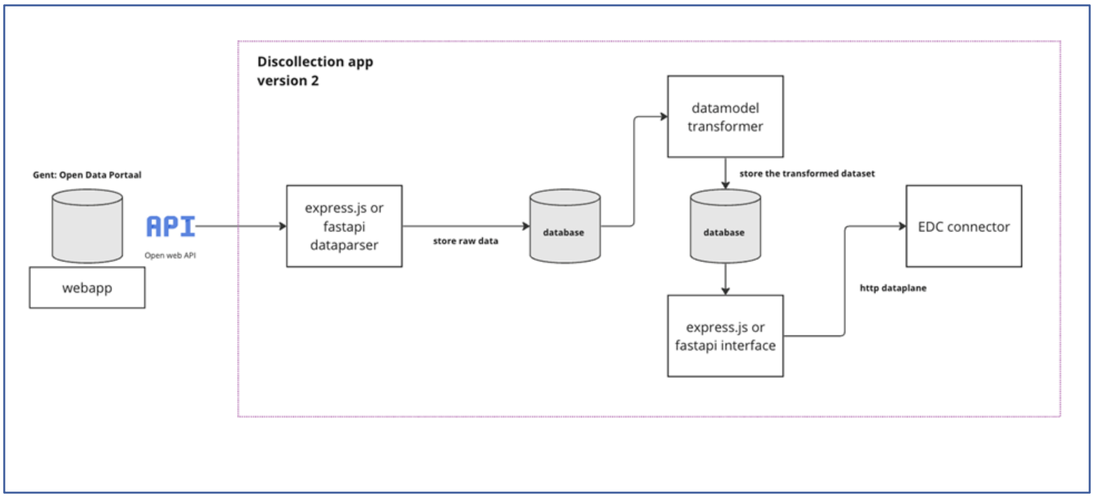

Figure 29: Architecture of the Smart Data Platform that will be developed under the context of the DISCOLLECTION innovation

5.4.2. The DISCO Urban Freight Dataspace

The DISCO Urban Freight Data Space (UFDS) functions as a comprehensive ecosystem where data providers contribute with predefined datasets, processed under confidentiality agreements. It deploys online tools and services to utilize this data, with the resulting analyses stored within the system for users to access and assess the findings. Additionally, it serves as an example of a federated platform that a city, aiming to optimize its logistics ecosystem and ensure the orderly operation of the urban freight domain, should follow as suggested by the Meta-Model Suite. The UFDS serves a critical role in facilitating efficient urban freight logistics through robust data integration and connectivity. By acting as a decentralized platform, the UFDS enhances the exchange of data among stakeholders, such as municipalities, city planners, and logistics operators, without storing the data itself. This ensures data sovereignty and security, promoting a trust-based environment where metadata about data availability is managed and exchanged.

The minimum UFDS structure to support this functionality includes four main components (using at this stage the data coming from two Starring Living Labs) as presented in the Figure 30 below:

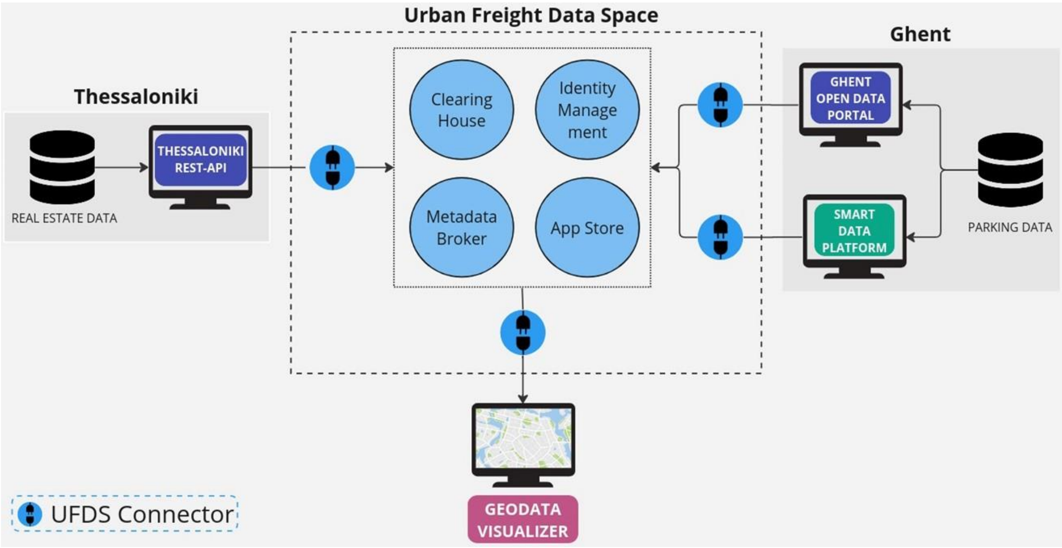

Figure 30: The UFDS components

1. One component is the **Metadata broker / federated catalogue** which will store all the metadata from the data assets in the connectors. The federated catalogue will be able to be browsed by the participants to find the relevant data they would like to utilise in their living lab. A suggestion of a metadata broker can be a datahub federated catalogue. Next is the Vocabulary Hub, where ontologies, reference data models, or metadata elements can be used to annotate and describe datasets, usage policies, apps, services data sources etc. are needed in the UFDS to make the data readable across the different living labs. The Living Labs are located in different countries and might have different interpretations of the data. The vocabulary which will include the data models chosen for the datasets in the DISCO-X applications will serve the purpose of making the data interoperable.
2. **Identity Provider components**
    - **Certificate Authority**: This component ensures that only registered and verified organizations can operate within the UFDS. It manages certificates that affirm the authenticity and integrity of the participants.
    - **Dynamic Attribute Provisioning Service (DAPS)**: Offers up-to-date information about the participants and connectors, such as supported transport certificates, enhancing security and compliance.
    - **Participant Information Service (ParIS)**: Provides business-related information about the participants, facilitating informed and secure interactions within the data space.
3. The **Clearing House** is a crucial logging component that logs activities relevant to data usage, clearing, and billing. This service supports the Data Space Operator with the automation of billing processes and validates usage claims, ensuring accountability and transparency in data utilisation.
4. Last but not least is the **App Store** which serves as a platform for registering and distributing applications developed for the UFDS. This feature enables the easy search and provisioning

of applications, enhancing user interaction and accessibility to tools that leverage the data space for urban freight management.

A key proof of concept application within the UFDS is the **City Geo-Data Visualizer**. This application is designed to showcase the capabilities of the data space by providing a user-friendly interface (similar to Google Maps) that displays geospatial data. Users can view detailed polygons and points on a map, along with properties such as parking zone pricing and building characteristics.

A use case of how the Meta-Model Suite utilizes the functionalities of the Urban Freight DataSpace is presented in the next chapter.

5.5. Dashboard

The dashboard is an essential component of the Meta Model Suite designed to provide a comprehensive and interactive overview of each city's urban logistics planning and implementation progress. This dashboard serves as a centralized platform that integrates the outcomes of various components of the Meta Model Suite, ensuring that city planners, policymakers, and stakeholders have access to all relevant information in one place. For each city, a customized dashboard will be developed to include several key elements:

- **PI-led Innovation Readiness Assessment:** This section of the dashboard will display the results of the PI-led innovation readiness assessment, providing insights into the city's preparedness for adopting Physical Internet principles in urban logistics.
- **Digital Transition Assessment:** The dashboard will feature the outcomes of the Digital Transition Assessment, detailing the city's maturity in digital transformation and highlighting areas for improvement.
- **Selected Scenarios:** Users will be able to view the selected scenarios that guide the city's digital transformation strategy, ensuring alignment with strategic goals and logistics challenges.
- **Selected DISCO-X:** The dashboard will showcase the chosen DISCO-X innovation, providing details on how it will be implemented and its expected impact on the city's urban logistics.
- **Blueprint of the City's Local Dataspace:** This section will outline the blueprint for developing the city's local urban logistics dataspace, including necessary steps and infrastructure requirements.
- **Transition Path for Implementation:** The dashboard will present a detailed transition path, illustrating the steps needed to move from the current state to the desired future state, incorporating the selected DISCO-X and other innovative solutions.
- **Checklist of Tools, Datasets, and Infrastructure:** A comprehensive checklist will be included to ensure that the city meets the minimum requirements for datasets, tools, and infrastructure essential for DISCO-X implementation. This checklist will provide detailed

6. Development Process

The implementation process of the Meta Model Suite in the DISCO project embodies a rigorous and structured approach, adhering to a phased methodology that iteratively cycles through needs identification, specification definition, architectural design, development, testing, and assessment. This cycle begins with a thorough needs analysis, where the specific requirements of urban logistics stakeholders are gathered and analyzed to ensure the suite addresses real-world challenges effectively. These needs are then translated into detailed specifications that outline the functionalities, user interfaces, and performance criteria the suite must meet. Following specifications, the architectural phase lays down the structural blueprint of the suite, detailing the technological frameworks, data flows, and integration points with existing systems, ensuring scalability and interoperability.

Development is the next critical phase, where the suite is built according to the predefined architecture and specifications. This phase employs modern software development practices to create robust and modular components that can be updated independently, facilitating easier maintenance and upgrades. Testing is conducted concurrently with development in a controlled environment where functionalities are rigorously evaluated against the specifications to identify any discrepancies or areas for improvement. This testing phase is crucial for ensuring reliability and effectiveness before the suite is deployed in more complex real-world scenarios. The final phase, assessing, involves evaluating the suite in operational settings to gather feedback from end-users and stakeholders. This assessment focuses on the suite's performance in live environments, usability, and its ability to integrate seamlessly into the urban logistics ecosystem. Insights gained from this phase feed back into the needs analysis, perpetuating the cycle of improvement in a methodical and structured manner. An ongoing and repetitive process was selected mainly to improve the product while also adapting to changing needs and technological advancements, keeping the DISCO Meta Model Suite at the cutting edge of innovation in urban logistics solutions.

Regarding Agile methodology, the development of the Meta Model Suite within the DISCO project leverages this adaptive approach to foster rapid prototyping, continuous improvement, and responsive feedback integration. The Agile methodology in this context breaks the project lifecycle into smaller, manageable phases of development, testing, and assessment. Each phase, or sprint, starts with a planning stage where development goals are set based on the current priorities and feedback from previous sprints. The development phase follows, where new features and functionalities are built, or existing ones are enhanced based on the sprint goals. This development is done in short bursts, allowing for quick adjustments and flexibility in feature rollout. Testing is integrated throughout the development phase, with continuous checks and evaluations to ensure that new developments meet the desired standards and function correctly within the suite. This integrated testing helps in identifying bugs and issues early in the cycle, making it easier to address them without significant backtrack. After development and testing, the sprint concludes with an assessment phase, where the outcomes are reviewed with stakeholders. This review focuses on evaluating the progress against the project goals and gathering feedback from the users. This feedback is crucial as it informs the next planning phase, allowing the project team to adapt the product development roadmap to better meet user needs and accommodate any changes in the project scope. This Agile approach ensures that the Meta Model Suite is developed in a user-focused and flexible manner, allowing for ongoing adjustments and refinements based on direct stakeholder input and real-world testing. It embodies a dynamic development ethos that is well-suited to the complex and ever-changing landscape of urban logistics technology.

In the DISCO project, in alignment with "D4.1 Agile Model Implementation Roadmap" the development of the Meta Model Suite is meticulously orchestrated using an Agile methodology, ensuring a flexible and responsive adaptation to the evolving needs of stakeholders across the lifecycle of the project. This strategic approach is characterized by iterative cycles and continuous feedback, crucial for aligning the suite's evolution with both the dynamic demands of urban logistics and the specific goals of the project.

From the onset in the initial phase (M1-M4), the groundwork is laid with the drafting of DISCO-X implementations and requirements, setting the stage for the Meta Model Suite's foundational functionalities. This early phase is pivotal in defining the broad capabilities and scope expected of the suite. Transitioning into Agile Cycle 1 (M4-M8), the project sharpens its focus, refining user stories and laying out detailed specifications that cater to the needs of multi-agent interactions within the urban logistics framework. This period involves rigorous iteration planning, architectural design, and the first cycles of development and testing, with each step designed to incrementally build upon the suite's functionalities while integrating stakeholder feedback to refine the user interface and enhance functionality.

As the project approaches M14 and gears up for the midterm review at M18, this phase marks a critical juncture where the first comprehensive draft of the Meta Model Suite will be presented. This draft will showcase the initial application of the Agile methodology alongside the core functionalities developed from continuous iterations and feedback up to this point. Expected to reveal the suite's foundational architecture and primary functionalities, the M18 review serves as a vital checkpoint to assess alignment with the overarching project goals and the suite's adaptability to the complex, multi-agent systems integral to urban logistics.

Post-M18, from M18 to M30, the development enters a phase of intensive refinement, expanding on the initial functionalities and integrating advanced features. This fine-tuning phase leverages insights from the midterm review, focusing on enhancing the suite's scalability, interoperability, and robustness under diverse urban logistics conditions through rigorous testing in the Living Labs. Throughout this period, the Agile methodology remains central, fostering a dynamic environment where flexibility and responsiveness to stakeholder feedback are prioritized. Continuous communication channels facilitate an ongoing exchange of ideas, with regular sprint reviews and planning sessions ensuring that each iteration aligns with and anticipates emerging trends and stakeholder needs.

By M30, the DISCO project aims to deliver a fully developed and finely tuned Meta Model Suite that embodies a broad spectrum of functionalities designed to enhance its utility in real-world applications. The suite is expected to support complex decision-making processes, integrate seamlessly with existing urban infrastructures, and provide scalable solutions to accommodate future technological advancements. This journey from M14 to M30 is not merely about technical development but also about cultivating a collaborative ecosystem where technology meets practical application. The ultimate goal is to provide a comprehensive tool that empowers cities and logistics stakeholders to innovate and improve efficiency through advanced digital solutions, meticulously shaped by real needs and iterative feedback, setting new standards in urban logistics.

The development of the Meta Model Suite within the DISCO project exemplifies a robust, phased approach that strategically integrates Agile methodologies to address the evolving needs of urban logistics stakeholders. Initiated with a comprehensive needs analysis as outlined in D2.1 at M9, the project advances through iterative cycles encompassing specification, architecture design, and developmental stages, culminating in a thorough assessment and refinement process. At M14, architectural frameworks are established, marking the transition towards practical implementation phases which intensify post the mid-term review at M18. This review evaluates the initial deployments of the suite's functionalities, setting the stage for subsequent refinement in response to real-world feedback from pilot implementations with cities and sector experts. By M30, the suite is expected to be fully developed, incorporating advanced features tailored to enhance decision-making and integration within urban infrastructures. The project's trajectory from initial concept through to the final documentation at M36 showcases a dynamic interaction between theoretical planning and practical application, driven by continuous stakeholder engagement and adaptive iteration, ensuring the suite's relevance and efficacy in transforming urban logistics.

7. Conclusions & Next Steps

The development and deployment of the Meta Model Suite (MMS) within the DISCO project framework have ushered in significant advancements in the domain of urban logistics, particularly through the integration of the Physical Internet (PI) paradigm. The suite has proven instrumental in redefining traditional logistics models, facilitating efficient, sustainable, and technologically enhanced urban logistics operations. As cities continue to face escalating challenges related to traffic congestion, pollution, and service delivery expectations, the MMS provides a strategic toolset designed to transform urban logistics systems into dynamic, data-driven networks. The adaptability and comprehensive nature of the MMS allow for a tailored approach to urban logistics, enabling cities to address specific logistical challenges and optimize overall logistics performance.

Looking forward, the next steps involve a dual focus on expansion and deepening of the suite's capabilities. First, an expanded phase of pilot testing across multiple urban environments is essential to assess the adaptability of the MMS to various urban logistics scenarios and to gather a broader spectrum of feedback. This feedback will be crucial for refining the MMS' functionalities and ensuring its robustness and user-friendliness across different regulatory and cultural contexts. Secondly, there is a need to deepen the technological capabilities of the MMS, particularly focusing on integrating its architecture with the DISCO Urban Freight DataSpace. Aligning these two systems is critical as the project progresses, ensuring they complement and fit within each other's frameworks.

Moreover, continuous collaboration with stakeholders—ranging from urban planners and city authorities to logistics service providers and technology developers—is vital for the ongoing development and refinement of the MMS in order to facilitate the practical application of the MMS tools and to ensure that the suite evolves in line with the latest urban logistics trends and technologies. Finally, the dissemination of findings and the development of training modules for city planners and logistics operators will be critical to promote the adoption of the MMS and enhance its impact on urban logistics systems globally. These steps will ensure that the MMS remains at the forefront of innovation in urban logistics, driving further advancements towards more livable and efficient cities.

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