D4.6: LEAD Roadmap and Policy Recommendations

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Reviewers List

Name	Company	Date	Signature
Baptiste Mougeot	Lyon Confluence	06/10/2023	

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Acronyms

Acronyms	Explanation
API	Application Programming Interface
B2B	Business to Business
B2C	Business to consumers
CO_2	Carbon dioxide
CoP	Communities of Practice
DT	Digital Twin
EC	European Commission
EGD	European Green Deal
EU	European Union
EVs	Electric Vehicles
GHG	Greenhouse gases emissions
HORECA	Hotel / restaurant / catering
ICT	Information and communication technology
IoT	Internet of Things
ITS	Intelligent Transport Systems
KPIs	Key Performance Indicators
LEAD	Low-Emission Adaptive last-mile logistics supporting 'on Demand economy' through digital twins
LCV	Light Commercial Vehicle
LEZ	Low-emissions zone
LL	Living Lab
LNG	Liquefied Natural Gas
LSP	Logistics Service Provider
NO_2	Nitrogen dioxide
PI	Physical Internet
PPP	Public-private partnership
R&D	Research & Development

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SaaS	Software-as-a-Service
SSMS	Smart and Sustainable Mobility Strategy
SULP	Sustainable Urban Logistics Plans
SUMP	Sustainable Urban Mobility Plans
TEN-T	Trans-European Transport Network
UCC	Urban consolidation centre
WEF	World Economic Forum

Executive Summary

Urban freight transportation is crucial for cities even if it has many externalities. However, due to several phenomena, including population expansion, urbanisation, rising consumer demand, and online shopping, urban logistics has grown significantly in recent years. Decision-making and operational planning in urban logistics have gotten trickier as a result. Cities must create technology and processes that can assist in addressing and better managing urban logistics as a result of these challenges.

Due to their comprehensive approach in integrating information from multiple quantitative domains like machine learning and mathematical optimisation to model and optimise the operational environment through constant data interchange with it, Digital Twins (DTs) have been utilised to address urban logistics difficulties.

Due to their potential to give users a greater understanding and sense of control over their assets, DTs already play a significant part in industrial transformations. Through real-time decision support modelling and impact prediction, DTs offer public administrations a smart and affordable way to improve not just urban logistics but also the ecological and financial outcomes.

One of the main outcomes of LEAD has been the creation of an open-source platform and experimented in six Living Lab's (LLs) activities. This document explores the potential of DTs for data-driven decision making on urban freight.

Despite its many benefits, DT adoption is hampered by problems with transparency and trust, particularly when it comes to data quality. A set of policy recommendations to accelerate the acceptance and implementation of DTs is provided below, based on the findings and key lessons from the LEAD project and the local pilot activities conducted in six European cities:

1. **Privilege a comprehensive strategy and a long-term outlook:** the creation of DTs must be driven by demand, data, and people.
2. **Invest in training and development:** teams with qualified modellers, e.g. from academic institutions and reliable IT firms, would be very helpful for local authorities looking to develop DTs.
3. **Encourage interdisciplinary specialists to increase innovation:** urban planners, commercial technology and logistics companies, research centres, universities, and other actors are urged to cooperate in the creation and sharing of DTs technologies.
4. **Data quality is important:** precise guidelines and rules for the gathering, storing, and usage of data in the DT environment are needed. The set-up of data security measures should be a top priority to safeguard sensitive data and guarantee adherence to privacy rules.
5. **Adopt open data standards and encourage interoperability:** do this to make sure that DTs can quickly connect to different systems and data sources.
6. **Promote public-private collaboration:** participants from the public and private sectors should work together to better understand one another's challenges and develop novel solutions.

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7. **Encourage co-creation with important stakeholders:** LLs for urban freight are a good approach to involve various city agencies and partnerships for freight quality, bringing together all stakeholder groups to talk about the core problems with urban freight distribution.
8. **Involve stakeholders in the decision-making process:** before any implementation is carried out or before long-term decisions are taken, urban planning scenarios can be simulated on DTs.
9. **Prioritise measures according to the cities SULPs / SUMPs:** prioritise DTs that cover the measures that are planned to be implemented in the future and develop specific use cases for testing and impact assessment.
10. **Identify issues that need to be addressed on a short-, medium-, and long-term basis.** green technologies and sustainable practices may cost initial outlays of money, but they can have long-term strategic advantages that benefit present and future generations.

1 Introduction

LEAD created Digital Twins (DTs) of urban logistics networks in six cities - Madrid, The Hague, Lyon, Budapest, Oslo, Porto - to support experimentation and decision-making with on-demand logistics operations in a public-private urban setting.

Innovative solutions for city logistics have been represented by a set of value case scenarios addressing the requirements of the on-demand economy while aligning competing interests and creating value for all different stakeholders. Each value case combined several measures (so-called LEAD strategies):

- innovative business models,
- agile urban freight storage and last-mile distribution schemes,
- low-emissions, automated, electric, or hybrid delivery vehicles,
- smart logistics solutions.

Cost, environmental, and operational efficiencies for value cases have been measured in six LLs. Evidence-proven value cases and associated logistics solutions have been delivered in the form of exploitable DTs, incorporating the models that support adaptation to different contexts and that provide incentives for Public-Private Partnerships (PPPs).

The LEAD consortium comprises 22 partners, all of whom are involved in the LLs. This structure incentivised the co-creation of solutions by city authorities, logistics industry leaders, start-ups, and research experts in freight modelling, complex simulation and logistics optimisation.

The long-term vision of LEAD has been to design an Open Physical Internet (PI)-inspired framework for Smart City Logistics that incorporates the created DTs, laying the foundations for the development of large-scale city DTs.

This deliverable is addressed to EC Services and EU policy makers, transport and logistics experts working in cities, regions and local authorities, network organisations representing local authorities, transport operators and IT managers. More specifically, they are identified as:

- Key staff from the EC and other EU institutions, working on urban mobility, spatial and logistics policies, climate policies.
- A wide audience composed of political representatives, policy makers, practitioners and experts in transport working for cities, regions and local authorities.
- Private and business sector, notably from the logistics and freight industry (freight forwarders, shippers, etc.).

2 The EU policy framework

According to Foresight Climate & Energy (FCE), freight transport represents a significant component of traffic in cities (10-15%), as well as air pollution[1]. It accounts for up to 25% of carbon dioxide emissions from transport, and 30-50% of nitrogen oxide and fine particles[2].

In 2011, the European Union (EU) set an explicit target of 'essentially CO_2-free city logistics in major urban centres by 2030[3], followed by a call for local actors to take action on sustainable urban logistics[4], also via the Horizon 2020 Programme.

The EU, following the Paris Agreements, is committed to being the first zero-emission continent. The process to achieve this goal involves reducing emissions for each economic sector. In the field of transport and logistics, the obstacles are even greater, as transport demand is expected to triple, with a consequent doubling of emissions by 2050 (International Transport Forum, 2019)[5].

The European Commission (EC) works closely with Member States to implement and enforce a regulatory framework for last-mile logistics. This involves monitoring compliance, providing guidance, and facilitating cooperation among stakeholders. The regulatory framework has been established to ensure efficiency, sustainability, and fairness of last-mile logistics operations within the EU. Key regulations and directives include:

- Directive 2008/50/EC - Ambient Air Quality and Cleaner Air for Europe. This directive set air quality standards and objectives. It indirectly affected last-mile logistics by influencing environmental policies, especially those related to vehicle emissions.
- Directive 2010/40/EU - Framework for the Deployment of Intelligent Transport Systems (ITS). This directive promoted the use of Intelligent Transport Systems, including those related to last-mile logistics, to improve the efficiency and sustainability of transport.
- Urban Mobility Package (2013). This package aimed to address urban mobility challenges, including last-mile logistics, by encouraging sustainable and efficient transport solutions in urban areas.
- Directive (EU) 2021/539 - Sustainable and Smart Mobility Strategy (SSMS). This recently adopted directive outlines the EU's vision for sustainable and smart mobility. It addresses various aspects of transport, including last-mile logistics, with a focus on reducing emissions and enhancing efficiency.

[1] *Foresight Climate & Energy, 2019. Transforming urban deliveries for zero emission cities.*
[2] *Ibidem.*
[3] *European Commission, 2011, Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system.*
[4] *European Commission. 2013. A concept for sustainable urban mobility plans, Annex to the Communication to the European Parliament, the Council, the European Economic and Social Committee of the Regions. COM 913 final.*
[5] *International Transport Forum. (2019). ITF Transport Outlook 2019.*

Even though urban freight is highlighted as a major issue to be addressed, it is often neglected in transport and urban planning. In 2021, the EC found that only 13% of cities have a Sustainable Urban Logistics Plan (SULP)[6].

There are several reasons for this. One is the lack of sufficient freight experts employed by governments. Another is that municipalities tend to incorrectly assume that urban freight is the solely responsibility of the private sector. After all, local governments are responsible for setting land use and zoning rules, curb regulations, truck routes, time of day loading and unloading restrictions, vehicle requirements and more — all of which play a major role in the sustainable and efficient flow of goods.

In recent years, cities have grown more concerned with how urban logistics affect traffic, noise, pollution, land usage, and traffic accidents. The EU is working to achieve the 90% reduction in emissions by 2050, as promised by the Climate Law, delivered by a smart, competitive, safe, accessible, and cheap transportation system, in accordance with the European Green Deal (EGD)[7] and the SSMS[8]. By defining initiatives like "*Making interurban and urban mobility healthy and sustainable*" and "*Greening freight transport*", the SSMS seeks to increase the sustainability of all forms of transportation. Offering widespread access to well-managed, secure, and ecologically friendly transportation is one way to do this.

The introduction of new vehicle technology in the upcoming years will have an impact on how urban freight transportation develops. Research and innovation projects can have a great impact on how new technologies will affect urban freight and how to effectively utilise them.

The EC in collaboration with local governments continue to adapt and refine the regulatory framework for last-mile logistics to keep pace with technological advancements, sustainability goals, and changing consumer demands. In this direction, the LEAD project results and recommendations can guide policy makers towards leveraging the use of DTs and promoting PPPs.

[6] *https://transport.ec.europa.eu/system/files/2021-12/com_2021_811_the-new-eu-urban-mobility.pdf*
[7] *https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en*
[8] *https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12438-Sustainable-and-Smart-Mobility-Strategy_en*

3 Main challenges of urban logistics

Logistics is one of the most active and fast-developing areas of urban transportation. With the emergence of on-demand logistics, last-mile delivery systems are straining to meet public expectations for responsive logistics systems delivering goods at low or even no cost. The COVID-19 pandemic has shown how crucial it is for the supply chain to be resilient, with the last-mile being the most challenging stretch. Consumer purchasing behaviour is also changing as more people use online, on-demand platforms. Therefore, this pressure on city logistics systems must be efficiently mitigated.

The demand for freight transport is expected to more than double over the next three decades, and in 2019, it was responsible for more than 40% of all transportation-related CO_2 emissions. According to a report by the World Economic Forum, the rise in last-mile delivery activities alone is expected to raise GHG emissions by 30%[9].

Urban freight transportation involves numerous journeys, modest loads, and short distances. Despite having a limited activity (3% of all freight activity), these movements are extraordinarily carbon-intensive, contributing 20% or more of all freight emissions. About 70% of all vehicles used for road freight are Light Commercial Vehicles (LCVs). The characteristics of LCVs used for last-mile urban deliveries make them particularly well-suited for electrification. By predicting the daily distance of the vehicles, optimal battery capacity and charger installations can be made. LEAD has achieved the granting of a patent for electric vehicles dynamic charging (LEAD Deliverable D5.2).

A study conducted by the World Economic Forum (WEF) reported that e-commerce recorded 129% of annual sales growth and 146% growth in terms of the number of orders[10]. The same study noted that the demand for last-mile deliveries in urban areas will rise by 78% by 2030, resulting in a 36% increase in delivery vehicles within inner-city limits.

The massive wave of e-commerce change presents enormous logistical challenges. The greater variety of products offered by e-retailers (heavy-tailed product portfolio) and the smaller, more individualised nature of e-orders all contribute to operational complexity and higher logistics costs. Short lead times for deliveries (responsiveness) necessitate quick pick-up times, prompt transportation, and the physical presence of inventory close to delivery locations.

Particularly, the growth of on-demand logistics poses serious obstacles for cities as they need to carefully plan and implement policies and infrastructure improvements to address these challenges.

- Cities must implement traffic management measures because on-demand services increase traffic congestion, especially during peak hours.
- An increase in the number of delivery vehicles, especially those with conventional internal combustion engines, may result in an increase in air pollution and greenhouse gas emissions.

[9] *International Transport Forum. (2019). ITF Transport Outlook 2019.*
[10] *The Future of the Last-Mile Ecosystem, Transition Roadmaps for Public- and Private-Sector Players, WEF, 2020.*

- The increased load from on-demand logistics is too much for the existing infrastructures to handle. To accommodate the increased traffic, roads, bridges, and other transportation infrastructure must be upgraded.
- When space is scarce in densely populated urban areas, cities must designate appropriate parking and loading/unloading zones. For curb space, there is competition from on-demand services, ride-sharing, public transportation, and private vehicles. It is a significant challenge to efficiently manage this area to allow for all modes of transportation.
- Greater noise levels caused by increased delivery vehicle activity can be disruptive for local businesses and residents.
- Since there is a risk of accidents increasing as there are more delivery vehicles on the roads, safety precautions must be enforced. To ensure that on-demand logistics companies adhere to safety standards, emission caps, and other legal requirements, cities must establish and enforce regulations.
- Customers' location and preferences are among the extensive amounts of data that on-demand logistics platforms gather about them.
- Ensuring the privacy and security of this data is a critical concern.
- It is difficult to guarantee that all residents, including those in underserved communities, have access to on-demand logistics services.
- It can be challenging and requires systemic planning to coordinate on-demand services with the current public transportation systems.

In consideration of the above, one of the solutions is the creation and implementation of digital solutions that can boost the network's and multimodal hubs' efficiency. A key building block for the LEAD project has been the development of an open DT infrastructure for urban logistics, enabling city and industry actors to take decisions on the preferable delivery solutions to be implemented. The approach employs simulation tools to experiment with possible strategies and business models, aiming at boosting end-user adoption and increase investors' confidence.

4 What are Digital Twins

Every day, cities are faced with making important decisions when it comes to mobility. How can traffic jams and rush hours be reduced? Where should new cycle paths be added? How can public transport be improved?

A DT allows urban planners to answer such questions in a virtual model and test alternative scenarios for potential interventions. This helps keeping an overview and enables them to make the right decisions, while making use of the costs and risks of failure in the real world.

DTs are virtual replicas of physical objects, systems or processes that organisations can use for a variety of purposes, such as production line control, object malfunctions or performance monitoring. The physical and digital worlds are connected through DTs.

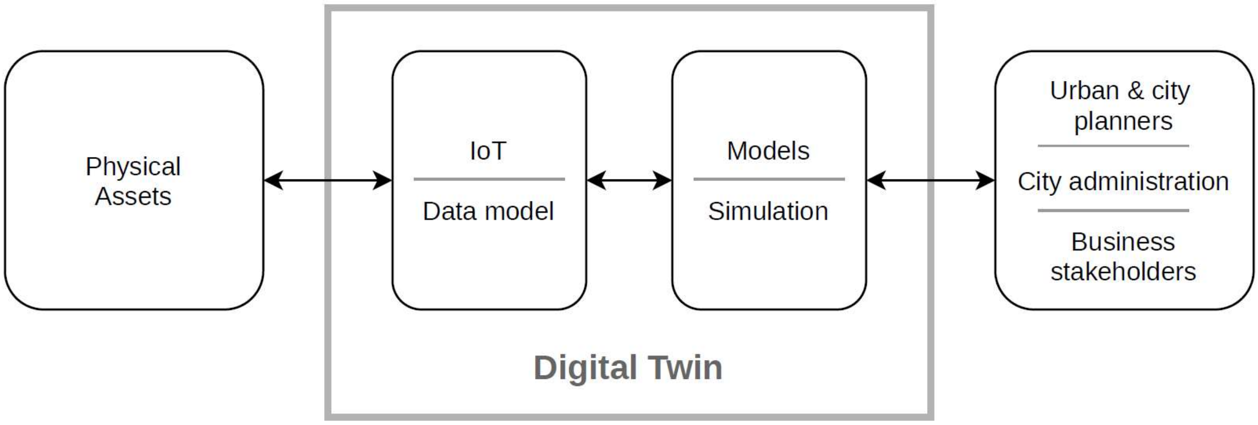

Figure 1 Digital Twin

DTs are based on data, algorithms, and modern Information Communication Technology (ICT) infrastructures. In cities, a lot of data are generated every day, by sensors, traffic cameras and tracking devices. This includes traffic data from all modes of transport, such as cars, lorries, and public transport, as well as socio-economic data such as living and working demographic information.

The impact of DTs on the industry is significant. They can provide knowledge that can be used to improve products, optimise processes or reduce manufacturing, production and delivery costs.

DTs technology finds applications in various domains, including manufacturing, energy, healthcare, transportation, and urban planning. Today, DTs can model entire systems: a building, an aircraft, a city, a logistics' value chain or a factory, for example. Once developed, DTs can be used to run two types of simulations:

- Present-based: visualising how the physical system would respond if current conditions were changed.
- Future-based: run predictive simulations to show responses to future conditions.

Specifically in the transport industry, DTs are anticipated to drastically change the transport systems' technology, as they enable monitoring of the whole transport system life cycle. DTs can help manage traffic and avoid traffic jams with real-time traffic information, optimise public transport (e.g., to the number of people using it by leading busses to event locations) and enhance mobility infrastructure using smart sensors.

DTs are becoming a reality thanks to the deployment of a few cutting-edge technologies. Firstly, the Internet of Things (IoT) and the advent of 5G make it possible to multiply the number of measurement sensors to better understand the different events taking place within a logistics chain.

Cloud computing and big data make it possible to store, analyse and interpret this data. Numerous on-premises and Software-as-a-Service (SaaS) software applications have been developed to optimise warehouse and transport management.

Machine learning make it possible to develop new autonomous systems to facilitate decision-making based on real-time operating conditions. Finally, 3D modelling and augmented reality tools enable content to be displayed in an "immersive mode", providing a new vision of logistics' infrastructure.

5 Digital Twins for city logistics

5.1 An overview

The planning and development of urban logistics policies can benefit greatly from the use of DTs to support experimentation under uncertain conditions. Urban freight planning using DTs, however, is still a relatively new field of study.

The complexity of DT is increased by the fact that urban freight planning involves longer feedback loops that rely on the cooperation of numerous independent agents. In order to develop a variety of logistics solutions for shared, connected, and low-emission logistics operations, the LEAD project proposed a framework and digital twinning platform for designing and evaluating targeted urban logistics policies, underpinned by an adaptive modelling approach. This framework advances research in DTs applied to city logistics and is core to the LEAD project vision (see Figure 2).

The DTs integrates data sources, models, and software tools, that enable a comprehensive evaluation of logistics operations considering contextual indicators such as emissions, congestion, and noise, as well as operations performance indicators, labour and costs impact.

Digitalising the entire urban logistics supply chain supports policy making and business decisions. Policy makers and operators can respond to emerging questions such as "*what are the effects of defining new low-emission zones?*"; "*what if we shift urban consolidation centre location, set up new ones or use other types of vehicles*?

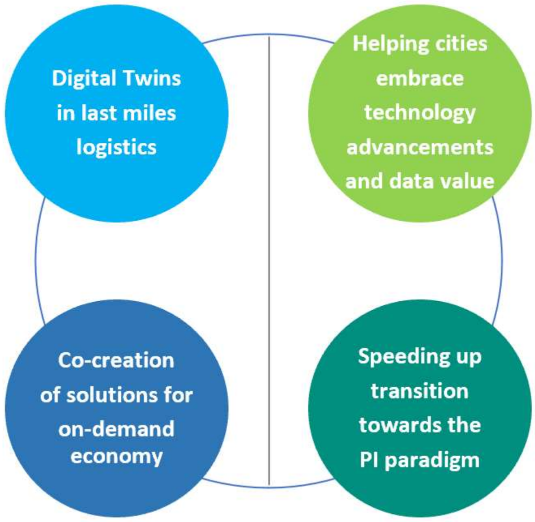

Figure 2 LEAD Innovations

5.2 What is the LEAD Platform?

The LEAD Platform is a sophisticated tool designed to assist in the optimisation of last-mile logistics operations, developed within the scope of the LEAD project. It provides an environment for simulating complex logistics scenarios, simplifying the evaluation process of several strategies, interventions, and policy decisions to promote sustainable last-mile deliveries[11].

What are its key features and benefits?

1. Impact Assessment: the LEAD Platform allows users to simulate complex logistics scenarios, making it possible to assess the impact of different interventions on operations. For example, it can help determine how changes in fleet vehicles, last-mile network configurations, or delivery methods affect efficiency.
2. City Logistics Strategies: city authorities can use the platform to evaluate alternative logistics strategies tailored to their urban environments. This includes optimising routes, delivery hubs, and vehicle types to reduce congestion and the environmental impact.
3. Data-Driven Decision-Making: the platform empowers decision-makers with well-informed insights. Users can explore "what-if" scenarios, such as changes in demand, handling times, or network configurations, to make informed choices that improve logistics efficiency.

How can you use the LEAD Platform?

To use the LEAD Platform, models must be integrated into the system. This is achieved by creating ad-hoc software containers based on the Docker technology[12] for each model, and by creating clear standardised specifications of their inputs, outputs, and metadata. The LEAD Platform enables users to connect multiple models in scenario workflows, facilitating data exchange between them. Users can

11 Please refer to deliverables D2.4 and D2.6 for technical details on the LEAD platform technical implementation. (https://www.leadproject.eu/resources/ resources/)

[12] *Docker framework website, https://www.docker.com/*

configure simulations by specifying scenarios and input data, which can be uploaded or selected from existing datasets created by the LEAD project's LLs. Once the simulation configuration is completed, the platform executes the simulation, providing users with graphical representations of the results.

Simplifying last-mile logistics, one simulation at a time

The LEAD Platform is a powerful tool that simplifies logistics decision-making by offering a robust environment for simulating and evaluating complex scenarios. It empowers logistics professionals and city authorities to optimise last-mile logistics operations, reduce costs, and minimise environmental impact. By harnessing the LEAD Platform's capabilities, users can make data-driven decisions that enhance the efficiency of logistics networks. The platform is a valuable resource for logistics professionals and city authorities seeking data-driven insights to enhance their operations.

In the LEAD project, DTs have been developed and tested for the 6 LLs. The DTs have been integrated in the LEAD platform, providing a virtual sandbox for experimentation endowed with the following capabilities:

- Modelling real-world cases in a controlled digital space. The representation enables planners and business stakeholders to experiment with different logistics scenarios.
- Simulating complex logistics networks. Urban logistics involve interconnected systems, including warehouses, distribution centres, delivery routes, and various transportation modes. The platform enables the simulation of these networks, providing insights into their efficiency and effectiveness.
- Optimising last-mile delivery strategies through experimentation with different delivery methods (e.g., electric vehicles, micro-fulfilment centers) and assessing their impact on delivery times, costs, and environmental sustainability.
- Evaluating sustainable practices, such as incorporating electric or autonomous vehicles, optimising routes for reduced emissions, and integrating alternative transportation modes like electric bikes.
- Using historical data to predict future demand patterns for goods and services. Planners can experiment with different inventory management strategies to meet fluctuating demands efficiently.
- Experimenting with various policy interventions, such as restricted delivery zones or incentives for green logistics practices. Planners can assess the potential impacts before implementing measures in the real world.
- Engaging stakeholders in the planning process, including logistics companies, urban planners, and community groups who can collaborate in experimenting with different logistics solutions, visualise the results of their choices and provide valuable input.
- Facilitating data-driven decision-making by integrating real-time data in the models and make informed decisions based on accurate, up-to-date information about urban logistics operations.
- Encouraging innovation by providing a platform for researchers, industry experts, and policymakers to collaborate on developing novel solutions.

Overall, the use of the LEAD platform has the potential to transform how cities and businesses approach last-mile logistics management. Other future use cases could include:

- Dynamic Traffic Management and Congestion Mitigation. Planners can use real-time data to adjust traffic signals, implement congestion pricing, and analyse the effects on traffic flows and delivery times.
- Resilience Planning. Simulate various scenarios, including unexpected events like natural disasters, cybersecurity attacks or major infrastructure failures. Planners can experiment with different response strategies to enhance the resilience of urban logistics systems.

Evaluating Multi-Modal Transportation Integration. Planners can experiment with the integration of freight trains, barges, and other modes to create sustainable logistics networks.

Key Performance Indicators

The impact evaluation of LEAD value cases has been based on Key Performance Indicators (KPIs) linked to the impact areas of "Environment" (4), "Social" (3), and "Economic" (7). These KPIs have been used to assess the direct impact of LEAD solutions by comparing the "baseline" scenario with the "after implementation" scenario (also known as the "what-if" scenario). A suitable methodology for measuring the indicator, the data needed, and guidance for obtaining the indicators has been agreed for each KPI[13].

KPI name / impact	Definition
Energy consumption	Energy savings compared to the "do nothing" scenario
GHG emissions	CO_2 equivalent emissions savings compared to the "do nothing" scenario
Air pollution	Savings of [PM] compared to the "do nothing" scenario Savings of [NOx] compared to the "do nothing" scenario Savings of [VoC] compared to the "do nothing" scenario
Noise impact	Reduction in decibels (dB), compared to the "do nothing" scenario

Table 1 Identification of impacts and indicators: Energy KPIs

KPI name / impact	Definition
Jobs created	Jobs compared to the "do nothing" scenario
Quality of the jobs	Qualitative evaluation of the types of jobs created by the LL according to the opinion of the CoP
Neighbourhood quality of life	People satisfied with the value case scenario compared with the "do nothing" scenario in terms of quality of life.

Table 2 Identification of impacts and indicators: Social KPIs

KPI name / impact	Definition
Average delivery cost of the business model	Average delivery cost savings of the business model compared to the "do nothing" scenario

[13] *More information regarding KPIs in Deliverables 1.4 and 3.1 of LEAD project (https://www.leadproject.eu/resources/resources/)*

Congestion	1. Changes in the share of shipments that are carried out within the congested hours of the day 2. Congestion contribution of delivery vehicles: Changes in the occupation time of the road
Urban storage & parking space	Urban space required for last mile deliveries (storage and parking) in comparison with the “do nothing” scenario.
Financial IRR	Financial internal rate of return of the investment conducted to implement the value case scenario
Shop / Retail benefits	Qualitative evaluation of retail benefits compared to the “do nothing” scenario
Delivery time	Average delivery time compared to the “do nothing” scenario
Delivery reliability	On time deliveries within the time window compared to the “do nothing” scenario

Table 3 Identification of impacts and indicators: Economic KPIs

5.3 The LEAD Living Labs: Testing innovative last mile logistics solutions

To better understand the digital representations and simulations ran in the LEAD Platform, it is essential to grasp the key challenges in each LEAD LL real-world environment and the solutions designed.

Madrid, Lyon, and Budapest centred their strategies on employing an Urban Consolidation Centre (UCC) in conjunction with low-emission vehicles. Madrid and Lyon used it in an underground parking garage bordered by the Low-Emission Zone (LEZ) delivery zone. On the other hand, Budapest duplicated an outdoor virtual hub within the delivery area and simulated it in 4 distinct configurations. Madrid targeted the B2C parcels, whereas Budapest and Lyon focused on B2B market.

The Hague and Oslo used different strategies to create use cases for crowdshipping services provided by a joint partner, NIMBER. The Hague paired it with a network of lockers in public spaces that served as transfer points between different operators or as pick-up/delivery points for users.. Oslo gradually expanded the complexity, defining four use cases. It tested everything from direct shipping with LEV to the usage of micro hubs with LEV and crowdshipping for returns. Oslo focused solely on B2C, but for a furniture manufacturer providing larger items than the Madrid and Lyon sectors.

The city of Porto participated in the Community of Practice (CoP) as an external stakeholder. The LL was led by a private entity – MC SONAE, the biggest food retailer in the country. Furthermore, this pilot is the only one led by a retailer committed to electrifying its fleet and introducing new value propositions. MC SONAE gained useful insights into the transition to electricity and Physical Internet (PI) paradigm by running two simulated use cases and one pilot that allowed real data to be incorporated into the DT. The following pages provide factsheets and a quick snapshot about the six LEAD LLs and some of the common learnings from the pilot activities.

Living Lab

Transforming a Parking Lot to an Urban Consolidation Centre

Context

- Madrid is an important logistics hub (between the Atlantic and the Mediterranean TEN-T corridors),
- Occasional air quality and congestion challenges,
- Madrid Low-Emission Zone (LEZ) and current regulations (Madrid 360),
- Rise of e-commerce and home delivery (even more due to COVID19 and post-COVID19 challenges).

Measures

- Demonstrate the better efficiencies in using a UCC connected to the TEN-T to deliver to the city center.
- Assess flows and congestion. Route optimisation engine in many-to-many and many-to-one scenarios, combining vehicles of different fleets.
- Explore alternative (and sustainable) business models.
- Public-private cooperation mechanisms, identifying new ideas for cooperation and evaluating the costs and benefits of implementation.
- The economic efficiency and reliability for courier companies, and for clients, of using the LEAD strategies compared to conventional freight delivery approaches.
- Explore potential incentives.

Results

Depending on what type of "what-if" scenario, key results for Madrid LL include mileage reductions of up to 33%, service time reductions of up to 28%, and travel time reductions of up to 14%.

Learnings

In terms of DT, more research is required to identify areas where DTs may need to be improved for the purpose of increasing their accuracy.

Simultaneous planning: Manufacturers can benefit from real-time DTs for joint sales planning with local companies.

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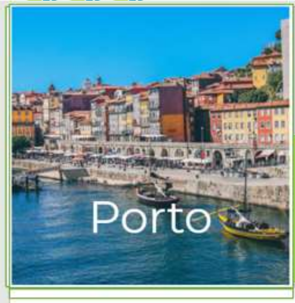
LEAD

Living Lab

Integrated last-mile logistics with demand-supply matching platforms

The Hague Next2Company nimber mypup cycloon

Context	Measures	Results
• Central Innovation District (CID), with the re-development of nearby area with new housing, high value industry & services, in a densely used location, • Vision for new mobility for CID, • Use is guided by digital platforms, • Move to a hyperconnected city under the concept of Physical Internet, • Mission: to connect shared freight movements via a digital freight fulfilment platform.	• Mixing transport services across platforms to create a more efficient and sustainable urban freight system, by sharing resources for carriers and improve offer for consumers	Crowdshipping and parcel locker implementation are estimated to result in carbon reductions and energy savings of 9.26%. Additionally, the crowdshipping component can create 309 additional working hours every day and reduce delivery costs for crowdshipped packages by 35%. **Learnings** Long-term environmental and social advantages will encourage the use of lockers as transhipment hubs for crowd shipping.



Living Lab

Turning retail stores to electric mobility nodes

inlecom ZLC MIT GLOBAL SCALE NETWORK Panasonic SONAE MC

Context

- The capillarity and convenience of Sonae MC stores on top of the electric mobility infrastructure that have been deployed for B2C provides a possibility of using it also to B2B electric charging docks for transportation/logistics services.
- This creates an advantage in the expansion of such grids and sustains a LL that mixes energy distribution, retail, logistics and transportation, leveraging & integrating synergies.

Measures

- The optimisation of delivery routes for EDV's, taking into consideration the potential grid of EDV charging stations.
- EDV's take-up projections if the grid enables mass adoption.
- The development of new business models (e. g. dynamic pricing, incentives research, cost optimisation, demand forecast, emissions and supply planning);
- Leveraging MC Sonae's digital platform to capture additional **growth, with new services to consumers.**
- Last mile optimisation for deliveries based on PI principles.

Results

A last-mile delivery solution that uses 75% electrical vehicles will allow to save 1.4 MJ of energy and 57g CO2e for every delivery. MC SONAE can anticipate savings of 131.425 kWh/year and 20t CO2/year over a 10-year period and can project delivery for the same time frame. MC SONAE does not need to place a charging station (CS) at every preparation shop to make the switch to a current EDV truck fleet.

Learnings

- Role of the Community of Practice in the Porto' region is essential**.**
- Data gathering was a difficult, it should be handled as early as possible to avoid project delays.

Living Lab

Spatial Planning of Inner-City Loading Areas

SZÉCHENYI EGYETEM UNIVERSITY OF GYŐR

BKK BUDAPESTI KÖZLEKEDÉSI KÖZPONT

ZLC MIT GLOBAL SCALE NETWORK

WABERER'S OPTIMUM SOLUTION

POLITÉCNICA UNIVERSIDAD POLITÉCNICA DE MADRID

Context

- Objective to evaluate a DT as a tool for creating distribution chains with multi-objective optimisation for all parties involved and novel distribution models.
- Better understand where urban consolidation centres could be positioned within the city to facilitate the freight flows.
- LL observations and framework to provide solutions and to quantify the different effects of the e-mobility to transportation scenarios.

Measures

The following elements have been explored:

- advantages of UCCs, optimal distance from endpoint,
- DT with existing macroscopic transport model,
- impacts of UCCs on air quality,
- ways to refine and develop policies,
- impacts of freight vehicles from UCCs on the environment,
- Exploring additional means to emphasise and promote e-mobility.

Results

According to the results of the KPIs, using alternative energy delivery vehicles (such as LNG trucks and e-vehicles) can result in greater environmental savings than the initial targets. The results also show significant gains in economic KPIs, particularly in traffic congestion and availability of parking space.

Learnings

The development of a regulatory framework for data transfer should be a primary priority.

Living Lab

Validation of last mile distribution models

Context

- Equip the urban planning team with a decision support framework to better evaluate the implementation of various logistics,
- Reduce motorised traffic,
- Implement a robust and flexible logistic infrastructure to support innovative solutions,
- Foster sustainable and economically balanced approaches,
- Leverage public policies to cope with socio-environmental objectives.
- Promote partnership governance.

Measures

- Exploration of last-mile distribution models based on soft modes and/or autonomous vehicles.
- Definition of framework conditions to deploy an urban logistic platform in an underground parking.
- Freight traffic flow qualification: detection of freight vehicles through video cameras.
- DT approach: synchronisation of onsite experimentations and modelling.

Results

At the local level, where we route all parcels in the Confluence study area, through a UCC that operates cargo bikes, it is observed that implementing the service provides a reduction of 78% in GHG emissions with an operating cost that remains below the average market operating cost in the region.

Learnings

A detailed analysis of the locations, demands, vehicle types, orography should serve as the foundation for choosing the services to reduce carbon footprint. Ex-ante analyses and support for strategic decision-making may be aided by the usage of DT, which is not just for B2C businesses. Most of the participants agreed that B2B use cases should be included in the DT and acknowledged the difficulties associated with collecting B2B-related data.

Living Lab

Green shipping of larger items through the urban transport network

Oslo · IKEA · nimber · Molde University College Specialized University in Logistics · inlecom

Context

- It concentrates on B2C and home-deliveries as the most preferred option from a consumer's perspective.
- It uses a micro hub located close to Lysaker, close to the main road system and a bus station. Four scenarios developed to fit with this location.
- The flexible service envisaged involves a pre-determined sequence of operators, namely: commuters, NIMBER's community members and regular logistics operators (trade-offs between costs and reliability issues).

Measures

- The interplay between demand and relevant supply design of energy-friendly dedicated services and crowdshipping services.
- The role for parcel lockers to enhance delivery/pick-up flexibility.
- The economic, financial, and environmental potential for a green dedicated and crowdshipping service.
- The Integration of data modelling with real-market data to support a DT approach.
- A stronger focus on sustainable crowdshipping of larger items.

Results

The overall findings are favourable in terms of energy usage (-72%), as well as emissions (GHG -99%; PM2.5 100%; NO_2 100%; VoC 100%). It also increased delivery reliability.

Learnings

- The deployment of e-vans challenging as the locations of the stores and the destinations of the deliveries are too far apart.
- Micro hubs in densely populated areas are difficult to find since they compete with other land use objectives.

5.4 Main challenges and learnings from the Living Labs

The LEAD LLs demonstrated the improvement of last-mile logistics in their cases and provided crucial insights to be incorporated into their sustainable and digitalisation strategic goals, and transferred across other European contexts. The following list summarises some of the main take-aways and technical challenges and barriers identified:

- The technical difficulty of integrating many models (both free and commercial) and data from various sources combined with the shortcomings in personnel modelling capabilities are still hindering progress.
- There is a lack of willingness on the part of operators or the government to gather and exchange data. In particular, there is often no added value for private operators to provide their data, and the process is time consuming.
- Data sensitivity and privacy concerns limit the capacity of the DT to test scenarios that are closer to reality.
- Future data-driven mobility necessitates the logistics community's willingness to share data using instruments that stimulate data-sharing, ensure confidentiality and privacy, and reduce cybersecurity concerns.
- Adoption of agile storage management demands more active participation and agility from public administrations to distribute public space, including space for freight logistics, speeding up procedures, and supporting operators' financial sustainability through fair and cost-effective public-private partnership agreements.
- Models need to be adapted to better understand and investigate the HORECA sector or other types of distribution, different to those tackled by the six LEAD LLs.
- LEVs powered by renewable energy significantly reduce emissions. For LEVs to be fully adopted, more charging locations and shorter times to charge are required.
- Crowdshipping improves last-mile logistics efficiency, but there are several hurdles ahead, including balancing bringers' remuneration and operators' bottom lines, as well as a lack of bringers' willingness to go the additional distance.

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6 Policy recommendations

LEAD cities underwent substantial changes over the course of the project. Previously seen as a minor aspect of mobility or economics, logistics is increasingly becoming a leading industry on its own. The urgent need to develop a clear vision for sustainable logistics - seen as an essential aspect of city life rather than a burden - is now being recognised by cities and citizens.

More in general, many cities have acquired more knowledge and experience in this field and have hired skilled professionals to aid in the development of their long-term strategies. They are working closely with stakeholders from the quadruple helix, including local business owners, residents, logistics firms, and specialists, to develop Sustainable Urban Logistics Plans (SULPs) that are fully integrated into their mobility plans (SUMPs). This collaborative approach is a significant evolution. Cities are actively looking for the best ideas and solutions that fit their needs, rather than just experimenting with different concepts.

Cities agree that policy will play a significant role in accelerating the transition to sustainable city logistics. Implementing these regulations will require a lot of political bravery because they might not satisfy all stakeholders equally. The secret to a successful implementation, though, will be strong and effective stakeholder involvement.

A Communication on the New Urban Mobility Framework was released by the EC in December 2021, and it includes, among other things, guidelines for accelerating zero-emission city freight logistics and last-mile delivery. The recommendation modernises the idea of SUMPs to consider the most recent developments in legislation and mitigation plans for climate change as well as new mobility services.

The recommendation emphasised the need for cities to adopt an integrated strategy for freight transportation and logistics in urban areas because doing so will guarantee that their SUMPs address every facet of urban mobility. This strategy will help cities achieve last-mile deliveries and zero-emission urban logistics.

DTs is an emerging field whose full potential has yet to be explored. However, it now seems to be one of the most appropriate tools for local authorities to collect information about their territory to assist in their daily management and decision-making process.

As LEAD demonstrated, some cities have already taken advantage of it on an experimental basis. DTs represent an opportunity for them to become more agile and resilient. The challenge for these local authorities will be to define their “right needs” (coherence between DTs and territory) as part of a gradual process to enhance their twin.

DTs can be instrumental in developing SULPs by providing city authorities with a comprehensive understanding of the existing logistics ecosystem and enabling them to make data-driven decisions. Here's how:

6.1 Recommendations to local authorities

Do not wait to embrace digitalisation!

The deployment of DTs at the local and regional level will only be possible by promoting a culture of innovation by encouraging creative thinking, experimentation, and a growth mindset to digitisation, data management and technology. The more mature a local authority is in managing IT projects, and the more experienced its human resources are, the more likely it is to be able to respond to the needs of its citizens.

Interdisciplinary experts should collaborate to increase innovation.

As the LEAD LLs have demonstrated, urban planners, commercial technology and logistics firms, research centres and universities, and other actors might be encouraged to engage in the cooperative development and sharing of DTs technologies. Additionally, by regularly hosting seminars and training sessions on DTs, cities, experts from business, academia, and research institutions can collaborate to explore and analyse the inner workings of urban development, promote the ideas behind DTs, and assist city managers in increasing the efficiency and effectiveness of their procedures.

Public-Private cooperation is key

A wide spectrum of public and commercial sector players is looking for a better mutual knowledge of difficulties as a consequence of urban freight partnerships. In certain instances, including within the LEAD project, these collaborations have also resulted in the elaboration of new solutions. More answers are based on the exchange of information and concepts as well as a deeper understanding of the requirements of the public and private sectors in the urban freight system.

Invest in training and development.

Finding people with the right knowledge and expertise to implement and manage DT technology is increasingly difficult. But it's an essential challenge to overcome to harness the full potential of this cutting-edge technology in your city logistics operations. Work together with educational institutions to access a pool of new talent and promote the growth of the abilities required for the deployment of DTs. Join forces with reputable tech companies that can help fill the skills gap and provide the know-how needed to create and maintain a DT environment. Local authorities wishing to develop DTs would greatly benefit from including trained modellers in their teams. Civil servants and modellers would benefit from existing capacity building and training, such as the LEAD Massive Open Online Course on DTs[14], and the Living-In.EU Initiative[15].

[14] https://www.leadproject.eu/mooc-new-platforms/
[15] https://living-in.eu/groups/commitments/education-capacity-building

A holistic approach and a long-term vision should be privileged.

The development of DTs needs to be demand-driven, data-driven, and people-driven. Building a DT city is not something that cities should do for its own purpose. Instead, cities' governments should examine the need for tracking urban operational indicators and create cross-sectoral, cross-industry scenarios that take advantage of DT technology's advantages. Defining needs and setting the strategic objectives for your DT objectives as an essential prerequisite. Create policies for the ongoing maintenance, updates, and sustainability of DT implementations. This includes regular data validation, technology upgrades, and budget allocation for continued development.

Data quality is key.

Good models depend on good data. DTs applications rely on data from external parties, hundreds or thousands of distant sensors functioning in challenging field settings and communicating over unreliable networks, it may be a challenging endeavour. Cities and companies need to implement procedures, at the very least, to handle gaps and irregularities in managing data streams as well as to recognise and isolate erroneous data. The challenge is organising the data and using it in the decision-making process.

Tackle data sharing issue at the early stage.

Getting information from the private sector and operators is frequently a hurdle. Similar patterns have been observed by LEAD, when operators initially agree to exchange data but things subsequently get more challenging (due to business objectives, rivalry, or GDPR concerns). To understand the issue and gather pertinent data, anonymising aggregated data should be given priority. Create structures and agreements for cooperation between local government agencies, business partners, academic institutions, and community organisations. To ensure that DT activities are as effective as possible, roles, duties, and data exchange processes should be clearly laid out.

Embrace Open Data Standards and Interoperability

Implement and enforce open data standards to ensure that DTs can easily integrate with various data sources and systems. This fosters collaboration among stakeholders and enables the seamless exchange of information.

Be realistic with available data.

Data management represents the first and core theme of the city DT. Building a successful model that properly represents historical and current knowledge for future scenario-planning requires the ability to synchronise and integrate existing data, which may be provided in various forms, with varying degrees of granularity, stored in different locations or even unavailable. This is often the case of logistics-related data, which is often owned by the private sector and cannot be shared to third parties for commercial purposes. Establish clear policies and regulations regarding the collection, storage, and use of data within the DT environment. Prioritise data security measures to protect sensitive information and ensure compliance with privacy laws.

Take stock of the existing DTs and best practices.

To understand the present adoption landscape and the data available to assist future implementation, a stocktaking exercise of any existing DTs would be helpful. Build on what already exists by taking stock of the technologies and standards already in place: the beginning of the city's DT already exist in most of local authorities. Find support from cities' network organisations that can divert and connect with forerunners and more experienced realities.

Ensure full alignment with regional, national and EU targets.

Urban planning scenarios are simulated before any long-term decisions are made. In the simulations real-world traffic and logistics data can be used along with the documented opinions of residents. Simulations and "what-if scenarios" should be coherent with the policy objectives set at the local authorities by the local authorities itself, as well as with the national and EU targets coming from legislation that entered into force to reduce traffic, congestion, and pollution.

Involve stakeholders in the decision-making process.

Urban planning scenarios can be simulated before any implementation is carried out or before long-term decisions are made. Urban planning decisions can be presented in a more visual way and therefore stakeholders' concerns will decrease due to more transparent processes and the availability of information. Decisions must be communicated to the wider public, and visual graphics is a helpful tool to convey this information in a comprehensive manner.

Establish Living Labs "Communities of Practice".

A community of practice is a setting for peer-to-peer learning that includes, among others, governmental entities, shippers, transportation associations, neighbourhood associations, riders, and business associations. It enables professionals to share their expertise with users and stakeholders outside of their organisation. This open membership provides access to a variety of experts to assist with technical difficulties, foster continual progress, and enable more significant contributions to the objectives of the LLs. As a result, cooperation between various domains is ensured through a better understanding of the anticipated effects of implementing modifications in particular scenarios.

Raise Awareness and Use DTs to Engage Citizens in Urban Planning

Engaging citizens in the design of DTs or logistics solutions is crucial for ensuring that the technology aligns with the needs, preferences, and priorities of the community. Begin by informing the public about the objectives and potential benefits, and how they can contribute to urban planning. Use various communication channels and social media. Maintain open and transparent communication about the developments, share progress reports, and address any concerns or questions raised by citizens. Organise workshops and public forums to gather input from citizens. And use these sessions to discuss potential use cases. Offer interactive demonstrations or virtual tours of the DT platform to allow citizens to explore its capabilities and understand how it can benefit the city. Set up online platforms or conduct surveys to collect feedback. Encourage citizens to contribute their own data, observations, and experiences related to urban environments. Ensure that the engagement process includes a diverse range of voices, including residents from different neighbourhoods, demographics, and socioeconomic backgrounds. Acknowledge the contributions of citizens in the design process and recognise their role in shaping the future of their city.

Prioritise measures according to the cities SULPs / SUMPs

DTs can play a crucial role in assisting cities in urban logistics planning, providing a powerful tool to analyse, optimise and manage city logistics operations supporting for example:

- Infrastructure Planning and Optimisation
- Collaborative Planning with Stakeholders
- Regulatory Compliance and Enforcement
- Warehousing and Distribution Efficiency
- Environmental Impact Assessment and Reporting
- Promoting Sustainable Practices through Incentives
- Resilience to Climate Change and Disruptions.

Prioritise developing DTs that cover the measures needed to implement in the future and develop specific use cases for testing and impact assessment. Implement KPIs and evaluation metrics to assess the impact outcomes. Regularly review and analyse data to make necessary adjustments and improvements. This approach should be tailored to the specific context, needs, and priorities of each city. Additionally, ongoing consultation with experts, stakeholders, and the public is crucial for refining and adapting policies as technology and urban planning practices evolve.

Co-creation with key external stakeholders

Co-creation labs focused on urban freight have proven to be effective. They involve different city departments and freight quality partnerships, i.e., permanent working groups involving all stakeholders' groups and companies to discuss the main issues related to urban freight distribution. Co-creation and the involvement of different partners in the setup of a logistic hub or a new logistic service is important, as more prominent business models and public-private partnerships are consolidated. This is expected to prepare the ground towards the physical internet paradigm, with the aim to digitalise the whole end-to-end freight journey.

Identify challenges on short, medium and long-term horizons

While the adoption of some technologies is a crucial need in order for private actors and their business plans to remain competitive in the current context, it is important to understand that green technologies and sustainable practices may require up-front investments but can provide long-term strategic benefits that will last for generations to come.

6.2 Recommendations to the EU Services

Build up from the outcomes of LEAD, its follow-up projects URBANE & DISCO (ongoing) and continue to test and include new use cases into the LEAD Platform and Model library.

The LEAD Platform has been based on the use cases derived from the six LEAD LLs, but it can be fed with more applications. LEAD started with very specific use cases with the idea that there is open access for external users to use it and to input their own models and data to run their own simulations for the different what-if scenarios that they would develop.

Make use of the open datasets and open-source software API developed by LEAD

As reported in D4.9 "*Open source packages and APIs*", LEAD makes available seven open datasets and one open-source software Application Programming Interfaces (API). They are focused on last-mile logistics networks and the examination of "what-if scenarios" regarding the several last-mile configurations in scope. Industry practitioners with strong ICT and R&D departments are encouraged to extract the most utility out of this set of tools. It can also be expected that many of these open outputs of LEAD project will be re-used since LEAD covered a lot of emerging research-intensive technical challenges to realising the DT Platform for the analysis of last-mile logistics networks, and they can benefit both research institutions and industry practitioners.

- **Allocation of funding via dedicated follow-up calls** within some of the most relevant Research Programmes promoted by the EU. Importance to associate with Climate Neutral Cities Missions, and other key policies, which receive associated funding from the EC. Promote further research on the interfaces of freight/persons, intra-/inter-urban, last-mile/ long-distance transport and spatial-economic analysis of cities. Research on DTs applied to transportation logistics is still very new and still developing. The applications of DT frameworks are mainly in the context of product management, shop floor or production management.
- Liaison with Living-in.EU, the movement for the European way of Digital Transformation of cities and communities will support the EDIC in the actual deployment of DTs and virtual worlds through 'the Citiverse' projects at the local level. Particular endeavours can be explored in specific Subgroups, such as the one on Education & Capacity Building group, to exchange on topics related to Digital Twinning capacity building, as well as with related resources being made available in the corresponding tool inventory.
- **Increase awareness of DTs potential** via dedicated events, webinars, trainings, and share of experiences at the EU level, not limited to urban freight and logistics but also involve other related fields (e.g., infrastructure, energy, housing, etc.)
- Facilitate the development of standards and protocols and Data Spaces connectors that ensure interoperability between different stakeholders in the last-mile logistics ecosystem, including logistics companies, municipalities, and technology providers.
- Create clear and supportive regulations for the use of micromobility solutions (e.g., cargo bikes, electric scooters) and innovative delivery methods like drones and autonomous vehicles.

- Foster collaboration between public authorities and private sector stakeholders to jointly develop and implement last-mile logistics solutions that benefit both the public and private sectors.
- Establish mechanisms to monitor the effectiveness of last-mile logistics initiatives, collecting data on key performance indicators and using it to inform future policy decisions.

These measures, when implemented in conjunction with local authorities and stakeholders, can help cities effectively tackle last-mile logistics challenges and create more sustainable and efficient urban logistics systems.

7 Conclusion

The use of DTs in urban logistics planning is an emerging field with significant potential for revolutionising the way cities approach freight management. DTs can support experimentation in the planning and development of urban logistics policies and the co-design of innovative solutions by local logistics communities.

However, as explained in the previous pages, despite several socia, economic and environmental benefits, some challenges are making the diffusion and implementation of DTs complicated.

DT creation and implementation are more expensive than basic control and monitoring methods. In addition, trained professionals are required to create, implement, and maintain a digital twin due to its technical complexity.

In the future, DTs should be able to share data with other cities or administrations thanks to studies that are being done to create standards and protocols. Future work and projects should focus on addressing scalability issues, such as lowering computing demands with simplified models and the integration of the LEAD platform with new and more sophisticated modules and libraries.

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LEAD Massive Online Open Course:
https://www.mobility-academy.eu/course/view.php?id=142

The open digital models of the LEAD project are placed in the LEAD GitHub Repository:
https://github.com/Horizon-LEAD