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DECARBOMILE
Decarbonise last mile logistics

D1.1 BASELINE SITUATION FOR URBAN FREIGHT LOGISTICS IN THE LIVING LABS

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Nature of the Deliverable		
R	Document, report	X
DEM	Demonstrator, pilot, prototype	
DATA	Data sets, microdata, etc.	
OTHER	Software, technical diagram, etc.	

Dissemination Level		
PU	Public, fully open and automatically posted online	X
SEN	Sensitive, limited under the conditions of the Grand Agreement	
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PROJECT SUMMARY

Logistics is at the core of modern society and essential to bring food and goods in the heart of cities, where a majority of Europeans live. However, there are a number of a challenges associated with transport efficiency in Europe and worldwide. Thus, significant changes are needed in supply chain operations, especially on the last-mile logistics chain. This lack of efficiency affects the economics of logistics and its externalities on the urban tissue, last-mile logistics representing 30% of the total emissions of logistics transportation.

The DECARBOMILE project is a comprehensive initiative aimed to minimize the negative impact of logistics by creating a more sustainable and environmentally friendly transportation system through introducing innovative solutions that encourage the use of alternative fuels and technologies, with the ultimate goal of reducing greenhouse gas emissions and combating climate change.

Gathering 31 partners from 10 different countries, DECARBOMILE aims to trigger an unprecedented improvement of the green last-mile logistics in Europe. To reach that goal, DECARBOMILE relies on a strong experience of decarbonising urban logistics through European initiatives such as CIVITAS. Partners will build upon all previous results to develop improved delivery methods, tools and methodologies, and implement them across Europe. The solutions developed in DECARBOMILE will demonstrate the full potential of decarbonised last-mile logistics.

Thus, ***the main objective of DECARBOMILE*** is to develop tailored solutions and demonstrate the full potential of decarbonised last-mile logistics in four living labs – Hamburg (Germany), Logroño (Spain), Nantes (France) and Istanbul (Turkey), and four satellites – Getafe (Spain), Tallinn (Estonia), Ghent (Belgium), Sarajevo (Bosnia and Herzegovina), in line with their technical, environmental and local socio-economic contexts.

The main objective is expressed in the six objectives listed below:

O1: Develop interoperable and multimodal vehicles for Last-mile Delivery (LMD) in urban contexts.

DECARBOMILE will work on logistics vehicles optimisation, especially regarding cargo-bikes and testing their combinations with transportation modes alternative to the road and conventional trucks (river, rail). Core focus will be: 1) the interoperability between solutions and adaptability to the local contexts on the hardware side and 2) innovative software enabling optimised vehicle loading and routing.

O2: Enhance collaborations between local and global stakeholders for long term successful uptake

DECARBOMILE will put a strong emphasis on the collaboration between local stakeholders and focus on piloting cooperation with private logistics operators and local businesses. DECARBOMILE will also collaborate with the CITIVAS and other relevant initiatives, in which several partners from the consortium are involved. DECARBOMILE will develop an urban consolidation model, allowing new functionalities to be tested and join the Digital hub for collaborative last-mile logistics.

O3: Optimise last-mile logistics planning and integration in the urban fabric by developing innovative ICT tools

The project will focus on the development of several digital tools to ensure optimised last-mile logistics, reducing the transportation time and associated traffic and GHG emissions, as well as costs. This will include the development of new tracking, tracing and monitoring tools to optimise the control over the flow of goods, network design and delivery optimisation. Emphasis will be put on the integrated approach of these tools and the development of a collaboration layer to assess their impact on the environmental and economic performance.

O4: Develop innovative tailored business models integrating social innovations for a strong market uptake

A key aspect of the project is to develop economic sustainability of the proposed solutions. DECARBOMILE will thus establish new models for addressing governance and management of logistics operations. This will include the integration of social innovations to ensure a larger acceptance of the solutions in the demonstration cities and for their replication across Europe.

O5: Demonstrate full potential green last-mile delivery in 4 living labs and investigate replication in 4 satellites

At the core of the demonstration, the four Living Labs will host full potential pilots. In addition, the four satellites will work on the pre-testing of specific developed solutions before their full-scale implementation in the living labs, and on their adaptability and replicability to particular contexts.

O6: Integrate the LML concepts in the local public policy plans and European regulations

Last-mile logistics faces specific regulatory and social contexts potentially impacting its implementation and limiting its spread. DECARBOMILE will propose recommendations on the implementation and improvements of last-mile delivery. To ensure a strong uptake of zero-emission efficient last-mile solutions, DECARBOMILE will integrate urban strategy co-creation, including traffic regulation, urban planning, and space management, with citizens in collaboration with local policymakers.

OBJECTIVE AND EXECUTIVE SUMMARY

The objective of the DECARBOMILE project is to focus and enable the full potential of green last-mile logistics, notably by developing and implementing comprehensive tailored technological solution that meets the needs and business requirements of the European cities. To showcase this potential, the project focuses on four living labs and four satellite cities that have different technical, environmental and local socio-economic contexts.

The aim of this ***D1.1 Baseline situation for urban freight logistics in the living labs*** is to provide a state of the art of the current urban logistic situation in project cities and in Europe, looking at logistic flows and related freight movements, existing territorial infrastructures and equipment, current freight and urban planning policies and regulation framework. It also details the potential of the use cases to be implemented in DECARBOMILE.

Project cities and technological partners contributed to the diagnosis by providing data and analysis on local urban freight situation, running needs assessment analysis, identifying and engaging relevant stakeholders, mapping their technical requirements, confirming the potential locations for the hubs' implementation, etc. In setting up collaboration with local stakeholders through co-creation kick off workshops, living labs aimed to gather as much accurate and relevant information as possible to detail the different use cases to be implemented, in accordance with the identified local context and needs.

A benchmark of urban logistic initiatives over Europe, including past and current projects internal and external to the consortium, has been conducted to highlight the associated lessons learned and successes in terms of policies, tools and methodologies, emphasising the five strategic pillars of the project (collaboration, space management, added-value services, regulation, digitalisation). A second benchmark, on the regulation of urban distribution of goods in cities both inside and outside of the consortium allowed to collect different practices and showcase the current local logistics assets, needs and regulatory frameworks in Europe.

In parallel, data collection, software and hardware barriers and levers for consolidation, model implementation and exploitation were consolidated through a design-oriented literature review, including on cycle-logistics viability's main drivers and business collaboration frameworks involving logistics, directly or as a supporting service.

In order to ensure that internal and upcoming external project activities (including the uptake of e-cargo-bikes logistics) are inclusive of every person and gender sensitive, a cultural and work-related assessment of gender dimension issues was undertaken. A gender equality plan was developed and provides insights as to how identify, take into account and tackle related issues, should they arise.

ACKNOWLEDGEMENT

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More information on the project can be found at https://www.decarbomile.eu

FIGURES

TABLES

ABBREVIATIONS

Abbreviation	Description
(A)LNS	(Adaptive) Large Neighbourhood Search
(MI)LP	(Mixed-Integer) Linear Programs
2E-VRP	Two Echelon Vehicle Routing Problem
ADF	Approximate Dynamic Programming
ADIF	Administrador De Infraestructuras Ferroviarias (Spanish Railway Infrastructure Administrator)
ATIS	Advanced Traveller Information System
ATMS	Advanced Transportation Management System
AV	Autonomous Vehicle
AVCS	Advanced Vehicle Control System
CA models	Continuous Approximation models
CDP	Collection and Delivery Point
CEP	Courier, Express, Parcel Providers
CFC	Chlorofluorocarbon
CH4	Methane
CL	City Logistics
CN	Congestion
CO	Carbon monoxide
CO2	Carbon dioxide
CO2e	Carbon dioxide equivalent
CPS	Cyber-Physical Systems
CVRPPAD	Capacitated Vehicle Routing Problem with Pick-Up and Alternative Delivery
Cyb	Cybersecurity
DaaS	Delivery-as-a-Service
DI	Digital Infrastructure
DSQ	Dock Scheduling and Queuing
DT	Digital Twin
DTSPP	Differentiated Time Slot Pricing Problem
EL-VS	Electric l-Category Vehicles
EV	Electric Vehicle
FP7	Seventh Framework Program
FSM-VRP	Fleet-Size-and-Mix Vehicle Routing Problem
GDPR	General Data Protection Regulation
GRASP	Greedy Randomized Adaptive Search Procedure
GHG	Greenhouse Gas
GPD	Gross Domestic Product

HGV	Heavy Goods Vehicle
ICT	Information and Communication Technology
IMM	Istanbul Metropolitan Municipality
IoT	Internet of Things
ISP	Internet Service Provider
IT	Information Technology
ITS	Intelligent Transportation System
KOM	Kick Off Meeting
KPI	Key Performance Indicator
LaaS	Logistic-as-a-Service
LC	Logistic Concepts
LCV	Light Commercial Vehicle
LEZ	Low Emission Zone
LML	Last-Mile Logistics
LNS	Large Neighbourhood Search
LP	Linear Programming
LRP	Locating Routing Problem
LSP	Logistic Service Provider
LTL	Less-Than-truckLoad
LTZ	Low Traffic Zone
LU	Land Use
MaaS	Mobility-as-a-Service
MD-2EVRP-DO	Multi-Depot Two-Echelon Vehicle Routing Problem with Delivery Options
MILP	Mixed-Integer Linear Program
MIP	Mixed-Integer Program
MNL	Multinominal Logit
MPS	Modal-Parallel Schiebewand (transport system)
N2O	Nitrous Oxide
NOx	Nitrogen Oxides
NP	Noise Pollution
O3	Ozone
OC-CR	Opportunity Costs that consist of Cost and Revenue effects
OLI	Open Logistics Interconnection
PI	Physical Internet
Pmx	Particulate matter
PT	Public Transport
R	Recipient
RFR	Random Forests Regression
SAA	Sample Average Approximation
SCND	Supply Chain Network Design

Sd/R	Stand-alone devices/Robots
SDD	Same-Day Delivery
SDT	Simulation and Digital Twins
SKU	Store Keeping Units
SLR	Systematic Literature Review
SME	Small and Medium Enterprises
SO	Simulation-based Optimization
Sox	Sulphur oxides
StVO	German Road Traffic Act
SUFT	Sustainable Urban Freight Transport
SULP	Sustainable Urban Logistic Plan
SUMP	Sustainable Urban Mobility Plan
SUTP	Sustainable Urban Transport Plan
TEN-T	Trans-European Transport Network
UAV	Unmanned Aerial Vehicles
UCC/MCC	Urban Consolidation Centre/Micro Consolidation Centre
UFT	Urban Freight Transport
UGV	Unmanned Ground Vehicles
UMC	Urban Micro-consolidation Centre
VFA	Value Function Approximation
VNS	Variable Neighbourhood Search
VOC	Volatile Organic Compounds
VR	Vehicle Routing
VRP	Vehicle Routing Problem
VRPCE	Vehicle Routing Problem in a Competitive Environment
VRPDO	Vehicle Routing Problem with Delivery Options
VRPLTT	Vehicle Routing Problem with Load-dependent Travel Times
VRP-RD	Vehicle Routing Problem with Release Date
VRP-TW	Vehicle Routing Problem with Time Windows

DECARBOMILE PARTNERS

Acronym	Organisation Name
IT	Interface Transport
HAM	Free Hanseatic City of Hamburg
ITS	ITS World Congress
LGN	Logroño Municipality
NANTES	Nantes Municipality
IMM	Istanbul Metropolitan Municipality
TLN	Tallinn Municipality
GETAFE	Getafe Municipality
GISA	Development agency of Getafe
SARA	Sarajevo Canton
TUHH	Technical University of Hamburg
CBS	Copenhagen Business School
CAPIT	Capillar IT
TMTX	Transmetrics
GGI	Genegis GI
NGS	New Generation Sensors
ITA	Ita Innova
IMTA	Institut Mines Télécom Atlantique
SCU	Sivas Cumhuriyet University
MIGROS	Migros
TRI	Les Triporteurs Nantais
OHB	Training Centre for Wood and Construction
INT	Intelligent Parking
LIHH	Logistics Initiative Hamburg
UBC	Union of Baltic Cities
CARA	CARA European Cluster for mobility solutions
ID4MOBILITY	ID4MOBILITY
FLEX	Fleximodal
RCXB	Red de Ciudades por la Bicicleta
EQY	Euroquality
DHL	Deutsche Post DHL

INTRODUCTION

D1.1 Baseline situation for urban freight logistics in the living labs provides a detailed diagnosis on the **baseline situation** of the pilot project cities (called *Living Labs*) (with details on their urban logistics situation and potential use cases) and lessons learnt from relevant projects across Europe, looking more specifically at the five pillars of the DECARBOMILE project: collaboration, business models and added-value services, urban integration and space management, regulation and digital infrastructure.

A **regulation benchmark** analyses the current legal framework related to urban distribution of goods, looking specifically at e.g., low emission zones, congestion charge zones, delivery tax, and the usage of cargo-bikes.

The **literature review** presents, in light of the five pillars of the project, alternative logistics concepts with a consolidation approach as urban consolidation centres or micro hubs, new places of delivery like collecting points or alternative home delivery, changes in the transport chain like multimodal last-mile logistics, innovative vehicle solutions, use of autonomous vehicles, metro based logistic underground, and presents the concepts of the Physical Internet including crowd logistics and the load pooling. For the five pillars of DECARBOMILE, different potentials and challenges for each pillar and existing systems are presented. Furthermore, different optimization algorithms for the network design and vehicle routing for last-mile delivery in cities are presented, looking at the optimisation potential of these logistics concepts, in terms of economical, ecological and social objectives.

The **Gender Equality Plan** (GEP) sets out the ambitions, priorities, and activities as well as the trajectories and targets of the DECARBOMILE project in terms of diversity, equity, and inclusion. It creates a set of commitments and actions that aim to promote gender equality within the consortium through monitoring and reporting and by facilitating the dialogue with stakeholders of the project regarding gender, i.e., to ensure all genders are fairly represented, and are given an equal say within the project and its processes.

1. BASELINE SITUATION IN PROJECT CITIES

In this section, an analysis per Living Lab (LL) provides detailed information on the local general context, state of the art of urban logistics (including economic activities and freight movements, infrastructures and main equipment/assets, public policies and regulations, local stakeholders and existing digital solutions), potential use cases to be developed, Key Performance Indicators (KPIs), and relevant use cases to build upon as the project develops. There is also a more general introduction to the so-called 'satellite cities' context and their baseline situation and potential use cases. Satellite cites are cities involved in DECARBOMILE as replicator sites, to test and refine the scale-up potential and strategy of solutions developed throughout the project.

For the KPIs, specific indicators will be developed per LL during the project, based on the experimentation and use cases. There are also common KPIs identified for all the LLs:

- Number of stakeholders
  - Involved in the pilot
  - Involved in the project
  - Sharing their data for the project
- Number of clients using the service
- Deliveries made by cargo-bikes
  - Number of freight units delivered
  - Number of kilometres made by cargo-bikes
- Average delivery time
- Average delivery costs / freight unit
- Quantity of carbon dioxide (CO2) + Particulate Matters (Pmx)+ Nitrogen oxides (Nox) per freight unit (*these KPIs relate to the level of pollution in the air*)
- Loading rate of delivery vehicles

1.1 Istanbul Living Lab

CONTEXT

Istanbul is a metropolitan city with a very diverse and interesting history and topography in the South-eastern of Europe, with over 16 million inhabitants. Istanbul is also known as Seven Hills because of its hilly surface.

Istanbul Metropolitan Municipality (IMM) is a key actor in the local administration organization of Istanbul. Its area of responsibility encompasses the entire provincial territory, which spans a total area of 5 343 km^2.

IMM has 28 municipal enterprises, 2 subsidiary public utility corporations (Transport Authority and Water & Sanitation Authority) and around 80 000 employees. **The city has 39 district municipalities** (shown in Figure 1). The area of responsibility of IMM covers the entire provincial territory. In DECARBOMILE, several Urban Consolidation Centres (UCC) with an area of ~500m^2 and Micro Consolidation Centres (MCC) with and area of ~100m^2 will be implemented and operated by logistic operators. Their precise location is not yet defined, but targeted areas include the centre districts of Beşiktaş, Bakırköy, Beyoğlu, Şişli, Kadıköy, Pendik, Fatih or Merter, given their high traffic and dense population. Further information on this is given in the use case dedicated section below.

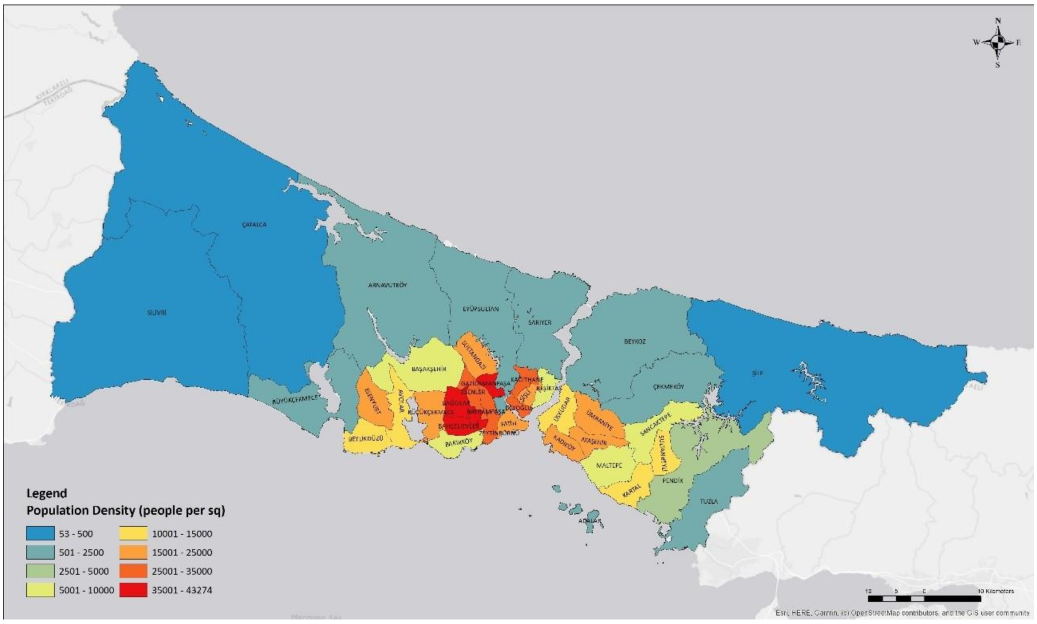


Figure 1: Istanbul Districts and Population Density (September, 2022)

IMM is the principal public body in planning, designing, implementing and operating the transportation sector in Istanbul. A number of affiliated companies are responsible for the transportation sector planning and land use, and its integration with other sectors, including traffic regulation and mobility.

IMM is responsible for a wide variety of areas including environment, natural-gas supply, energy, infrastructure, planning and development, information technology, transportation, community services and vocational education, health-wellness, food & catering, culture, tourism, etc. The city itself is one of the regions where the densest vertical urbanization is observed not only in Europe but also in the globe (a significant factor which increases the rate of logistics traffic/trips per mile considerably).

More than 30 million daily trips are made in Istanbul (mobility of persons and goods), so the public transport system plays a vital role in supporting the economy and providing citizens with access to basic services, such as work, health and education, through healthy and environmentally sustainable options. In recent years, a lot of money has been invested in the city's public transport system. **The rail network is gradually being** extended and the existing public transport network is being improved by implementing additional technology and smart applications.

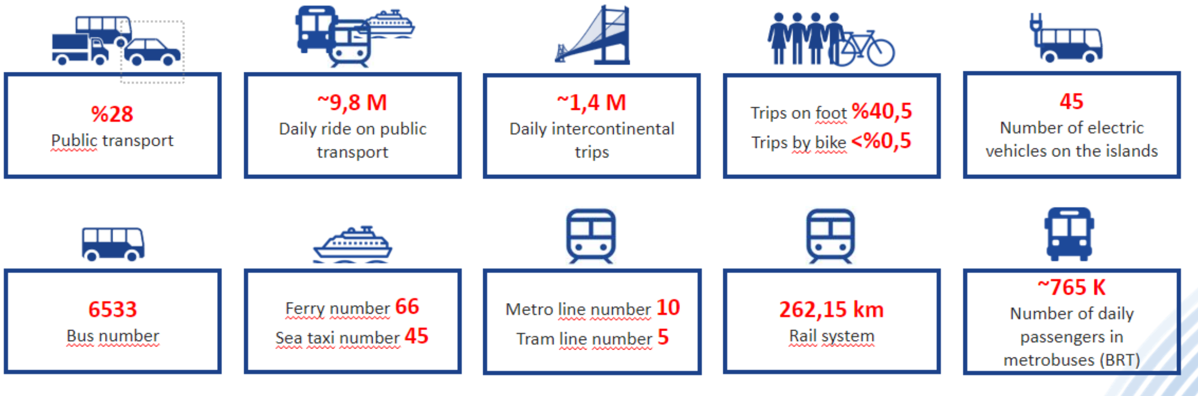


Figure 2: Istanbul Mobility in Numbers (DECARBOMILE KoM, September, 2022)

Today, **Istanbul has 262.15 km of rail network operating**, with a total of 208.90 km under construction, of which 103.30 km is being built by the Ministry of Transport and Infrastructure. The rail network projects currently being planned will extend the overall network to 637.90 km by 2029. Moreover, including the lines planned to open after 2029, the length of the rail network system is targeted to reach 817.51 km in 2040.

Recent public transport projects – such as the Metrobus, the Marmaray rail improvements and other rail system projects – have strengthened social inclusion and improved access to economic, social and cultural opportunities for people living in the outer regions of the city.

Istanbul has four different effective coastlines, on the north and south sides of the city and along the Bosporus and the Golden Horn. The total length is more than 500 km and therefore offers a great potential for water-based mobility options, like barges for example.

Figure 3: Classification of Istanbul coastline (source: F. A. Türer Başkaya and E. Tekeli, "Coastline Changes and Istanbul Coastal Landscape")

Due to its strategic location between Europe and Asia, Istanbul has always been a major economic centre. The city hosts 20% of the country's workforce and accounts for 1/3 of the national production in the industrial and service sectors. In 2019, 31.7% of Turkey's total Gross Domestic Product (GDP) is produced in Istanbul.
However, the Gini coefficient in Istanbul, which is used to measure income inequality with values between 0 (low inequality) and 1 (high inequality), increased from 0.35 in 2003, to 0.40 in 2015, to 0.45 in 2020. Indeed, migration within Turkey has led to increasing inequalities within Istanbul.

URBAN LOGISITCS

Economic activities and freight movements

Istanbul has a diverse range of industries, because of its 16 million residents. Also, the city connects Europe with Asia. As a result, it becomes **a bridge for transit vehicles which are carrying their loads between Europe and Asia.**

There are about **30 million** daily trips in Istanbul (for persons). The number of daily trips will increase to **38 million** in the 2040s. Almost **60%** of Turkey's annual logistics movements take place in Istanbul. The **international road freight transportation ranks first** with 21.6% of the total transportation flows in Istanbul, followed by **Maritime transportation** (18.2%) and **Domestic Road freight transportation and distribution** (16.9%) in the city.

When looking at the sectors that require logistics services, the **machinery manufacturing sector** ranks first with a rate of 28.3%. It is followed by the **metal products sector**, the **automotive sub-industry**, and the **textile sector**, in that order.

Service and industrial sectors are the most important ones in terms of economic activities in Istanbul. To provide Istanbul a competitive advantage on the world stage, it is planned to restructure the existing sectoral structure into **high-level services, finance, and informatics industries** based primarily on information and technology.

There are **eight organized industrial areas and 113 small industrial areas** in the city that employ over 150 000 people. Also, **six wholesale markets, three free trade zones and five ports** are located around the city. One of the ports, Pendik Port, is being used for ro-ro (roll on – roll off) transportation.

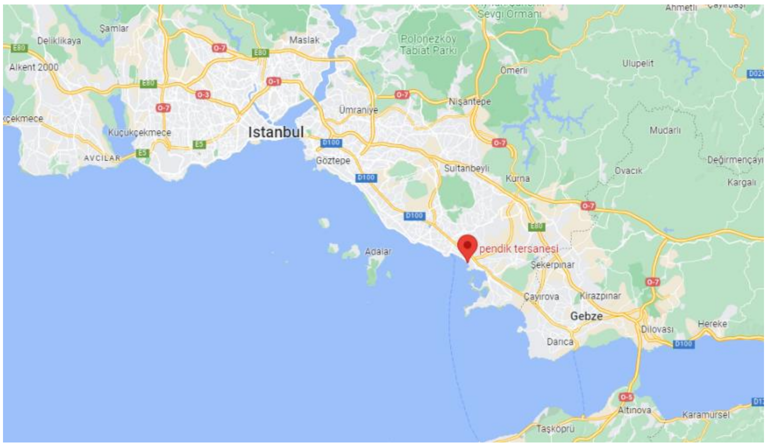


Figure 4: Pendik Port (source: Google maps)

The number of **shopping malls**, which are the places where the retail sector coexists most, is over **120 in Istanbul**.

Direct international freight transit is carried out within the scope of International Railway Transportation, with border crossings via Kapıkule to Bulgaria and via Uzunköprü to Greece. In addition, a domestic railway transportation is available. Halkalı (Figure 5) is the only loading and unloading station used to carry goods by railway, with Modal-Parallel Schiebewand (MPS) wagons (a specific type of rail transport system).

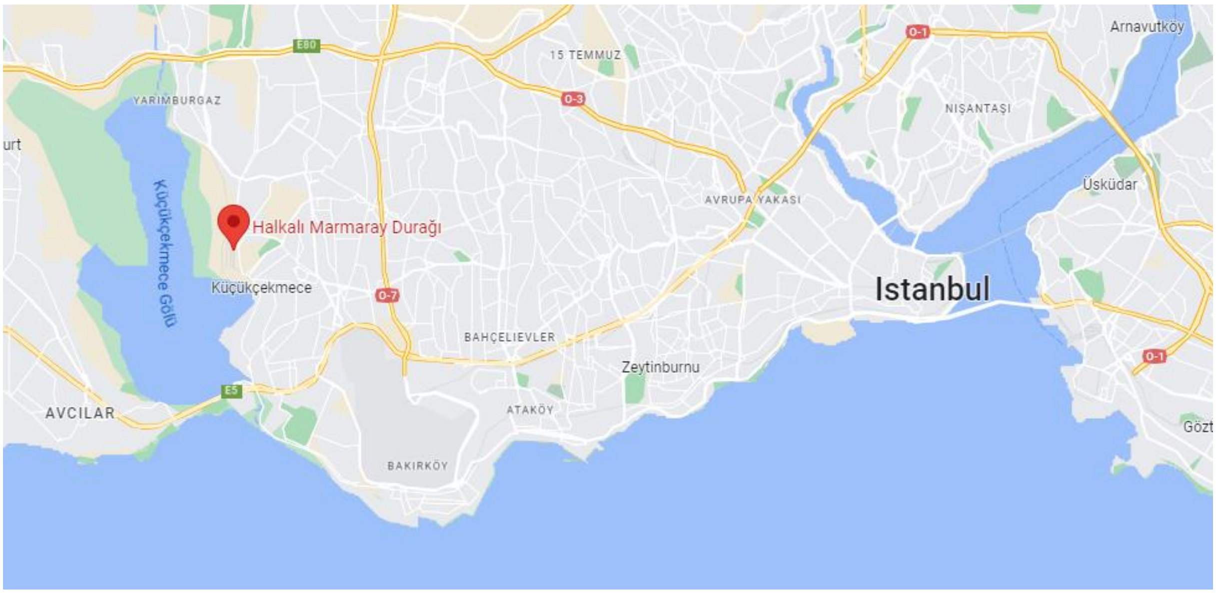


Figure 5: Halkali (source: Google maps)

As a result, Istanbul has a relatively high density of logistics operations. The highway has a lot of traffic because both freight and passengers use the same infrastructure. Intersections between freight and passengers must be avoided or minimized as much as feasible in this situation.

Infrastructures and main Equipment/assets

Istanbul has numerous logistics focal points of various sizes because it is a large and crowded city. According to the most recent logistics analysis research, made by Istanbul Logistic Master Plan prepared by IMM in 2018, 72 logistics focal points have been identified. These focus points can be seen on the Figure 6 below.

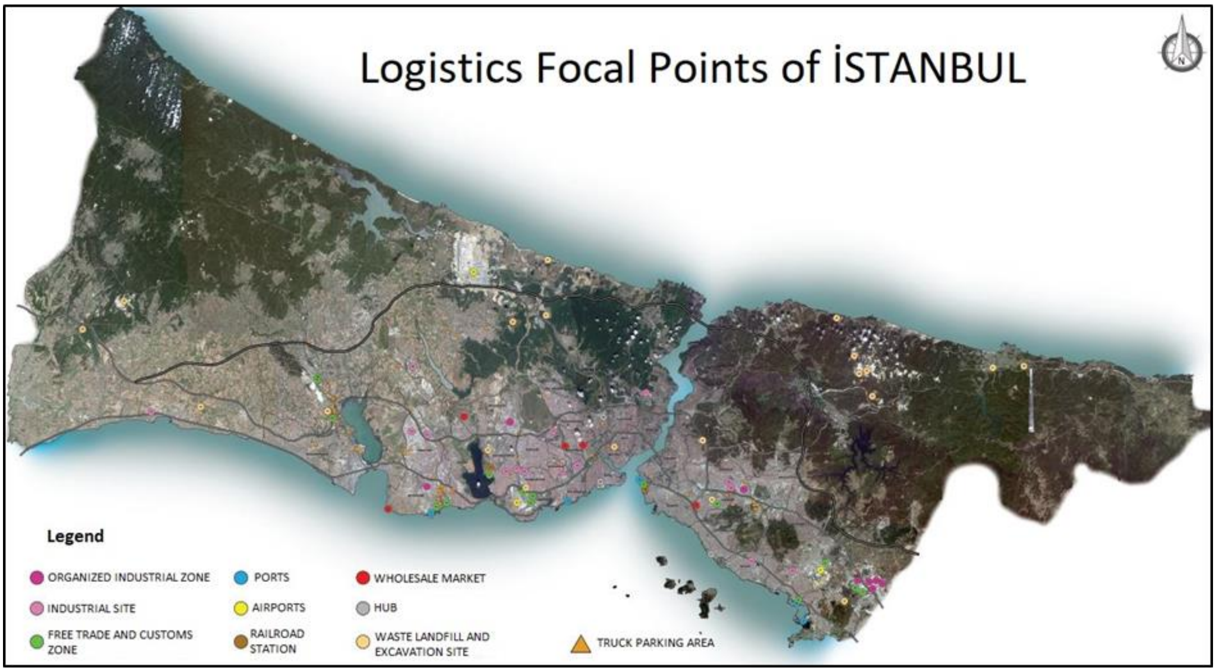


Figure 6: Istanbul Logistics Focal Points (source: IMM)

As it is shown, all kind of logistics are represented in Istanbul. However, because of the large borders and rising migration from other cities, all logistics zones have been spread around the city. To prevent the spread and the multiplication of little hubs, a multimodal approach of logistics is being set. Having several **multimodal logistics centres** around the city will be a step towards achieving this goal.

At the moment, there are no public examples of consolidation centres being implemented, as they all are at the planning stage (a UCC will be established). Prince Island is the only location where a logistic consolidation pilot project is currently taking place. The island is Istanbul's first 100% electric transportation area, with all public transport (PT) vehicles being electric since 2020 and the aim to have 100% of all the logistics (processes) electrified by 2025, including personal vehicles. The question of ensuring sustainable and green energy sources for operations is key.

Logistic vehicles of 3.5 tons and above are only authorised to pass through the Northern Marmara Motorway and Yavuz Sultan Selim Bridge. This specific regulation concentrates the flow of heavy goods vehicles to the north of the city. This concentration implies a concentration of associated nuisances, more congestion and a faster degradation of the transport infrastructure.

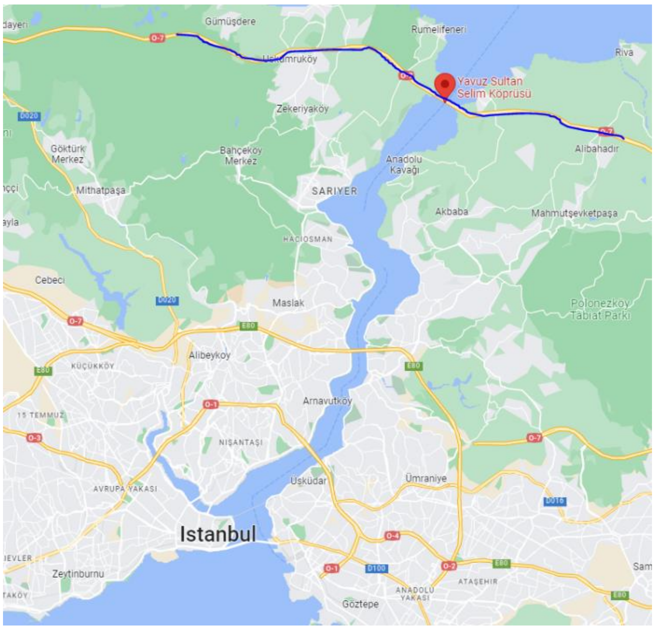


Figure 7: Istanbul Marmara motorway (source: Google maps)

Logistics companies and individuals receive **Route Permit Documents** from the Logistics Management and Terminals Branch Directorate. On those documents, the routes on which they will carry their loads are written, and they can move around the city with this approved document.

According to the data obtained from the Police Department in 2021, the **number of registered vehicles carrying out freight transportation activities in Istanbul was stated as 360,919, and only 17% of them have a document** approved by the Logistics Management and Terminals Branch Directorate. In fact, logistic flows are difficult to control by the municipal authorities (as cargo is being transported in places outside of the municipality's control), so the aim of the municipality is to make consolidation centres and urban logistics, which are complex and scattered, more controllable.

New logistics activity areas can be selected from the empty land on the Northern Marmara Motorway route, which is the axis with the **highest load mobility**.

At the moment, there is a relatively weak public private partnership on last-mile logistics, with a low use of intermodal logistics (sea, rail, etc.). An increasing use of last-mile delivery by e-cargo has been observed (this is an observational interpretation as there has been no study on this topic yet).

Public policies and regulations

Several planning studies related to different areas and sectors were conducted or are ongoing in Istanbul. Evaluations will ensure that these ongoing plans are compatible with the **Istanbul Sustainable Urban Mobility Plan (SUMP)**. Sectoral plans such as the **Istanbul Parking Master Plan**, revision of the **Istanbul Bicycle Master Plan**, **Istanbul Pedestrian Master Plan**, **Istanbul Logistics Master Plan**, **Istanbul Public Transport Master Plan**, **Istanbul Traffic Safety Master Plan**, **Istanbul Vision 2050** and the **Istanbul Climate Change Action Plan** have been completed or related studies are in progress. Istanbul also prepared a **Local Equality Action Plan 2021-2024**, which contains measures to secure 24-hour access rights, to ensure transportation for disabled people, to provide multilingual services and measures related to rights for those working in the transportation sector.

Regionally, the **Marmara Region (the North-West part of Turkey) Spatial Development Strategic Framework Document** was completed in October 2021 by the Union of Marmara Municipalities that includes IMM as a Member. This document evaluates the current problems and potentials of the Marmara Region and addresses its future spatial development strategies at the regional level.

In addition to several regional laws, regulations and directives, the **National Transport Master Plan** and **Turkey Logistics Master Plan** have been completed at national level. Although these plans were only completed recently, it was decided to merge these two plans to become the **National Transport and Logistics Master Plan.** This study is still ongoing.

Istanbul SUMP

Istanbul Sustainable Urban Mobility Plan process, started in September 2019 and took approximately 2 years.

Figure 8: SUMP timeline (source: Istanbul SUMP)

Istanbul SUMP is the first SUMP study conducted in a city with a population of 16 million, both in Turkey and in the world. It entered the European SUMP literature with the pandemic process studies and created its own literature as it was the first plan made in a metropolitan area with a population of 20 million. It aims for an inclusive and innovative transport system, focusing on people and the environment, providing the right mix of safe, integrated, accessible and affordable mobility alternatives, compatible with the unique geography and historical values of Istanbul for a sustainable and resilient future. It sets a number of objectives:

1. Have an accessible, affordable, integrated and inclusive transportation system.
2. Have an environmentally sustainable transportation system.
3. Have an economically sustainable and resilient transportation system.
4. Improve the safety and security of transport and travelling.
5. Reduce traffic volumes, congestion and automobile dependency.
6. Stimulate the modal shift to public transport.
7. Stimulate the modal shift to active modes (walking and cycling).
8. Have a transportation system that promotes compact and polycentric development.
9. Have an efficient city logistics system with minimal negative impact.

2030 Istanbul Smart City Strategic Plan

The Smart City Strategic Plan includes short, medium and long-term projects that meet the needs of the citizens in order to make the city a sustainable city, in which all the stakeholders of the city are integrated in the process of creating and managing the city in order to increase the quality of life of Istanbul residents and to use resources effectively and efficiently.

The plan was released in December 2021 with the vision of "A sustainable Istanbul that is ready for tomorrow through innovative, inclusive and data-based solutions" and the mission "To improve the quality of life of Istanbul residents using technology, data and information" and "To build a strong and comprehensive city economy within a safe and liveable environment".

In the current situation analysis, Stakeholder Management Plan and Stakeholder Map studies were carried out, and a participatory path was followed with stakeholder surveys. With eight thematic areas, including Smart Mobility, three enabling units, 26 strategic goals and 56 initiatives and nearly 180 projects, it is ensured that Istanbul can compete with other Smart Cities in the world by 2030.

Istanbul Vision 2050

The Scheme of Istanbul's 2050 Vision includes spatial strategies for 2050, based on a three-level system.

1. The first level includes Fatih, Beyoğlu, Kadıköy and Bosporus settlements, which represent the spaces of traditional manufacturers, historical and cultural centre, centre for creativity and tourism, technological transformation areas and innovative rooms for the future.
2. The second level includes the Sultangazi in the north and Bakırköy in the south of the European part and Çekmeköy in the north and Bostancı in the south of the Anatolian region. The second level consists of the transformation of nodes, clean production areas, innovative and technological hubs and the financial and economic base for the future.
3. The third level includes Hadımköy in the north and Beylikdüzü in the south of the European part, and Tuzla in the Anatolian region. This level consists of the main entrances and exits, the logistic hubs, technological production and education areas of the city. Every level is constructed in a manner of self-sufficiency regarding housing and production. Levels can also relate and are ready to transmit today's values to future generations.

Istanbul, a national and international transit point connecting the Asian and European continents, aims to be a logistics centre by 2050, where the circular economy is supported with its transportation and logistics infrastructure.

In this context, in the first level, it is aimed that **light commercial vehicles, electric vehicles and bicycles will be used in the city, and heavy vehicles will be prevented from entering the urban traffic except for transit passes**; thus, their carbon footprint will also be reduced. In the second and third levels, freight mobility will occur gradually and effectively following the steps written above.

The seven themes include:

1. The Climate Adaptive City That Protects the Environment
2. Transformative And Resilient Economy
3. Accessible And Fair Urban Amenities for All
4. Vibrant And Sensible Spaces Assuring Good Living for All
5. **Effective And Inclusive Mobility (five sub-goals, 31 Objectives)**
    - ***To provide accessible comfortable travel with integrated transportation systems***
    - ***To promote pedestrian and bicycle transportation as a mode of transportation throughout the city***
    - ***To ensure traffic safety***
    - ***To ensure inclusiveness of the transportation systems***

- ***To provide environmentally- compatible human and freight mobility with strong global and regional connections***

6. Integrated And Smart Infrastructure Systems
7. Equal And Free Society

Pedestrian Transportation Master Plan

As a leader in pedestrian accessibility, The Pedestrian Transportation Master Plan, started in 2020 and was completed in 2022. In order to increase the share of pedestrian transportation throughout Istanbul, short and medium-term targets were determined, looking at the pedestrianized road length, safe school zones, child-friendly streets, etc.

Fatih, Şişli, Eyüpsultan and Beşiktaş districts stood out as districts where pedestrian movement was intense. Thus, the municipality decided to focus the projects on Şişli and Eyüpsultan. In addition to that, focus has been made on Esenler, Gaziosmanpaşa, Pendik Districts, Bahçelievler and Bakırköy.

The "**Yaya Durağı (Parklet)**" project, which was developed together with the World Resources Institute Turkey, and should ensure road safety in urban transportation, and encourage using alternative modes such as cycling and walking instead of using motor vehicles, was approved by the 'Healthy Cities Partnership (PHC)'. It was put into practice on Halaskargazi Street in Şişli District in June 2022. It aims to collect the demands of the citizens through a survey (that can be found at the following address: https://forms.ibb.gov.tr/yayaduragi) and to spread the Parklet (pedestrian stops) to whole Istanbul, especially the determined districts. 25 Parklets will be operational for 2025 (speed limit will be reduced to 40 km/h in the application area). There are 35 current demands throughout.

The ambitions of Istanbul regarding urban logistic policy are to:

- **Identify Integrated Bicycle Systems with PT lines** by the sub-project of Strategic Cycling network, Transfer Centres and Mobility Hubs,
- Reduce traffic congestion by using e-vehicles in logistic sector by Mah-HM project (Mahalle Hareketlilik Hizmet Merkezleri) within the SUMP implementation,
- Reduce the noise and air pollution by using alternative solutions in transportation such as e-vehicles with the Noise Master Plan and Climate Action Plan,
- Create **secondary (Micro) Consolidation Centres** (MCCs) to increase efficiency with the Logistic Master Plan,
- Use electric vehicles (EV) in maritime for PT and create an integrated hub including logistics.

Low emission zones are planned for the near future around the city. A pedestrianization project is also currently being developed for the Historical Peninsula of Istanbul.

During rush hours (06:00 - 10:00 and 16:00 – 22:00), heavy vehicles cannot enter certain roads in Istanbul. Three bridges and a tunnel connect the European and Asian sides of the city. **However, heavy vehicles can only use the northernmost bridge** (Figure 9). Others are forbidden for this kind of vehicles.

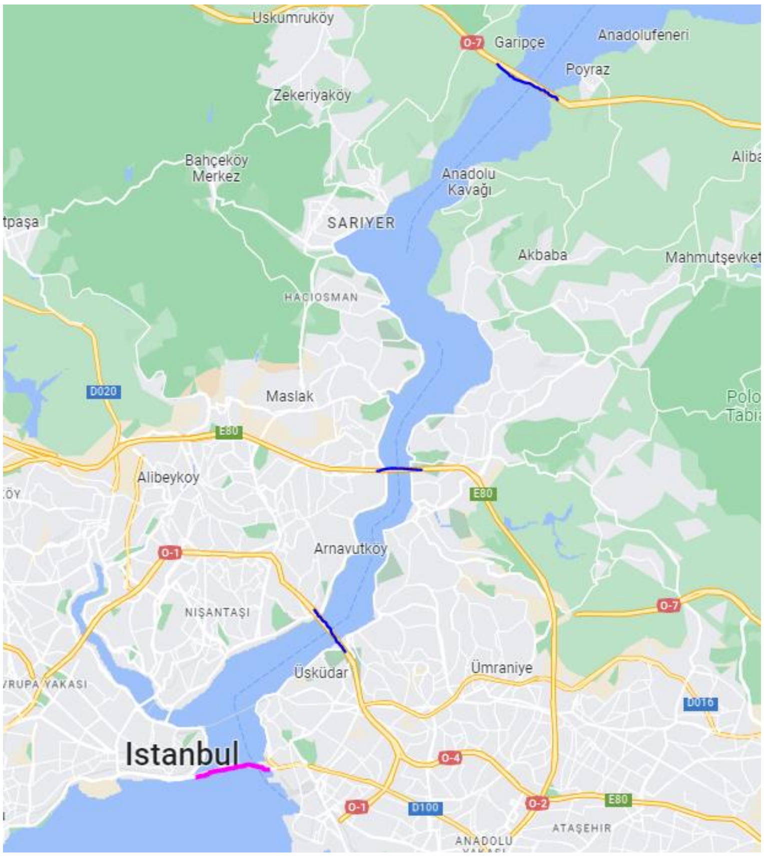


Figure 9: Istanbul bridges (in blue) and tunnel (in fuchsia) connecting Europe to Asia (source: Google maps)

Istanbul has a big earthquake problem. A devastating earthquake is expected in the city in the near future. As bridges and the tunnel are the only way to connect the two sides, an emergency could be chaotic. To minimize the chaos, emergency logistics depots should be built at both sides. This is in the study phase and location has not yet been defined.

In addition, according to an IMM recent study, the following main urban logistics problems have been identified:

- Traffic congestion and jams
- Environmental factors (visual appearance, noise, air pollution, effluvia, vibration, topography, etc.)
- Waste of energy,
- Ineffectiveness of logistics sector,
- Security of food, load and vehicle,
- Disaster logistics requirements,
- Logistics area requirements at ports,
- Reverse logistics,
- Internal/multi-modal terminal need,
- Necessity of quality workforce,
- Logistics Costs
- Lack of cooperation

One of the leading solutions to prevent most of these problems are logistics centres. Logistics centres are especially important in terms of being facilities where all the activities of logistics can be executed together. Clustering all logistics activities at the same point is important in terms of ensuring efficiency and optimization, which are among the most important factors of logistics sustainability. In order to establish an effective and efficient logistics management in Istanbul, it is necessary to open **regional logistics centres on both the European and Asian sides**.

Another solution to overcome these problems are **Urban consolidation centres, that are** differentiated into Primary Consolidation Centres and Secondary Consolidation Centres. Especially in the case of İstanbul, it is advised to build four primary consolidation centres around the city, each of them specialized in different goods like food, chemicals, textile. From the Primary Consolidation Centre, the load will be transferred to Secondary Consolidation Centres which should be designed to carry goods only for between 1-15 kms by the vehicles.

In addition to that, **terminal depots' capacity** is going to be alarming soon. So additional depots are needed, and these depots should be integrated with Primary Consolidation Centres. Also, heavy and light commercial vehicle parking areas are a big necessity to the city.

For organising these new systems, innovative urban logistics management will be needed and essential.

Local stakeholders

The local stakeholders that were analysed in this Living Lab are either individuals or a group of people or companies that are indirectly or directly affected by the actions of the Istanbul LL.

Local stakeholders can consist of various associations and organizations such as end consumers, local and economic actors, such as the food sector, the industries, transport & logistics operators, and NGOs and environmental groups. Additionally, local government officials and community residents from metropolitan and district municipalities.

For the Istanbul use case, the stakeholder mapping (figure 10 below) developed from the initial stakeholder mapping exercise done during the Kick off meeting (KOM) with local stakeholders, following ranking exercise combined with the presentation during the technical visit. The figure indicates how currently everyday retail from supermarkets and related services are the key central actors for the existing delivery demand, primarily executed by third-party delivery services. In this visual, the centre indicates the core of the services – meaning the most direct/high impact stakeholders in the centre and the further out you reach, the more indirect stakeholders are listed.

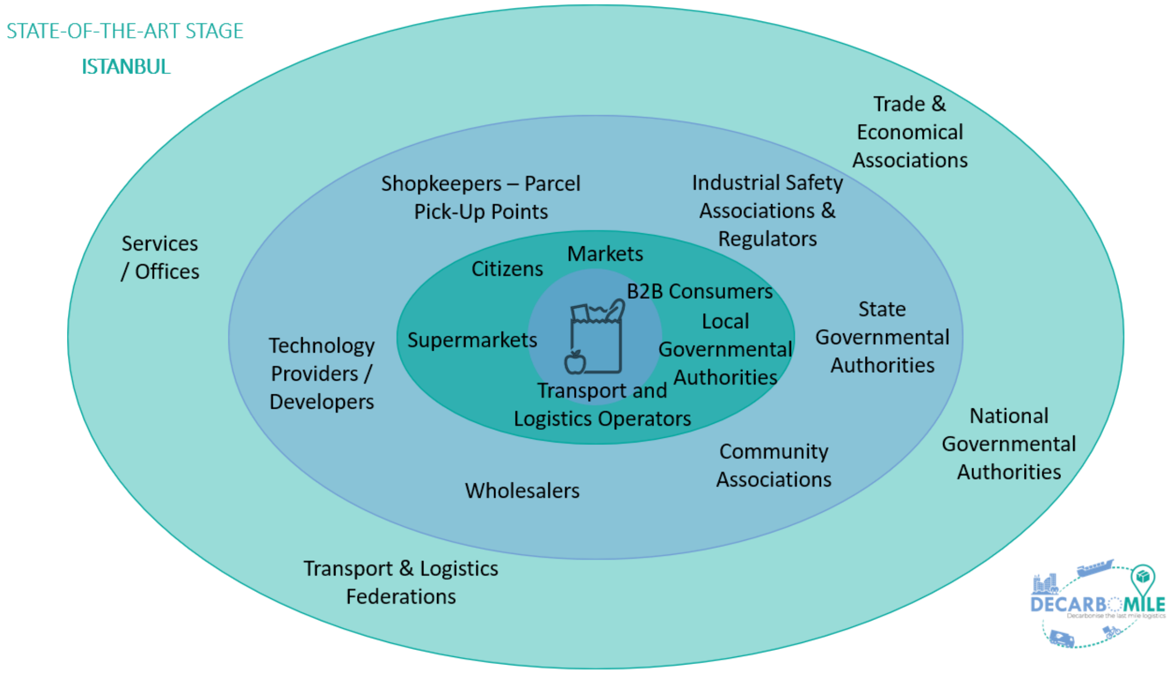


Figure 10: Key sets of stakeholders in Istanbul Living Lab current scenario (source: CBS)

For a perfect collaboration, the main stakeholders should be informed about the rough project process and should come together and discuss the current state of the project regularly - the goal is to reach a consensus for further procedures.

Based on a preliminary mapping, the following stakeholders have been identified as extremely valuable to the project, and with a strong engagement potential for the upcoming developments:

- Technology providers:
  - Google Waze (willing to provide "real-time traffic" data for the DECARBOMILE cities through their program so called "Waze for Cities")
- Transport and logistic operators:
  - HepsiJet (e-commerce logistics service provider, established by Hepsiburada)
  - Sendeo Kargo (Koc Holding)
  - Iletmen
  - ULAK
  - Scotty
  - Surat Kargo
  - Yandex (Yango) Delivery
  - MobiQu (needs the aggregated info of available spaces for different transporters (logistics service providers) and transportation modes)
  - ParkPalet (AirBnB of WareHouses)
  - Kadikoy Municipality and HepsiJet (an e-commerce logistics service provider) are interested in collaborating together (with each other) within the scenario of "mixed use of vehicles"
- Trade association:
  - ITS Turkey (Turkish Branch of International Association of Intelligent Transportation Systems)
  - World Resources Institute (WRI) Turkey (also run an "urban mobility" project across the country including "urban logistics" aspects)
- Local/governmental authorities:

  - Ministry of Transport and Infrastructure (as they develop the national/ nationwide Mobility-as-a-Service (MaaS) hub)
  - Kadikoy Municipality, Istanbul (interested in the establishment of a new UCC and/or MCC in their authorization region)
  - Marmara Municipalities Union (The first and the largest regional Local Government Association in Turkey)
- Universities:
  - Koc University
  - TUBITAK TUSSIDE
  - Istanbul Technical University
  - Yildiz Technical University
  - Maltepe University

On Wednesday 25th January 2023, IMM hold their first workshop with these local stakeholders, gathering around 100 persons from different IMM departments (smart city, logistics, urban planning, etc.), logistics operators, smart lockers producer (Kargopark), software providers, fashion shops (Hepsiburada an online hub which 3rd party retailers like MIGROS can use to sell products), transport companies (Yango), a shop keepers representative, etc.

Below is an overview of the needs, challenges and solutions that were discussed.

NEEDS

- Related to the cargo-bikes:
  - Increase the number of e-bikes parking and charging stations
  - Increase cargo-bikes capacity
  - Safe driving education
  - Ensure sufficient human resources for deliveries
- Related to the use cases in general:
  - Road / land optimisation
  - Harmonized measurement methodology
  - Increased storage facilities, such as smart lockers and shared consolidation centres
  - Business models supported by authorities to be sustainable
- Social needs:
  - Lower return rate to decrease traffic
  - Increase smart lockers use (in workplaces for instance)

CHALLENGES

- Weather conditions and topography

- Operational challenges:
  - Parcel weight
  - Disposable batteries for e-bikes
  - Integration of consolidation centre use + of software in the companies involved
- Location of the consolidation centre + the cargo-bikes and lockers: questions related to infrastructure and data management (with different operators / companies, involvement of the municipality, etc.)
- Social habits of getting home deliveries
- Insurance of stolen goods
- Environmental impact
- GDPR (General Data Protection Regulation)
- Price of the real estate

SOLUTIONS
- Mobile containers and warehouses
- Seaway intramodality
- Develop new improved e-bikes (GPS sensors, etc.)
- Use lockers as local markets

The way / scope / extend /etc. in which the different stakeholders will be involved in the use case, alongside MIGROS, still needs to be defined. They could be engaged in the hub simulation, on the regulation level, etc.

In addition, a survey has been shared with logistic operators, for which it was managed to get four respondents: Ekol Lojistik, Paket Taxi, Yango and Aras Kargo. They mostly work in the moving sector (100%) as well as shopping and parcels deliveries (66%), and mail delivery (33%). All of them deliver wholesalers, and most of them (3/4) deliver offices and restaurants / hotels / coffee shops. Only 2 of them do home delivery. The average distance covered by one tour is 50 km.

It came out that vehicles operate mostly (75% of the time) at full capacity and are considered reliable most of the time (50%) or on average (50%). Some of the biggest challenges identified, and which echoes what has already been stated in this document, relate to congestion, as well as delivery hours and opening hours of receivers (or the lack of information on their availability), regulations or physical limitations of some streets or streets segments, and the lack of interconnection with IT systems of customers / contractors / partners. Regulations on motorization, the lack of tools to optimise the process and to analyse the activity for better strategic decisions were not identified as key challenges.

Interestingly, two of these operators already share loads, hubs, and vehicles with other operators to increase their capacity and environmental impact, and one doesn't but would be open to. On the environmental side as well, they all said that their customers do ask for a "greener" service. Deliveries are mostly made by vans or light commercial vehicles (up to 3.5T), but two respondents shared that they already use cargo-bikes, and two of them also mentioned motorcycles as a delivery vehicle.

All respondents also shared that they would like to be involved in workshops related to Istanbul as a DECARBOMILE Living Lab, and 3 of them in events (webinars or conferences), or in testing tools or vehicles improving operations. None of them however seemed interested in connecting their tools to other systems and data bases to help operations.

Existing IT solutions

Based on the logistic operators' survey data analysis, the following IT systems came out:
- *Routeq* for traffic management, optimization and planning, and parcel loading

- *YandexMark* for stock management

None of the 4 respondents in the survey seemed interested in connecting their tools to other systems and data bases to help operations. MIGROS, for example, develops and uses its own software and IT system for e-commerce, logistics and warehouse operations, and is very satisfied with it.

MIGROS' two types of deliveries (Instant and Time-slot) are providing an estimated time of arrival to customers which ensure satisfaction measurement, through GPS of the mobile phone of the delivery person. Customers can then track them on their mobile phones. At the moment, route optimisation does not take into account the congestion / traffic nor the road slope degrees, only "the shortest route". Drivers can freely decide the road if there is a congestion.

MIGROS currently has an optimisation process for their internal routing for both customer deliveries and for deliveries between warehouses and stores. **MIGROS also has data on their number of packages, deliveries, e-bikes and other metrics they can share with IMM.** On the other side, IMM could share other data on upcoming urban planning strategies, or on road traffic, for instance. They have cameras measuring the main / municipal road congestion level, traffic, etc. which could be interesting for MIGROS. As local streets are under the control of district municipalities, IMM does not possess however such data for *local* streets (which would be used by cargo-bikes in DECARBOMILE).

Yandex (a Russian search engine and web portal which offers internet search and other services like maps, navigator, public transport, taxi, weather, news, etc.), which owns data on smaller streets, is willing to share it with DECARBOMILE partners. A follow up email has been sent on 06/02/2023 by CAPIT after a first meeting on 27/01/2023.

On 22/02/2023, MIGROS and CAPIT/TMTX had a technical meeting to discuss potential projection algorithms, linked to MIGROS e-commerce operation.

- Option 1: forecasting the demand in upcoming days/weeks for a specific area around the hub location, based on e-commerce customers' historical order data shared by MIGROS (e.g. which customer segment, how many orders, how many items per day / per week).
    - The aim is to better plan the delivery operation and the inventory of the hub.
- Option 2: forecasting the fleet of electric vehicles (what kind of and how many) for a new hub location or for the same hub location in a given period of time according to the given input parameters (customer profile, demand volume etc.).
    - The aim is to better plan the rental or purchase of new vehicles.
- Option 3: forecasting/selecting the location of a new hub (i.e. MCC/UCC) according to the parameters which can be shared by IMM (demographic, economic, cultural characteristics, traffic data of potential areas in Istanbul) or can be received from open data services/sources.
    - The aim is to optimise the hub location.

SUMMARY OF THE SITUATION AND POTENTIAL USE CASES

Synthesis and knowledge

The main needs and challenges identified by local stakeholders can be summarised as follow:

- Main challenges:
    - Economical: economic crisis, lack of stakeholder's cooperation and coordination
    - Ecological: high congestions, low road regulations implementation, topography, low use of bikes
    - Technical: lack of common hubs and cooperation systems

- Main strengths:
    - Economical: High use of e-commerce and diversity of logistics operators
    - Social: tourism as a strong opportunity to decarbonise logistics, young population tech-savvy
    - Technical: multimodal city with different transportation modes (metrobus, metro, tram, bus, ferry, etc.)

Potential use cases

INTRODUCTION OF THE REFERENCE SITUATION

Traditionally in the Istanbul Historical Peninsula, "*hamal*", also called "*çekçekçi*", are workers who carry goods on their back, or with a trolley, from an "*ambar*" (consolidation centre) to local shops. This *ambar* will be owned by IMM but is not yet operational, as it is still under discussion with the urban planning department.

The main regulation is that delivery trucks are only allowed from 10AM to 4PM and then from 10PM to 6AM. This restriction does not apply for *çekçekçis,* who are irregular / informal and for whom there is no control and enforcement. This is why a renewal plan is being prepared in this area, to better control and regulate their operations.

IMM has some interactions with *çekçekçi* representatives (social organisation) who are in charge of managing the different deliveries in a specific area (orders coming by boats, deliveries to shop owners, etc.).

Figure 11: Morning deliveries in Istanbul (source: IT)

MIGROS, local partner of the project, has around 700 stores in Istanbul (over 2 900 in Turkey in total), and around 35 dark stores (distribution centres that exist exclusively for online shopping) in Istanbul, located in the warehouses of regular stores. MIGROS e-commerce uses dark stores in the locations with high order numbers to separate e-commerce and store operations.

MIGROS dark stores are supplied as normal stores by the main distribution centre in the area or the city. Some fresh products are supplied directly from product suppliers to stores. Main distribution centres are supplied by product suppliers.

Table 1: MIGROS stores organisation

DISTRICT	MAIN STORES	ONLINE STORES (TIME SLOT DELIVERY)	ONLINE STORES (INSTANT DELIVERY)	DARK STORES
KADIKÖY	92	4	8	1
PENDİK	34	3	5	0
FATİH (includes HISTORICAL PENNINSULA)	14	1	3	0

MIGROS offers 2 types of delivery modes:

- **Instant / fast delivery** (MIGROS Hemen): within 30 minutes, usually for one-two packages on average, average package weight is two kg per one order, more expensive as harder to optimise the delivery. Consolidation potential as there are only two orders per route at the moment. Delivery is handheld by motorcycles with an area of distribution of two km.
- **Time-slot deliveries** (MIGROS Sanalmarket): this mode is more optimized, and for one order, the package weight is six kg in average. One route lasts two hours and includes ten customers/orders. For time slot deliveries, only scheduled orders (previously demanded by customers) are delivered. Delivery held by panel van cars with an option of refrigerated deliveries for fresh food products. Area of distribution: six km.

An interesting addition could be to add an option for customers to choose "free delivery if by e-cargo bike" or "discount coupon for next order if by e-cargo bike".

These 2 types of deliveries are operated directly from the stores, or from the dark stores. Both delivery modes provide an estimated time of arrival to customers which ensure satisfaction measurement, through GPS of the mobile phone of delivery men. Customers can then track them on their mobile phones.

MIGROS subcontracts the company Paket Taxi for B2C deliveries, who uses e-cargo-bikes, motorcycles and panel van cars, in addition to another company called Murat Lojistik for only panel van deliveries.

While the use of smart lockers is not yet widespread in Istanbul, Kargopark, a branch of Hepsiburada, manufactures and rents smart lockers to several companies. They place them at local markets, and customers come and pick up their orders. IMM will gather data on the use of smart lockers by the companies, to understand customers' habits and use of these solutions.

The two figures below are supporting the understanding of the reference situations. The first one only concerns Migros logistic operations. The second one, more general, represents the reference situation for other operators, based on the result of a survey sent to the stakeholders involved in logistic operations.

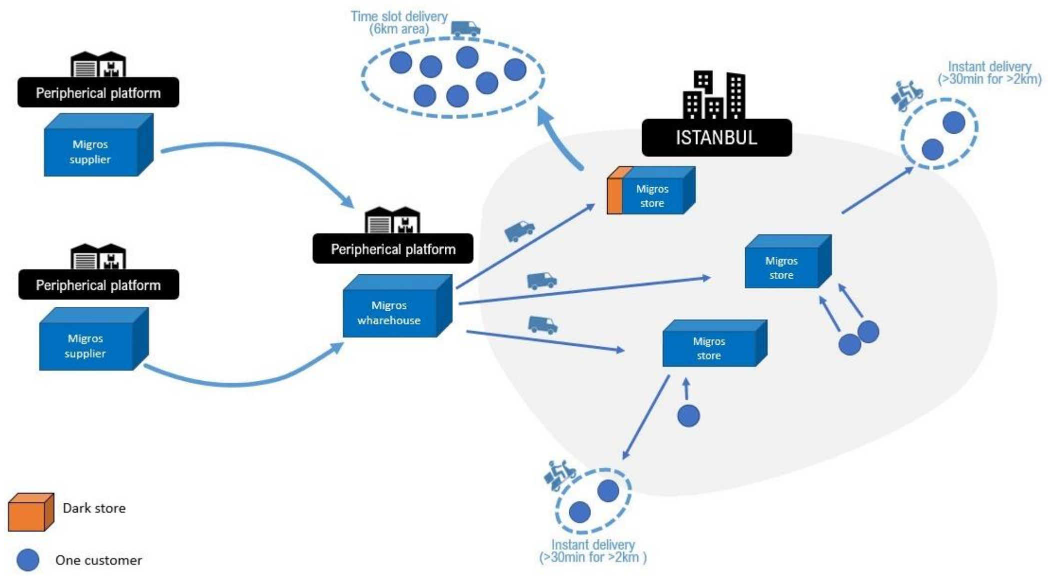


Figure 12: Reference situation for MIGROS store (source: IT)

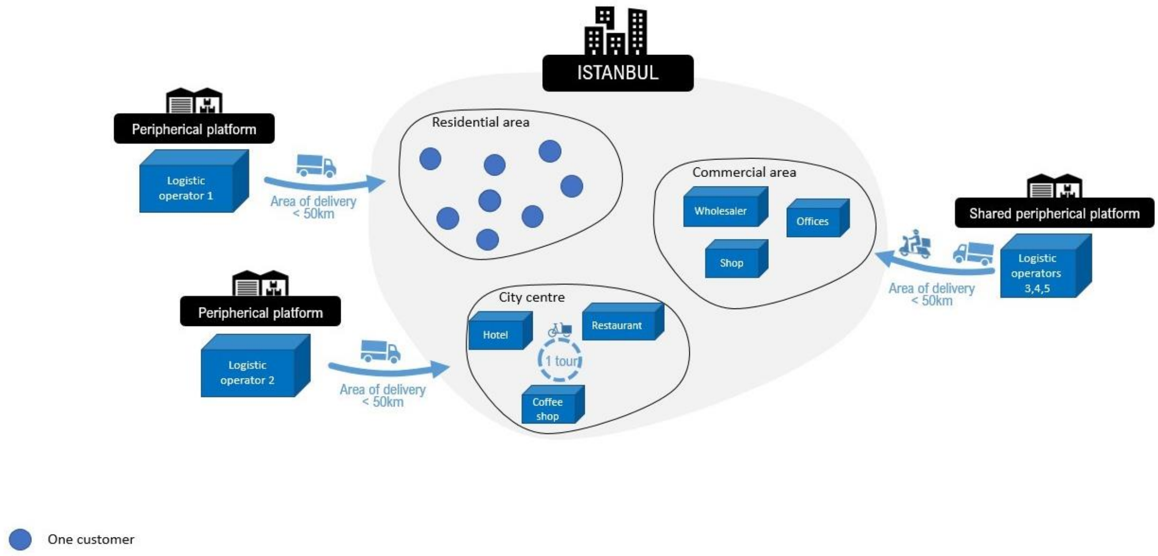


Figure 13: Reference situation for other operators (source: IT)

USE CASES

The use cases in Istanbul will focus on last-mile logistics using **electric cargo-bikes from its consolidation centre in the city centre**. The Urban Consolidation Centre (UCC) and Micro Consolidation Centre (MCC) implemented will be used by MIGROS in priority, for the home deliveries associated to their e-commerce branch (probably not to improve the deliveries to the stores).

SCENARIO 1 – MICRO CONSOLIDATION CENTRE FOR MIGROS DECARBONATED INSTANT DELIVERIES

In a first scenario, DECARBOMILE's partner MIGROS would store its products in a 100m² MCC (real estate provided by MIGROS as a standalone hub location, not located near a MIGROS store) – average of 3 000 Stock Keeping Units (SKU), for instant deliveries by cargo-bikes.

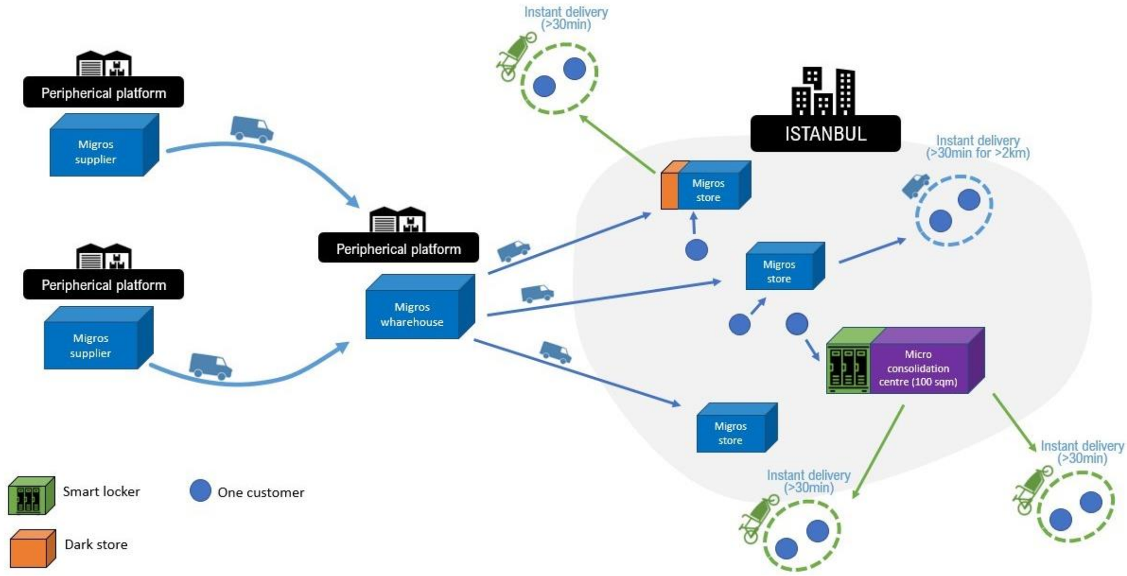


Figure 14: Pilot situation for MIGROS stores (source: IT)

In this micro consolidation centre, some smart lockers will be implanted too, in order to diversify the delivery methods and focus on the in-store experience. What is changing from the reference situation is that the instant deliveries would be made by cargo-bikes, without excluding that some deliveries would still be made by motorbike or small truck (in case the 10 cargo-bikes planned in the use case are not sufficient for the coming orders).

SCENARIO 2 – SHARED URBAN CONSOLIDATION CENTRE

In the second scenario, IMM would provide a larger space (an Urban Consolidation Centre of 500m²) to logistic operators, including MIGROS (for their e-commerce operation with over 3 000 SKUs, Hepsiburada, Trendyol etc. MIGROS' daily distribution will be carried out using electric cargo-bikes purchased with project funding and will be further diversified with smart lockers provided by IMM, which will be located near the urban consolidation centre.

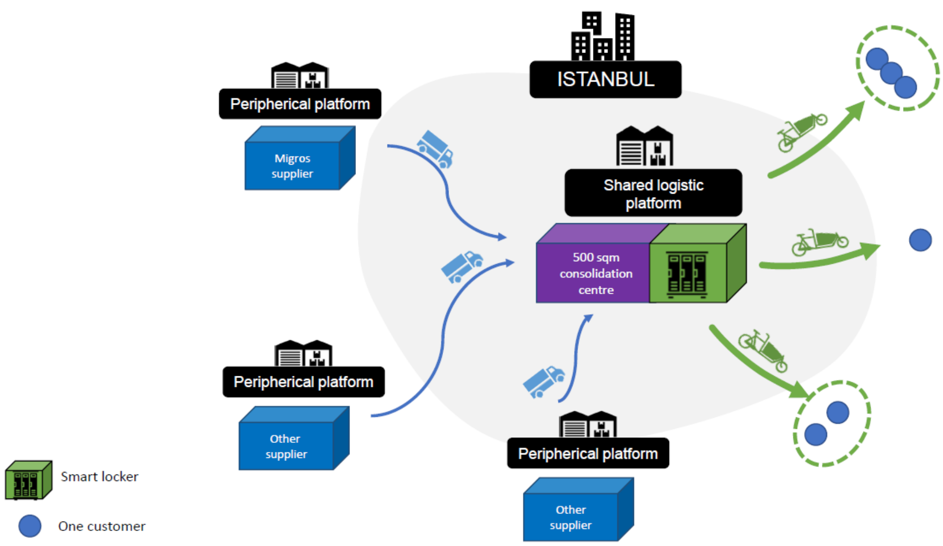


Figure 15: Pilot situation for other operators (source: IT)

This use case focuses on consolidating the flows from MIGROS in one logistic hub. IMM will also study the possibility of consolidating flows from other logistics operators (invited shareholders like hepsiburada or trendyol etc) in one or several hubs. Then the parcels are mixed and delivered by sectors of the city with e-cargo-bikes.

The following requirements were identified to implement the different use cases in Istanbul:

- Availability and good functioning of e-cargo-bikes
  - MIGROS already has four 3-wheeled cargo-bikes operating for one store on Prince Islands (where no diesel or gasoline vehicles are authorised), which would need to be improved in balance, mechanics (hydraulics and differential systems), and battery life.
- Availability and good use of smart lockers
- Availability and good use of charging stations in hub locations
- Proper location and management of consolidation centres
  - **One Urban Consolidation Centre of 500m² + one Micro Consolidation Centre of 100m²** have been foreseen in the Grant Agreement; they would be located where the daily logistics traffic is very dense.
  - Hub type and location is key for **MIGROS** as it should meet its needs and reach the Key Performance Indicators set by both IMM and MIGROS (at least on the environmental side; **economically, the hub business model needs to be sustainable for MIGROS and for replication purposes**).

<u>4 real estate options were mentioned for the hub/s:</u>

1. MIGROS rent a warehouse,
2. Use one of MIGROS's own store / warehouse,
3. IMM to provide a space it already owns,
4. IMM to buy a space for this purpose.

POTENTIAL HUB LOCATIONS

The map below shows the global logistic situation of the city. In blue and red dots are marking points of interest of the city where it is envisioned to develop logistic hubs. They are listed below as well.

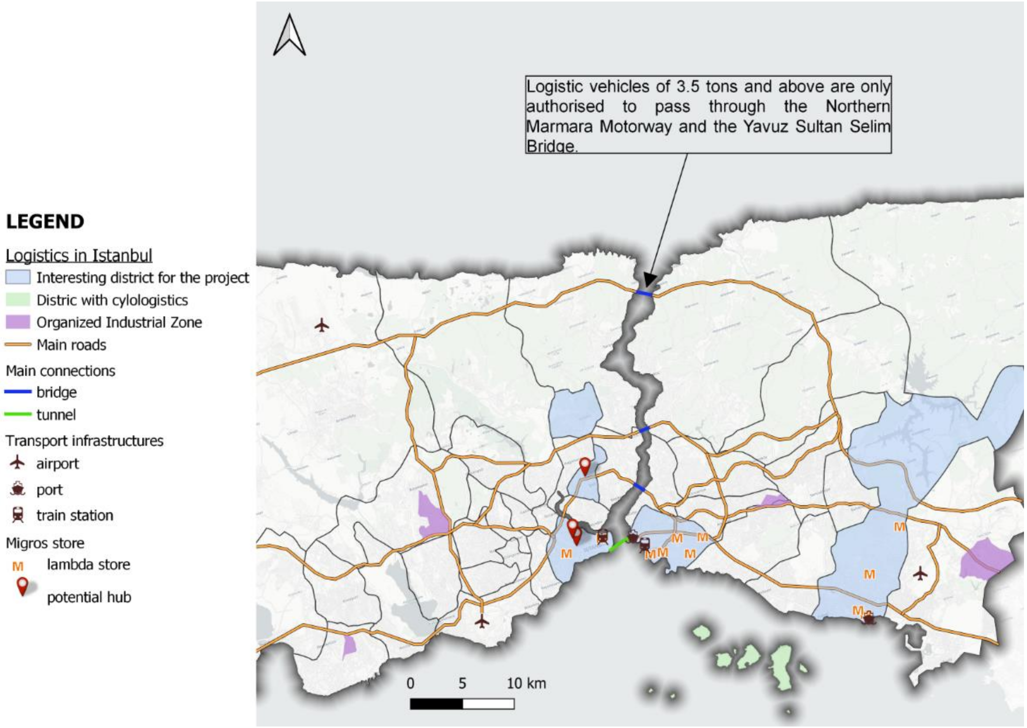


Figure 16: Map of Istanbul (source: IT)

- The historical peninsula

Gathers historical small-scale businesses / manufacturers and mostly textile and touristic shops. They are willing to keep the operations in that area. A challenge of supplying MIGROS stores there is due to the logistical constraints.

Figure 17: Map of the Grand Bazaar area (source: IT)

IMM needs to collect data to check the real estate available in that area. At the moment, there is none either because of historic buildings, or it is not well located. IMM also needs to check options in the rest of the peninsula as well.

IMC (İstanbul Manifaturacılar Çarşısı = Istanbul's large textile / drapery / upholstery / flooring / wallpaper / musical instrument complex, organisation of shop owners) could provide their car parking as temporary hubs if shop owners used urban transport.

An idea mentioned was to operate a floating hub on the river by the bridge (like the "River tri" and "FLUDIS" projects in France), whose implementation during the project lifetime seems ambitious given its low maturity.

- Kadıköy (a district municipality)

Mostly residential, presents a higher interest for MIGROS as they already operate e-commerce deliveries there.

- Pendik area

Area that combines a port, an airport, rail options, etc.

- The Caglayan Courthouse Istanbul Palace of Justice

Where MIGROS has a store big enough to set up a UCC, located within a mall, in a busy area.

A key question that needs to be figured out is who will be operating the hub: public authority, an operator, an NGO? If shared, it might be harder to agree on specifications, surface used, time slots, etc.

Key Performance Indicators

Specific KPIs for Istanbul will be developed later on, once the use cases are more specific. General indicators could include:

- Number of freight units collected in smart lockers
- Loading/unloading time at the warehouse
- Allocation of public space for UCCs (m^2)

Relevant use cases to build upon

Based on the use cases identified, the additional following projects could be of interest for Istanbul:

- FLUDIS: Boat delivery, with 4 checkpoints, with crane (un)loading and cargo-bikes for B2B last-mile logistics.
- KARGOPARK : Cargo smart lockers placed at Migros retail stores to enable customers to self-pickup their packages (orders from ecommerce sites, self-pickup, e-commerce cargo) while they come for shopping.
- HALLO : Creation of shared urban consolidation and distribution centres (UCDCs), with fossil-free logistics.
- IWTS: Modal shift from road to water, using smaller, or under used complementary waterways with links to the main TEN-T corridors (EU's Trans-European Transport network policy[1] with the Middle East and Asia connection corridor that passes through Istanbul).

A more detailed document gathering information on the above projects will be shared with the LL to enhance collaboration on these topics.

1.2 Nantes Living Lab

CONTEXT

Nantes is an Atlantic port city on the estuary of the river Loire. Over the last 20 years, Nantes has been one of the top 3 cities in France, with a strong demographic (+1.4% per year), economic (salaried employment rate of over 21% since 2009, compared to 6% in France) and cultural growth. Distinction between the commune of Nantes and Nantes Metropolis (Figure 18 below) is key:

- Nantes Metropolis (also referred to as *Nantes* in this document) is the sixth largest metropolitan area in France, gathering 24 cities, 650 000 inhabitants, 523 km².
- Nantes commune (or city, in yellow in the map below) gathers 303 400 inhabitants over 65 km².

Moreover, Nantes is located in the Loire-Atlantique department (one layer above the metropolis).

[1]https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en

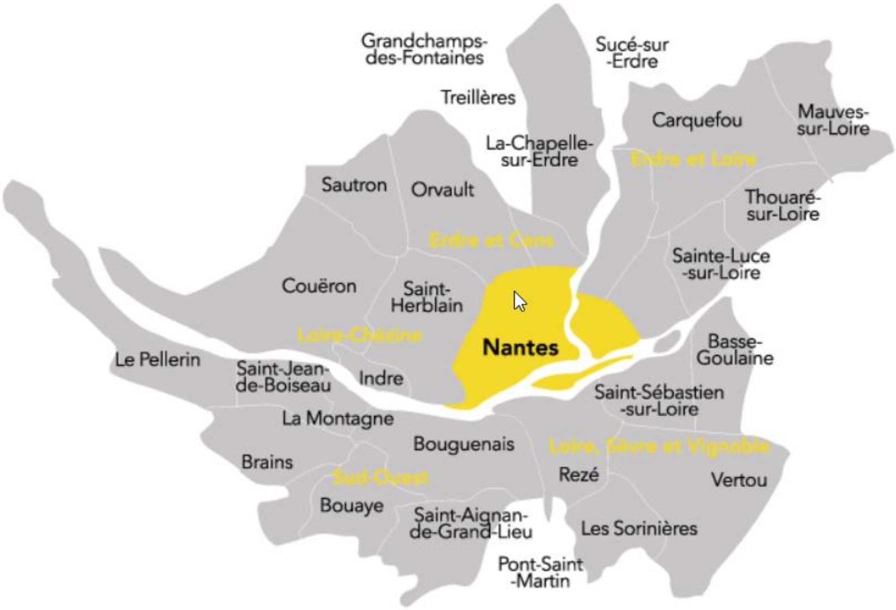


Figure 18: Nantes Metropole, gathering the city of Nantes (in yellow) and 23 other cities (source: Proxicab)

Nantes is also the leading economic area in Western France with 25 100 companies providing 353 000 jobs. This stems from both traditional sectors, like naval and aeronautic construction, agri-foods and service, and from innovative sectors, such as composites, health, biotechnologies, Information and Communication Technologies (ICTs), creative and cultural industries. Since July 2012, Nantes Metropole have been grouped with 5 other inter-municipalities to create the Nantes Saint-Nazaire Metropolitan pole, which stands out as an attractive logistics pole, with economic weight and dynamism, and a role as a product distributor.

URBAN LOGISITCS

Economic activities and freight movements

A few key figures

- ~ 50% of Nantes Metropolis' logistics movements are linked to establishments located in Loire-Atlantique (25% for the city of Nantes).
- E-commerce is growing by 14%/year and has increased by 37% in 2020 due to the health crisis (COVID and lockdown).
- The share of alternative motorisations is currently very marginal in the vehicles fleet: 97% of professional vehicles and 99% of the personal vehicles, both registered since 2000 and located in Nantes are petrol or diesel.
- Almost 1/3 of trucks involved in international transport in Europe are under-used or run empty (Eurostat,2019).

Freight movements (distribution / collection flows of private sector establishments)
A total of 777 000 urban logistics movements are carried out each week by establishments in Loire-Atlantique. Nantes Metropolis accounts for 51% of the movements generated (394 000 movements of goods per week), the Nantes commune accounts for around 25% (194 250 movements of goods per week) of the flow. In Loire-Atlantique, the top three of the economic sectors generating the most transportation is 1. crafts and personal services, 2. wholesale trade and 3. small shops.

Beyond the metropolis, there are:

- The Carene and the port site of Saint-Nazaire-Montoir-de-Bretagne (8% of the department's movements),
- The communes of La Baule and Guérande on Cap Atlantique (5% of the department's movements and 14 business activity zones),
- The industrial pole of Ancenis St-Géréon,
- Châteaubriant (Val Fleury business park),
- Pornic (several commercial and business zones)

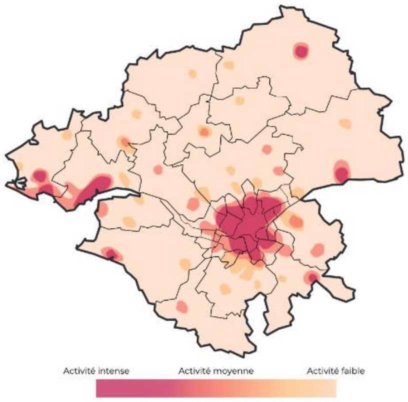


Figure 19: Density of movements in Loire-Atlantique (source: Systra - FRETURB, SIRENE 2018)

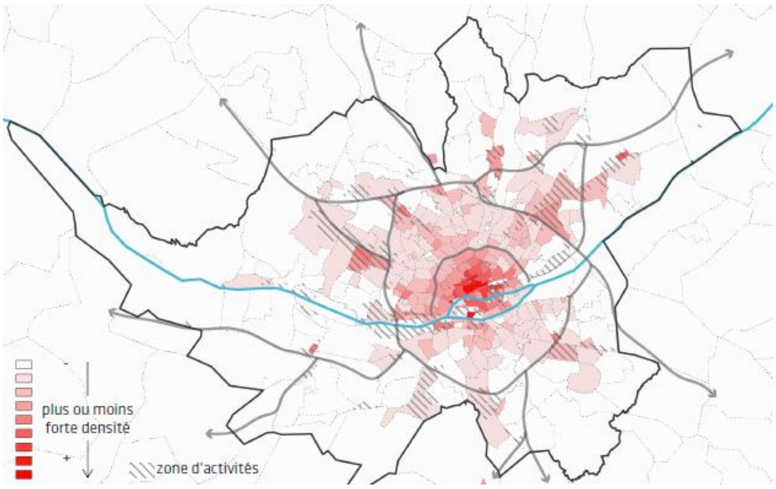
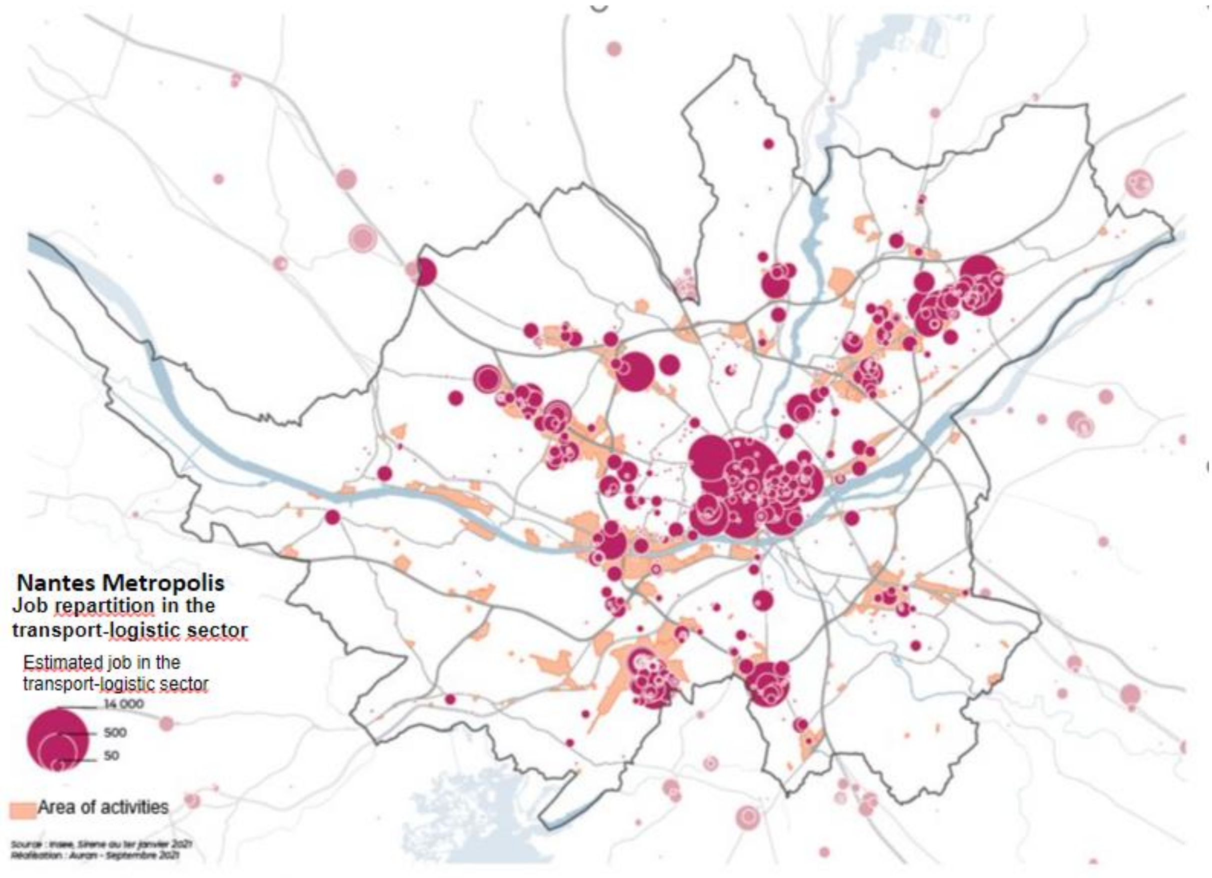


Figure 20: Density of movements in Nantes Metropolis (source: Systra - FRETURB, SIRENE 2018)

These vehicle movements are based on ratio defined by type of establishment and by number of employees (according to the FRETURB model developed by the French research laboratory LAET). This flow density is hence correlated with the density of establishments and jobs in the Metropolis, as can be seen in the map below.



Source : Insee-Sirene 2021, cartographie Auran

Figure 21: Job repartition in the transport-logistic sector In Nantes metropolis (source: Insee-Sirene 2021)

The "craft and personal services" sector is the main generator of logistics movements at both levels (Loire-Atlantique and Nantes Metropolis), with almost 1/3 of the movements carried out in this sector. The “wholesale trade" sector is coming second, with 19% of the flow for Nantes Metropolis, although it represents fewer jobs and establishments.

The daily distribution of logistics movements (from the City Goods surveys carried out to set up FRETURB) reveals two peaks of movement generating road occupation constraints:

- in the morning from 8am to 10am
- in the afternoon from 2pm to 4pm

By cross-referencing this time distribution of "goods" mobility with "passenger" mobility (daily trips of the inhabitants of Nantes Metropolis), it can be seen that:

- there is a direct competition with the morning peak period (7am-9am), which therefore aggravates the road congestion observed at that time.
- the logistics afternoon peak occurs slightly before the passenger’s mobility evening peak period (4pm-6pm), so its impact on traffic is less .

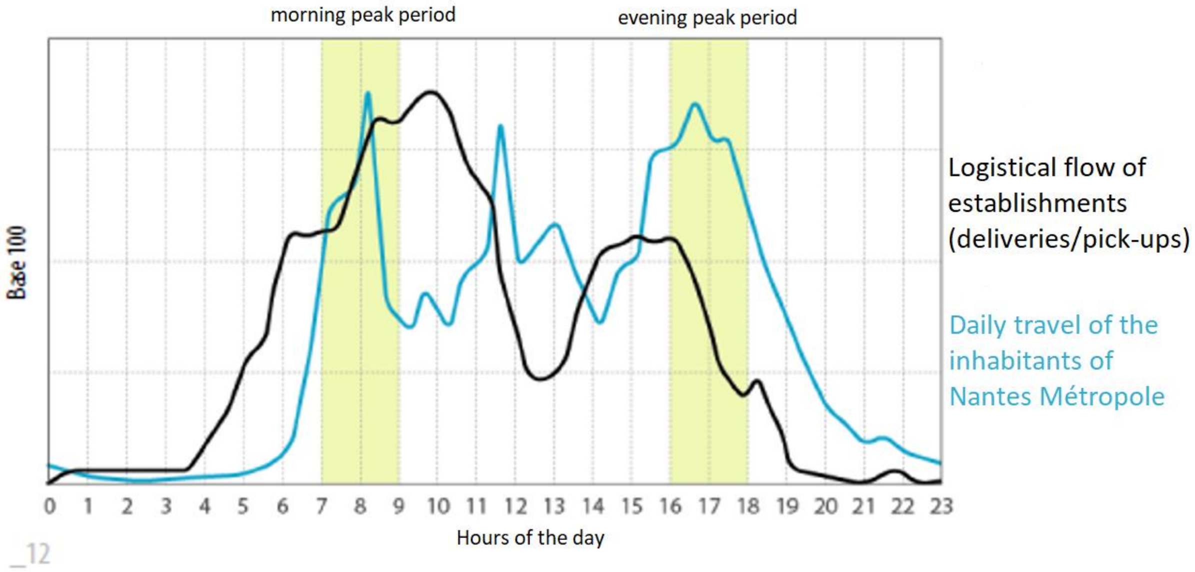


Figure 22: Daily travel patterns (source: Auran - FRETURB - EDGT 44)

Infrastructures and main Equipment/assets

The Nantes-St Nazaire / Rennes bi-metropolitan cluster polarises the Greater West logistically, but Nantes remains a relatively modest road logistics crossroads compared to those of Bordeaux, Tours or Rennes. Nantes Metropolis is not, like Brittany, a large transit area due to the fact that it is not a major centre of logistics nor a major transit area due to its quasi-peninsular location.

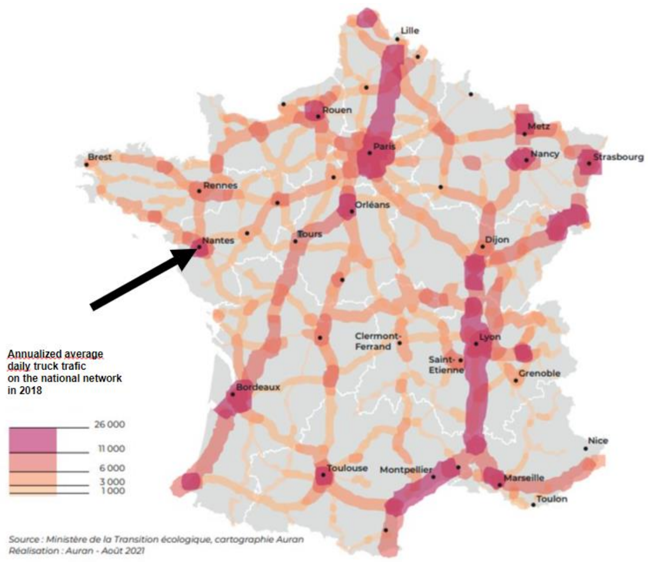


Figure 23: Daily truck traffic on the national network (source: Ministry of Ecological Transition, Auran mapping)

Although it might appear as a relatively modest logistical crossroads at national level, the region Loire-Atlantique remains equipped with structuring network of transport infrastructures.

- Main road network: motorways (A11, A83), national and departmental roads (N137, N165, D751), the Nantes ring road, which plays a major role as an interface between logistics centres (most heavy good vehicles (HGV) traffic is in the north of the area between the Paris motorway and the route de Vannes road).

- A 4-branch railway star (Nantes-Angers, Nantes-St-Nazaire, Nantes-Clisson, Nantes-Châteaubriant).

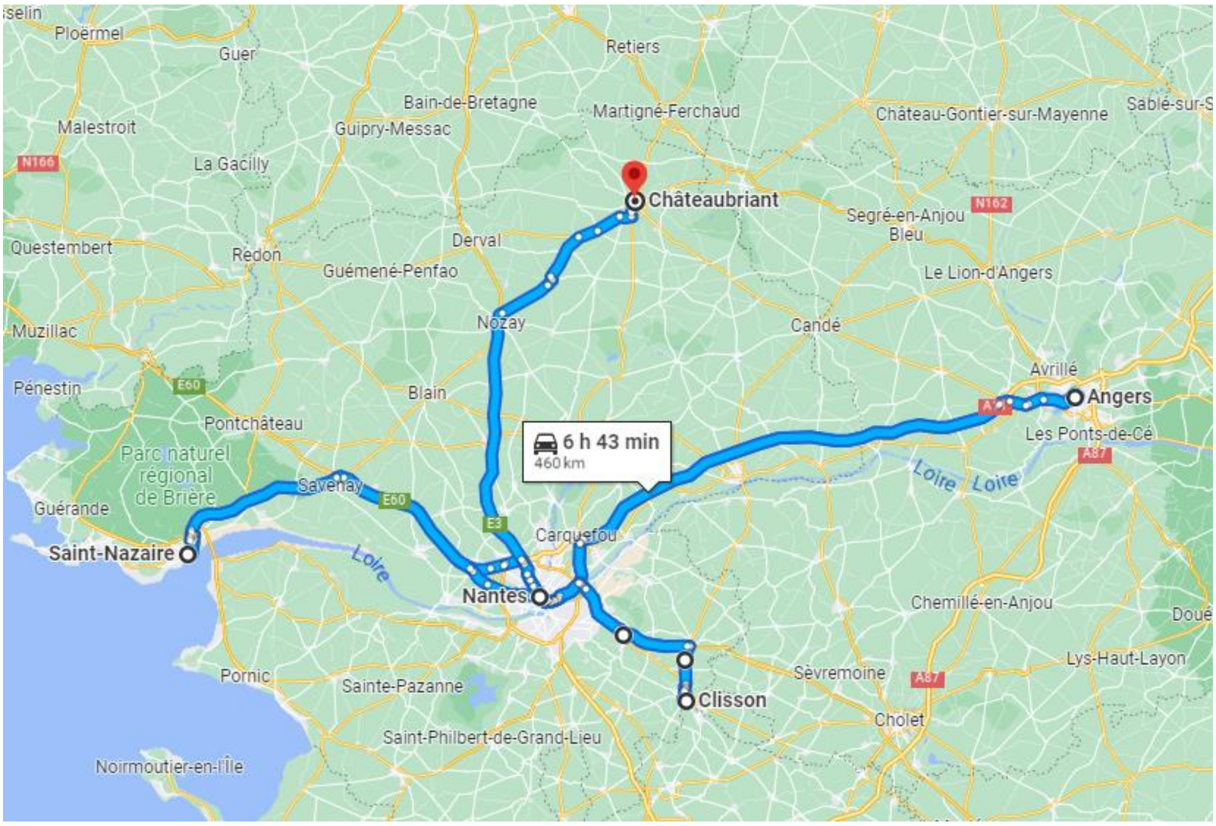


Figure 24: Nantes 4-branch railway star (source: Google maps)

- Nantes Metropolis is located on the secondary rail freight line in the West of France, with the Lyon-Nantes route (the main rail freight line being between Paris and Rennes).
- The river network of the Loire and the large port of Nantes-St-Nazaire, which is the fourth largest French seaport, generating 28 500 jobs (according to a study based on 2018 data from the INSEE, the French national institute of statistics and economic studies and accounting for 30 million tonnes of traffic per year.
- Nantes Agropolia for food flows, where the National Interest Market (wholesale market) is located, gathering 200 businesses and generating 2 000 jobs.
- Nantes-Atlantique airport, welcoming around 6 million passengers per year, generating 2 500 jobs at the airport level and up to 15 000 in the region (through tourism).

According to the OSS (Observation and Statistics Service of the Ministry in charge of Ecological Transition), five "dense logistics areas" are recorded in the territory of Nantes Metropolis, representing a total of almost 753 000m², located near the main axes of the territory's structure (ring road, river, airport, stations).

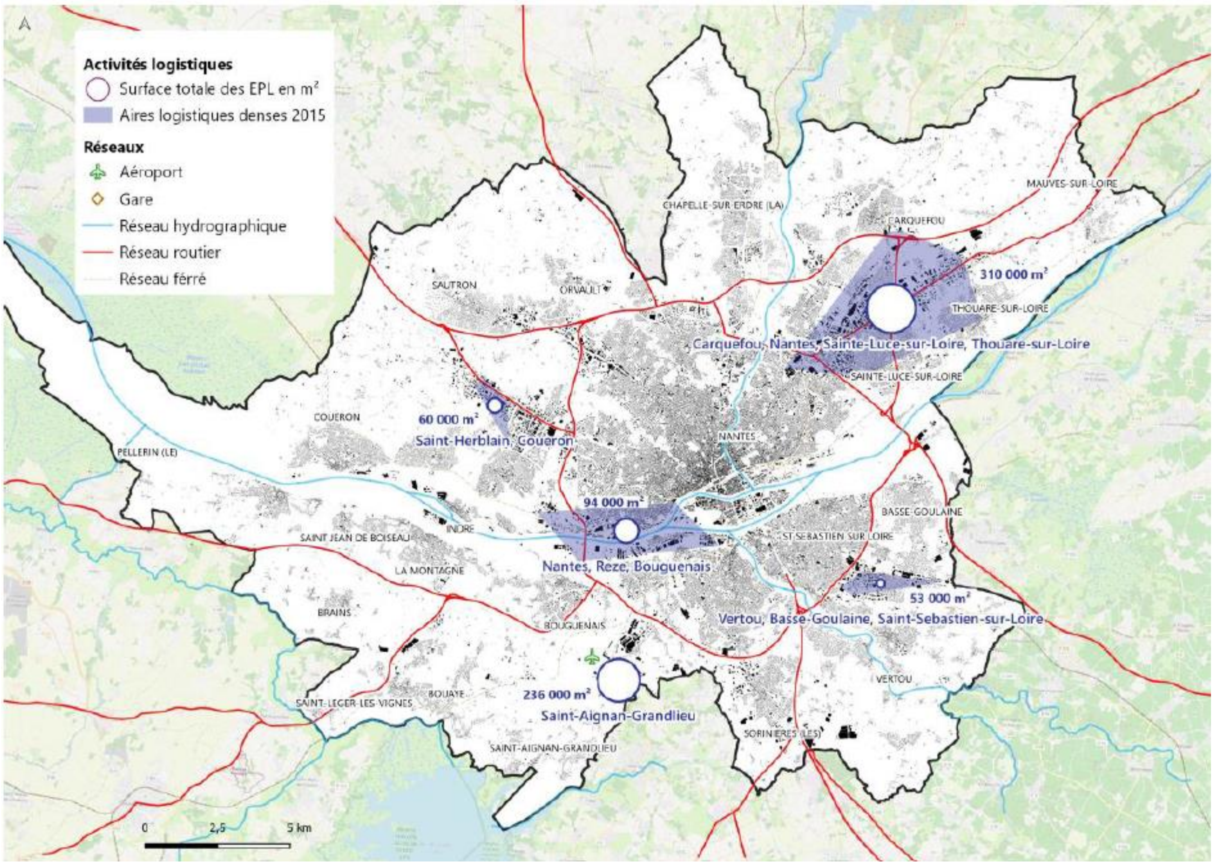


Figure 25: Nantes Metropolis' main logistics areas (Source: Lestou et associés, 2022)

Public policies and regulations

Several regulatory documents provide a framework for the establishment of logistics activities, namely:

- Plan Local d'Urbanisme Métropolitain (the Metropolis local urban planning)
- Schéma de COhérence Territoriale (territorial coherence scheme)
- Deliveries regulation in Nantes' city centre
- Limited Traffic Zone
- Low Emission Zone (upcoming)

Metropolis Local Urban Planning (PLUm)

This document sets land use regulations, to which each city' mayor on the territory should obey. To complement this PLUm, the 'Orientation d'Aménagement et de Programmation' (Guidelines for Development and Programming) were developed. These guidelines aim to identify at the scale of the metropolis:

- Delivery flows by using survey data.
- Good flows to city centre and out-of-town shops based on the ratios associated with the surface areas and types of activity.
- Flows of home deliveries or relay points using FEVAD (Federation of e-commerce and distance selling) data.

A second complementary document is the 'Projet d'Aménagement et de Développement Durable' (PADD) (Sustainable Development and Planning Project). It aims to strengthen the industrial and logistics base at the service of the metropolitan productive economy, and to strengthen logistics centres, contributing to the development of the metropolitan industrial sectors.

Territorial COhérence Scheme (SCOT)
This document aims to frame the urban development ambitions of the Metropolis by 2030, and more specifically:

- To develop metropolitan logistics by conducting an economic and planning strategy that supports all logistics functions and sectors,
- To develop an estuary-wide logistics development plan,
- To improve accessibility: land, external and internal links, port and airport developments.

Deliveries regulation in Nantes'city centre
Since 2023, a new regulation is being implemented in Nantes City Centre for parking.

- Yellow zone (peripheral): paid parking from Monday to Saturday, from 9AM to noon and from 2 PM to 7PM, with a maximum of 8 hours with a price of 3.10€ for2 hours.
- Red zone: paid parking from Monday to Saturday, from 9AM to 7PM, with a maximum of 10 hours, 2h = 5.30€.

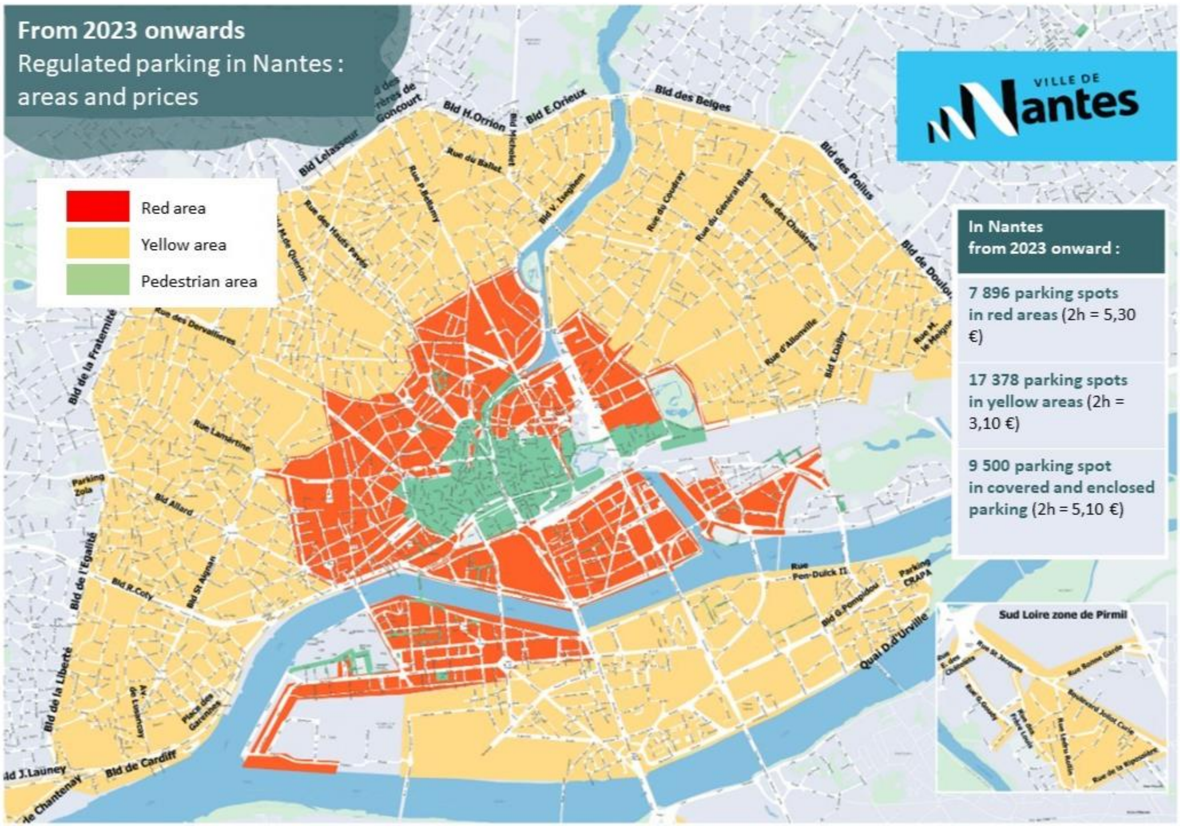


Figure 26: Regulated parking in Nantes (source: Nantes métropole)

In Nantes' pedestrian areas (city centre, island of Nantes, etc.):

- Only vehicles with a pink delivery disc are allowed to stop there, for a maximum of 30 minutes.
- All authorised delivery vehicles can circulate from 4 AM to 11:30 AM (before 2021, it was from 7 AM to 11:30 AM),
    - Big supermarkets usually open early in the morning (4 AM) so there is no issue with their deliveries. In some cases, delivery companies can have a spare key of the storage room so that they are able to deliver in the early morning. More and more cycle-logistics companies also make appointments with shop keepers to agree on a time slot for delivery before their opening times.

- Only delivery vehicles running on alternative energies (gas / electric / hydrogen) and cargo-bikes can circulate from 4AM to 11PM. These vehicles must use a green delivery disc. This is an incentive to reduce the ecological impact of goods transport in the city.
- Vans longer than twelve metres are also not allowed to make deliveries in Nantes city centre.

Figure 27: Explanatory scheme for parking in Nantes

Comment:

- These regulations only apply to deliveries. There is an ongoing reflection by Nantes metropolis to apply this regulation to craftsmen as well.
- Rush hour for deliveries have been identified to be between 9 and 11 AM.
- There is the issue of noise pollution in cobbled streets, not tackled by any regulation at the moment.
- The metropolis is also reflecting on implementing new regulations to encourage less-polluting vehicles, such as zero-emission delivery vehicles, consolidation hubs, etc.
  - At the moment in France, car stickers indicate a vehicle pollutant level based on an air quality certificate: see more info here.

Limited Traffic Zone (LTZ)

Nantes Metropolis has a LTZ in place. It covers big streets of the city where the access is regulated and only residents, delivery staff and security services are allowed. This regulation applies to the Cours des 50 Otages, Cours Olivier de Clisson, Allée Brancas, Allée Duguay Trouin, Rue du Calvaire, Rue de Feltre et Rue de l'Hôtel de Ville (can be part of the street or the whole street). In the map below, the streets where you need yellow or purple stickers to enter the zone are represented in orange. These stickers are different from the Crit'air ones. They are used to reduce any kind of nuisance (noise, light…), not only to limit carbon emissions. Although there is no access point to the LTZ. Drivers are asked to be civic-minded. Delivery staff, residents and security services are allowed without any restriction in the LTZ.

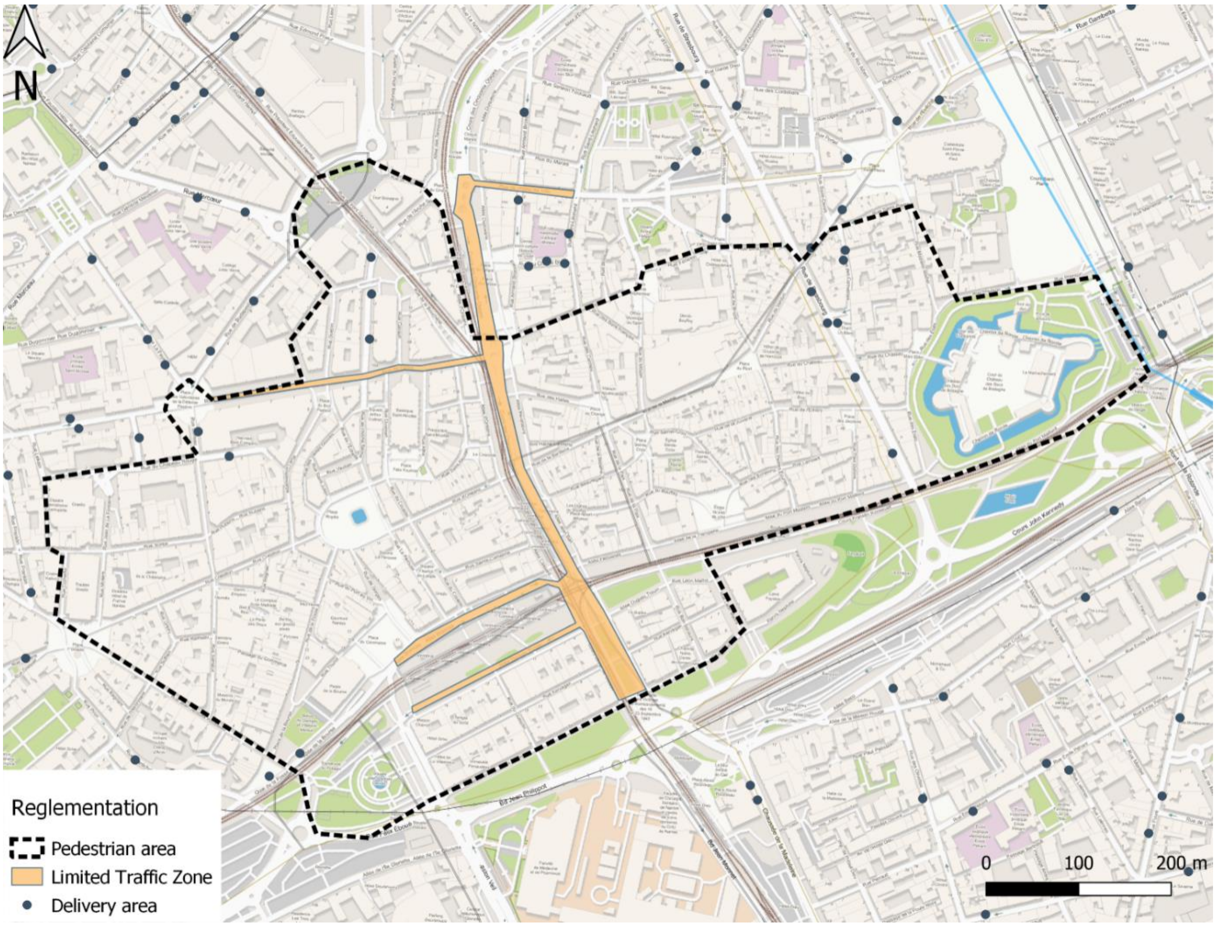


Figure 28: Focus on the regulations in the city (source: IT)

Low Emission Zone (LEZ) - upcoming

Nantes Metropolis must implement a LEZ before 1 January 2025 (Climate and Resilience Act). The perimeter and the level of restriction envisaged will be decided in mid-2023. Thus, the flow of trucks and vans will be restricted, which will encourage the implementation of shared solutions such as logistics hubs. See below a map of the future "pacified areas" of Nantes metropolis, that are planned for 2030. Pacified areas are areas limited to 30 km/h, meeting zones, limited traffic zones and pedestrian areas.

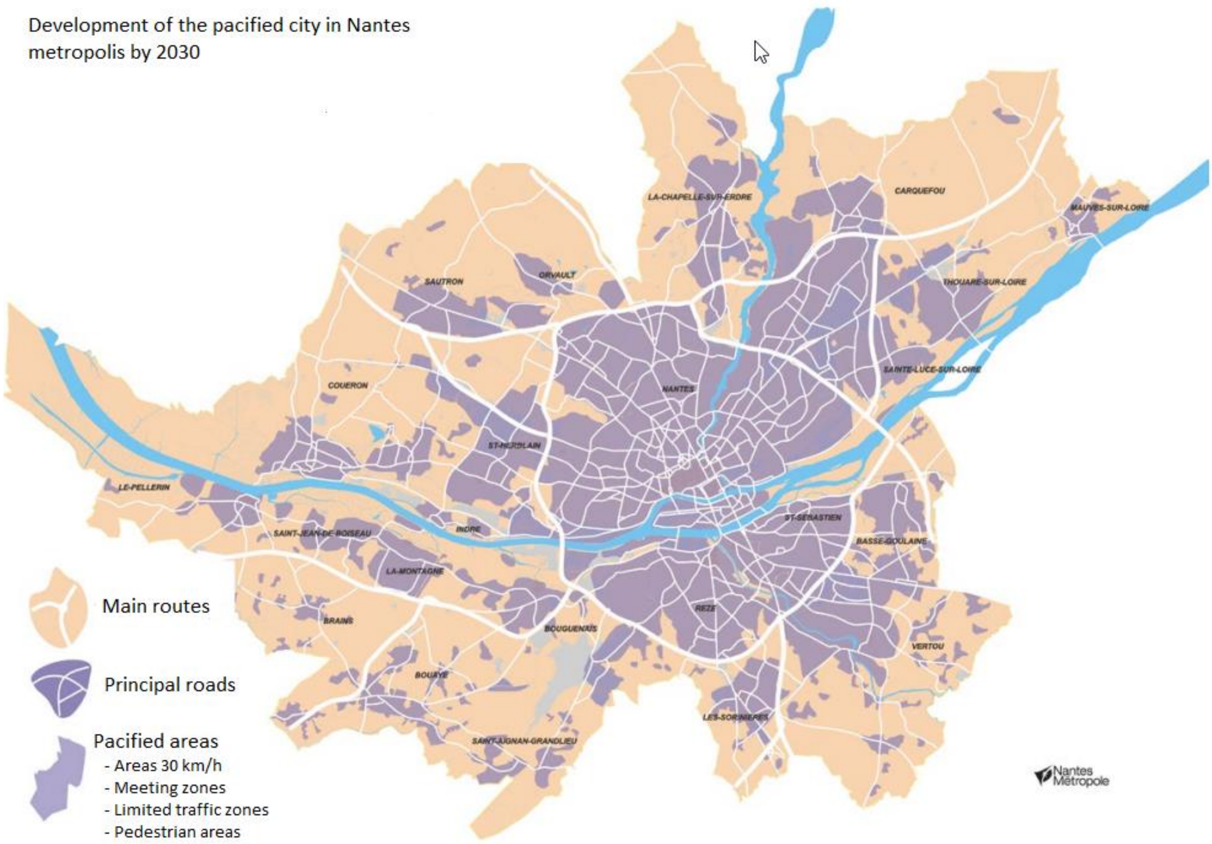


Figure 29: Pacified areas of Nantes (source: Nantes métropole)

Local stakeholders

Relevant stakeholders of Nantes Metropolis have been identified, based on their engagement potential and value to the project. They belong to the following categories:

- Interprofessional organization and consular chambers
- Craftsmen and freelancers
- Associations and cooperative societies
- Purchasing centres, wholesalers, distributors, distributors
- Carriers, logisticians, deliverers
- Vehicle and industrial rentals
- Service companies, managers and operators
- Large distributions

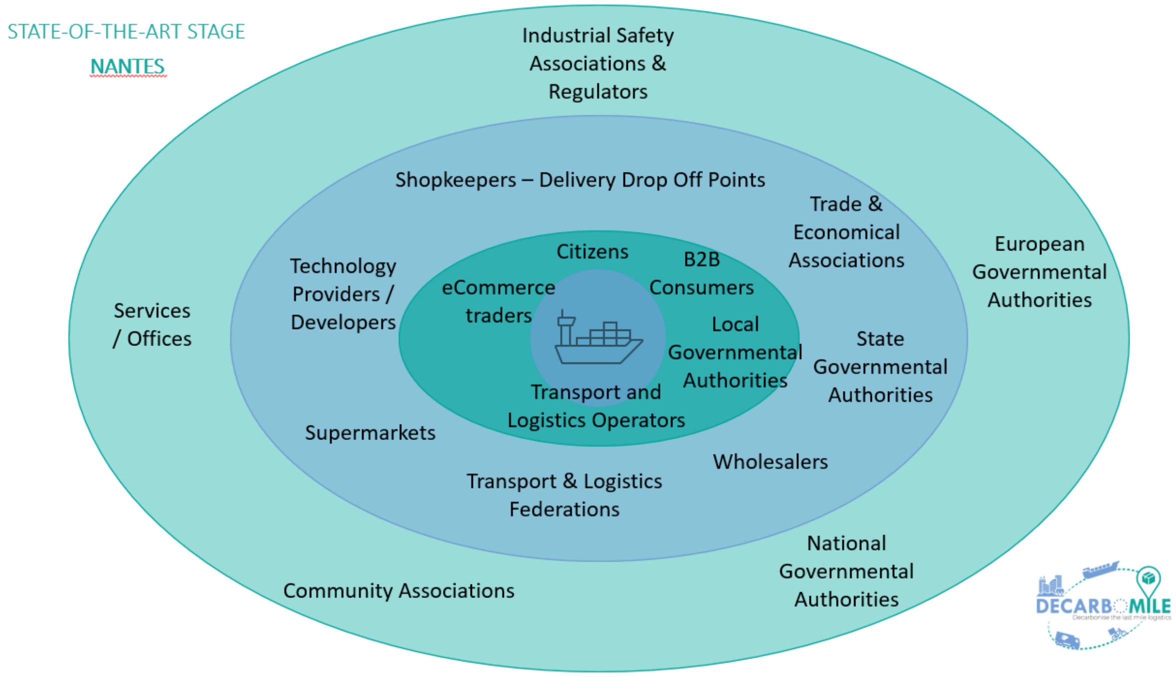


Figure 30: Mapping of Nantes Living Lab key types of stakeholders in the current scenario (source: CBS)

On the stakeholder mapping of Nantes above, it's depicted the current key stakeholders of the deliveries and logistics services developed from the initial stakeholder mapping exercise done during the KOM combined with following ranking activity and the presentation during the technical visit. Through this visualisation, the Nantes use case relies on integrating B2B, local authorities and logistic operators to facilitate novel delivery and storage opportunities within the city centre. It is also an indicative on how the integration of such actors is required in the steps towards the upcoming interventions. In this visual, the centre indicates the core of the services – meaning the most direct/high impact stakeholders in the centre and the further out you reach, the more indirect stakeholders are listed.

In a survey dedicated to economic actors, where one wholesaler, one logistics service provider and one interprofessional organisation provided answers, it came out that the main challenges encountered when delivering Nantes' city centre are (in order of importance): delivery hours and areas, storage capabilities, waste management, reliability of delivery, and managing orders from customers.

Interestingly, it was also identified among respondents that both reducing traffic and pollution, and getting deliveries by employees with fair social conditions, were important criteria for costumers.

In addition, all respondents declared that they would be interested in sharing logistics resources with other economic actors in order to improve their service / costs, and that they would be willing to participate in future project workshops at the Living Lab level.

Local cycle-logistics operators in Nantes include:

- Les coursiers nantais and Naofood (both part of Coopcycle)
- Les Triporteurs Nantais
- Les Boîtes à vélos
- Bicicouriers
- Green course,

During the technical visit on 02.03/02/2023, we met with Les Triporteurs Nantais and les Coursiers Nantais.

TRIPORTEURS NANTAIS (TRI)

They have a hub of 280m² in the city centre of Nantes, with 8 employees doing deliveries from 9 AM to 4 PM. They place social sustainability as key, despite the hardship of the job (physically tiring, subjected to changing weather conditions, pollution, etc.). They are currently looking for an Urban Distribution Centre, of 1200m² to supply the city-centre hub and the rest of the city. They might be interested in sharing it, if the surface is big enough. TRI is willing to share available operations data to run simulations and explore improvements and best development options.

They operate within the Limited Traffic Zone, where some restrictions for cars can be bypassed with cargo-bikes and a related business model, with the following vehicles:

- four 3-wheel freight bicycles
- two 2-wheel freight bicycles
- one electric Kangoo
- one 20m² Natural Gas Vehicle (which makes up to 120 stops per day)

They are specialized in pallets delivery (working with FlexiModal since 2015).

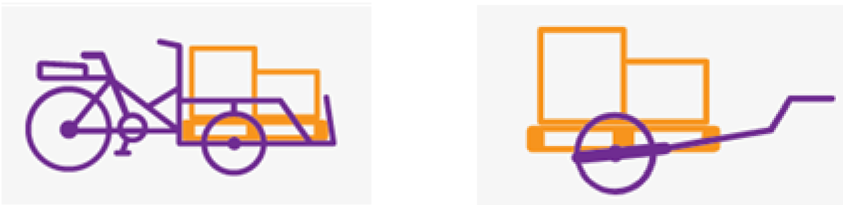


Figure 31: Diagrams of Triporteur palet delivery methods (source: les triporteurs français)

A usual day at TRI starts at 6AM with three truck deliveries (which handover paper listing and delivery slips where an IT optimisation could be useful); then they manually dispatch of the goods into delivery tours.

- Micro tours of 3-4 stops, 20-30 minutes each, eight to nine tours a day > 25-35 delivery slips per day.
- First shift within five to six km from the hub with 3-wheel freight bicycles (mostly beverages to restaurants in the morning), second shift with the rest of the parcels in a larger perimeter with the e-vehicle.
- Up to 500 kg per delivery with both the front bike (350 kg) and the trailer (150 kg).
- 90% of B2B (restaurants, schools, hospitals, etc.), 10% of B2C.

LES COURSIERS NANTAIS

They were previously situated close to les Triporteurs Nantais and are now based in Le Wattignies since 2017 (in a previous garage place now shared with other economic actors (a bar, a plant shop, a second-hand shop, etc.). The rent is small as the building is owned by the municipality and they can stay minimum until 2024.After that, a deep refurbishment is planned, where Les Coursiers Nantais might need to move while the works is ongoing, and they will be able to come back once it is completed.

The Wattignies site has been identified, in a previous Interface study, as a relevant location for an urban logistic hub, based on several criteria: existing upstream/downstream freight flows, central location in the city, direct access to Nantes' city centre, increasing concentration of economic actors in the area, upcoming multimodal traffic plan in the area which will allow proper integration of cycle-logistics.

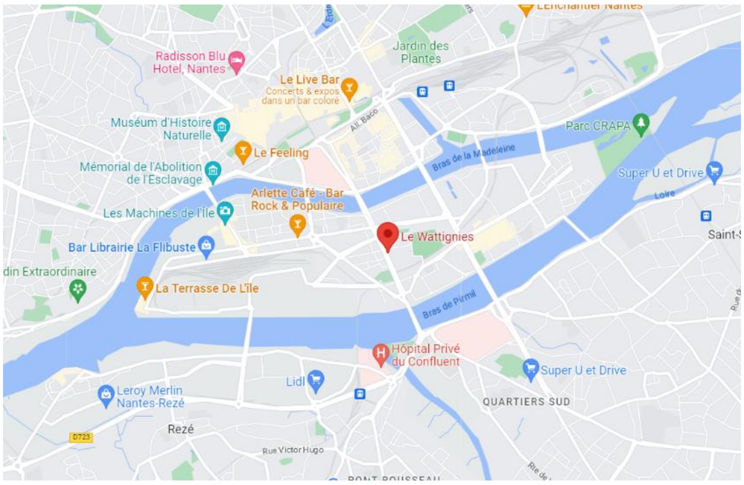


Figure 32: Location of Les Wattignies (source: Google maps)

They are part of CoopCycle (a federation of bike delivery actors) and have 15 employees, including seven persons being part of the federation.

Delivery services are from 7 AM to 8 PM in shifts. Originally, it was mostly grocery focused, and then it evolved into a hybrid business model offering (i) time slot delivery, and (ii) express delivery (to Carrefour, office software shops, etc.). Les Coursiers Nantais don't have a big storage room, and only store goods for a few clients (see third "temporary storage" services below). The preferred business model is to go pick up the parcels directly at the providers / shops to bring them to the final clients.

They use some muscular bikes, but mostly e-bikes with two models: integrated hub to the bike (preferred), and trailer. They also offer pallet delivery, and have controlled temperature boxes, which are first stored in a cold room at Wattignies. They are used; for example for: meat delivered on Monday by La Stef and then transported to kindergarten during the week).

- +/- 85% of deliveries are made within three km from the hub.
- Almost no route optimisation between clients.
- Urby also subcontracts Les Coursiers Nantais to perform two deliveries / week with a branded bike they provided.

Additional services offered include:

- Bike maintenance services (to external customers, as well as internalised to delivery bikes, which is economically interesting).
- Temporary storage, invoicing sqm² to clients: this is included in the business plan, where clients which can guarantee a turnover above 500€ per month will get free storage of their goods, in view of encouraging delivery services over storage services.
  - Challenge: not so much visibility on the delivery (when, how much, etc.)

Les Coursiers Nantais don't use digitalisation so much (mostly paper format), which is being tackled by CoopCycle (working to improve the tool at the moment). CoopCycle has a TMS (Transport Management System) to plan regular and punctual deliveries (providing different data on the deliveries; number, etc.). Time tracking for the staff to track if they are working on orders, admin stuff, preparation side, etc. is missing, and should be integrated.

FLEXIMODAL – SOLUTION DEVELOPMENT

FlexiModal (FLEX) is a solution provider in Nantes LL, part of the project consortium. It develops and conceives urban logistics material in the form of trailers designed to reduce the impact of transloading, smoothen delivery and reduce carbon footprint.

Originally aimed to tackle the lack of lifting equipment in the market, FLEX developed a patented tool for last-mile delivery designed around the Euro-Pallet format for a better integration in the supply chain (see figure below).

Figure 33: FlexiModal trailer scheme (source: Fleximodal)

At the moment, it seems that French cities are the leaders in Europe in pallet deliveries by bikes. Currently in France, 25 cities use FLEX solutions to deliver pallets. FLEX has twelve employees, and all products are designed and produced in Brittany (FR).

Within the scope of the DECARBOMILE project, FLEX is going to develop a **tricycle** that can easily lift and carry goods, as well as microcontainers to optimize the last-mile logistics (see figure below). The tricycle is a variation of the BicyLift trailer, recognized for its ability to easily handle pallets with its patented Lift & Go lever mechanism that employs the user's weight (without complex system or adding external energy). This tricycle solution will use the same **lifting system** (Figure 34) while being smaller than bike + trailer, both for use and storage.

Figure 34: Illustration of the TricyLift and its lifting mechanism (source: FlexiModal)

The target price is maximum 10 000 euros. Four items will be available at the end of 2023 / Spring 2024 with a presentation on Eurobike fair this summer.

The multimodal chain aimed by DECARBOMILE requires encapsulation of goods to protect them in the different modes of transport and during transloading. The ideal size is the European pallet standard, the main format used in Europe which is adapted to the existing handler and transport tools. Therefore, microcontainers must be designed following this standard.
As the existing pallet boxes are **not optimised and adapted to urban logistics (ergonomic, goods protection, usable volume),** FLEX will develop microcontainers based on the European size (the EU pallet) that respond to these issues and are conceived to adapt to the existing tools of the supply chain.

Micro containerization aims to optimize several aspects of urban logistics such as time saving during transloading. It also enables to prepare delivery tours before getting to the city centre. Micro containerization ensures to delocalize tours preparation in logistics warehouses with efficient selecting tools and automated loading. By standardizing the containers, loading can be mechanized in order to optimize the beforehand filling adapted to the microcontainers usable volume and tours sequences. Finally, it optimizes microcontainers drop off in different parts of a city: microcontainers will be strategically dropped off in public spaces or pick-up points according to their shipment and the recipient's geographical location. Having the microcontainer in the middle of its delivery zone will increase the courier productivity.

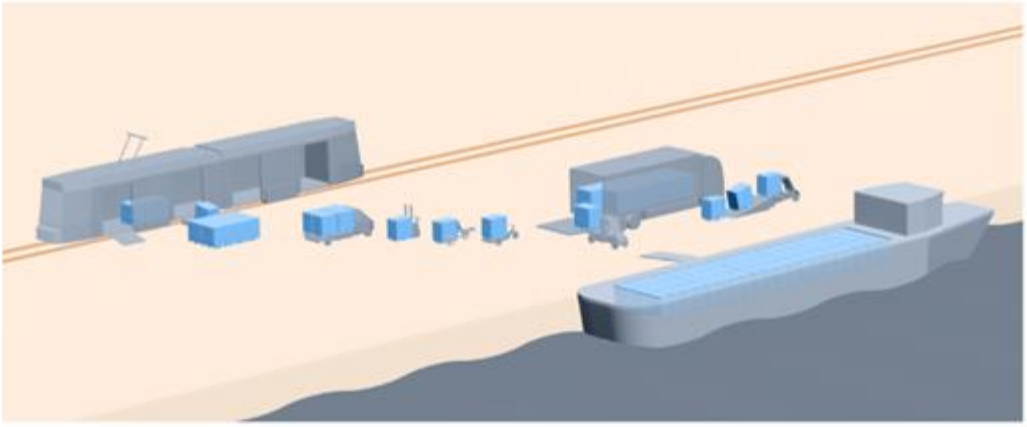


Figure 35: Containerization applied to urban logistics (source: FlexiModal)

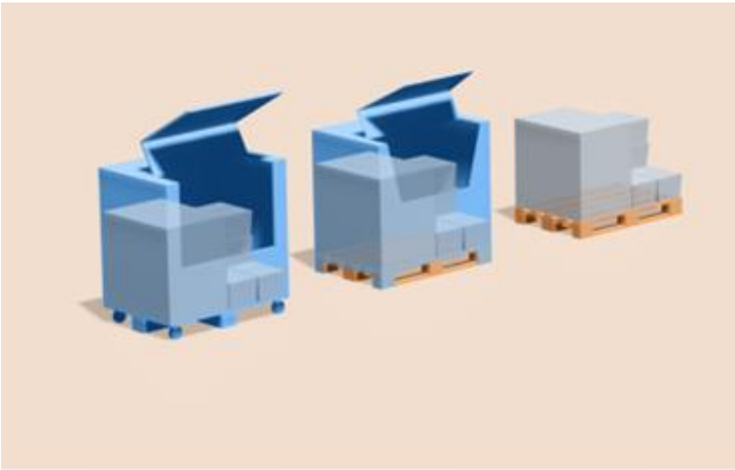


Figure 36: An illustration of microcontainers (source: FlexiModal)

Keeping transhipment optimization in mind, FLEX will also study the capacity to aggregate microcontainers among themselves or using an added chassis. They need to develop IT solutions to optimize the filling of these micro containers, the drop off localization by geographical zones and tours sequences according to the shipment, etc.

Existing IT solutions

Nantes Metropolis use the IT tool FRETURB (soon to be: SILOGUES) for logistics distribution flows and national level flows, developed by the LAET. FRETURB has two different models, one of which is composed of a 4-step urban freight model:

- Simulation: 1a. Vehicle tracking (number of stops to (un)load), 1b. Estimation of the number of shipments and receptions per households (home delivery or not), 2. street occupancy rate by delivery vehicles stops by sector, 3. street occupancy rate by delivery vehicles in circulation (classification by vehicle type, distance, etc.), 4. daily distribution of traffic volumes per 30-minute segments.

- Distribution: 1. Based on average distances per operation classification, 2. inflows and outflows per zone, 3. correction based on the distribution per activity.

Other interesting IT tools available in Nantes include:
- Observatoire des mobilités: mapping of parking places, regulation zones (mobility + freight), mobility (not freight) flows covering all the metropolis. It can be shared with DECARBOMILE partners.
- Open data of Nantes: Accueil — Open Data Nantes Métropole (nantesmetropole.fr)
  - already used by companies to develop apps for parking spaces, open service bikes, etc.; but not yet on logistics flows.
- Nantes dans ma poche : real time data on public transport, parking availability, nearest public bike station, waste management, etc.

Les Triporteurs are working with a local start up to develop an EDI (Electronic Data Interchange) tool to track deliveries (numbers, state, flow optimisation, etc.). The best optimisation tool for deliveries remains the human over the electronic: importance for the staff to know the clients, their habits and needs, etc.

Several IT systems shared by the transport and logistic operators through the survey include: STRADA and Teliaé for TMS, optimisation and planning, Stock it for stock management, and Proginov and Transopimun for all of the above plus parcel classification and loading.

SUMMARY OF THE SITUATION AND POTENTIAL USE CASES

Synthesis and knowledge

The city of Nantes gathers almost half of the logistic flows from the Metropolis (up to 45%), with most of it being located on the island of Nantes (hyper centre), with more than 50% of the deliveries being executed with light commercial vehicles (vans). It has been identified that craftwork, small businesses and wholesale trade are the three strongest sectors generating movements both in the city of Nantes and on the island of Nantes.

Below, a map of Nantes metropolis provides a global view on the situation.

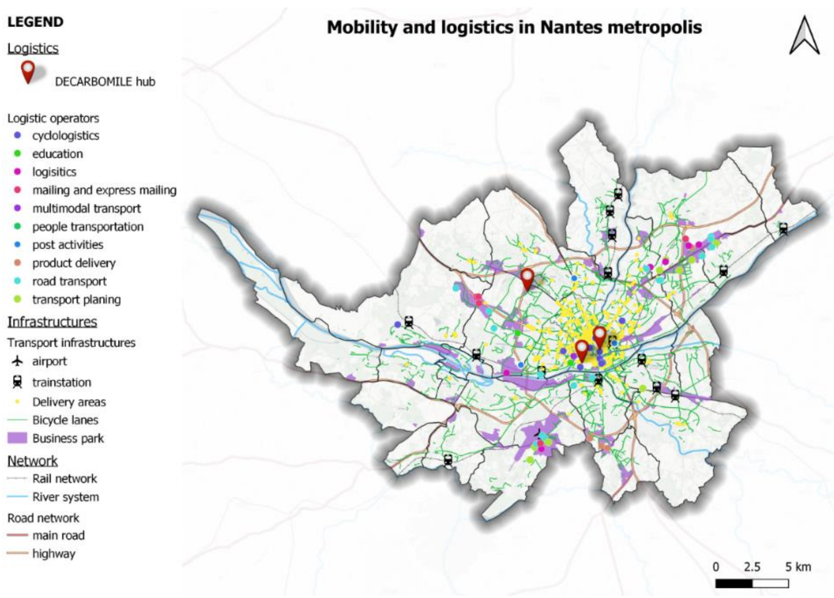


Figure 37: Mobility and logistics in Nantes metropolis (source: IT)

As described in the context section above and identified by a study carried out by Interface Transport 2021 for SAMOA (in English, the West Atlantic Metropolis Development Company), the main challenges for distribution operators in Nantes are traffic density, delivery areas, and traffic regulations. We can see on the map below the usual congestion peak is on a Tuesday at 8:30 AM, with a usual dense traffic between 7:30 AM and 9:30 AM.

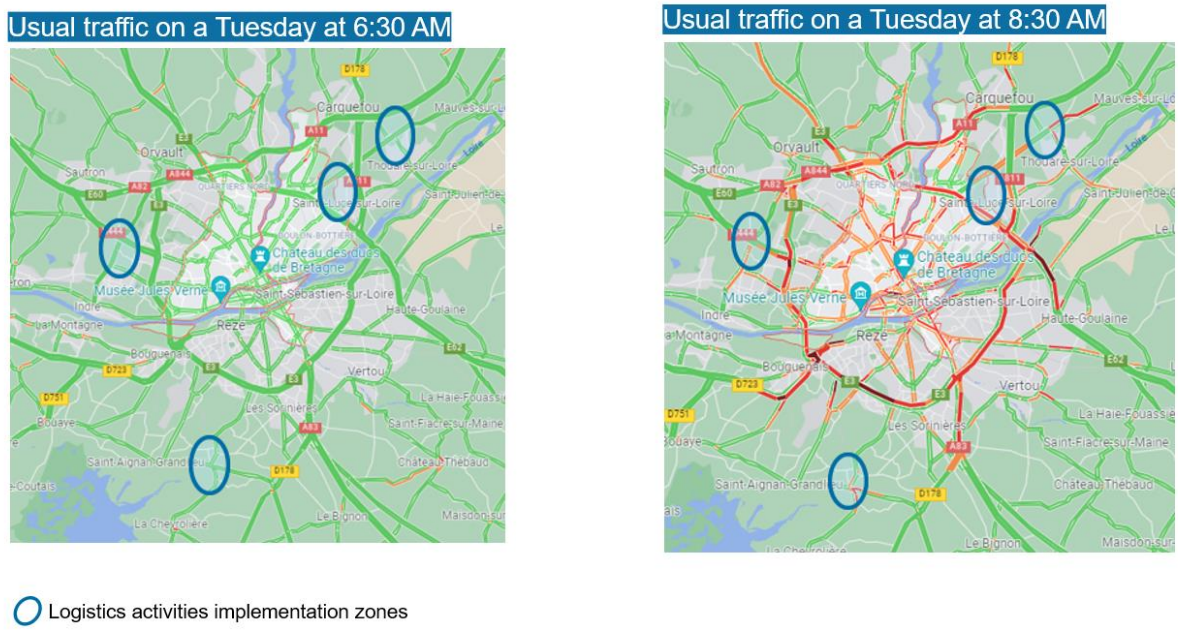


Figure 38: Congestion level in Nantes (source: Google maps)

In 2018, Nantes Metropolis launched a call for proposals to encourage greener delivery methods and urban logistics operations through a larger access to the limited traffic zone, and longer delivery time slots. Most of the projects aimed to implement greener transportation, logistic hubs, and B2B services. The following issues were identified thanks to the call:

- Need for logistic optimisation (enlargement and pooling of operations)
- Importance of the energy transition and urban integration
- Key to have pilots and labs to test things
- Willingness to see stronger cooperation in the sector
- Challenge to find relevant real estate opportunities that meet urban logistics' needs near the city centre

All of these will aim to be tackled through DECARBOMILE's use cases. Indeed, at least two or three new fixed micro consolidation centres will be considered (logistic optimisation, stakeholders' cooperation), located on the "Ile de Nantes" (central island on the Loire rive). There are available areas suited for this purpose in Ile de Nantes due to its industrial past. These logistics hubs are planned to cover the city centre at large (Ile de Nantes and the surrounding riverside areas). The network design will be especially important to identify the best possible location of these hubs (urban integration), it will also allow to compare the benefits of having two or three hubs (testing).

Pending questions which still need to be discussed include:

- the business interests of (cycle) logistics operators on operating from these hubs,
- the interest of Nantes Municipality of upgrading its simulation capabilities based on FRETURB experience and evolution.

While the latter can be addressed with a specific meeting with Nantes technological teams (which will be scheduled in May 2023), the former requires to engage with logistics operators' current and potential customers, which will need to be further discussed in future engagement workshops.
A key challenge will then be the availability of data from shopkeeper's multiple selling channels enabling proper demand forecast (similar to FRETURB' simulations at the moment) and useful delivery and supply needs estimation.

Public authorities may use regulatory leverage to enforce restrictive frameworks and encourage cycle-logistics to be economically interesting and have more cargo-bikes as delivery vehicles. It may be interesting to foster urban integration as well, to support incoming flows consolidation, connexion between warehouses and the city centre, etc.

In any case, the way in which the city is able to promote and implement sustainable and fair distribution and delivery patterns for all economic partners will be crucial, as they need to be involved in the long run. Strong cooperation and trust between them will also be crucial for the project to succeed, if we aim for massified flows – including at the IT level.

Potential use cases

Here is the reference situation that represent the logistic functioning in Nantes.

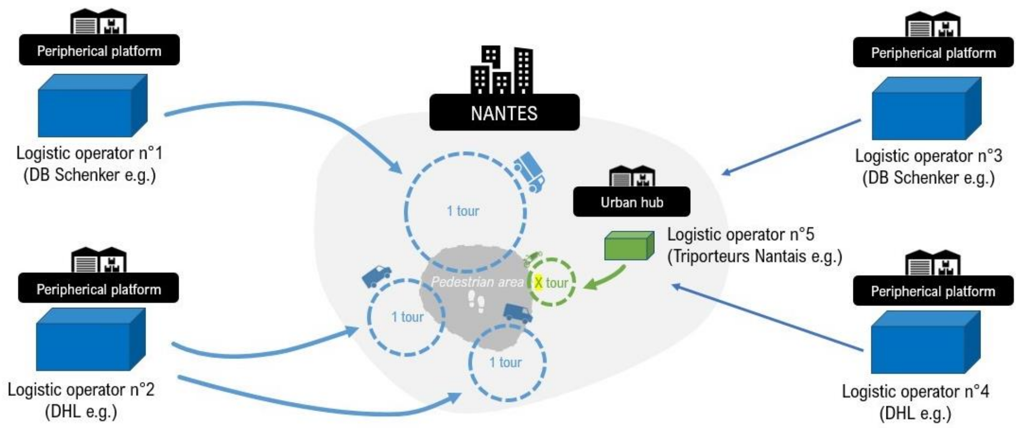


Figure 39: Reference situation (source: IT)

<u>USE CASE #1: Micro-hub in Parc des chantiers</u>

LOCATION

Parc des chantiers is located close to *Les Machines de l'Ile* and *le Boulevard de la Prairie au Duc.* This public space could be a potential hub location, which would need a Call for Public Services to operate the hub (TRI, Coursiers Nantais, etc.).

Local stakeholders in the area: university, shops, schools, a hospital in the long term.

- 1 investor owning all ground floor shops on the Boulevard de la Prairie au Duc > easy to communicate with.

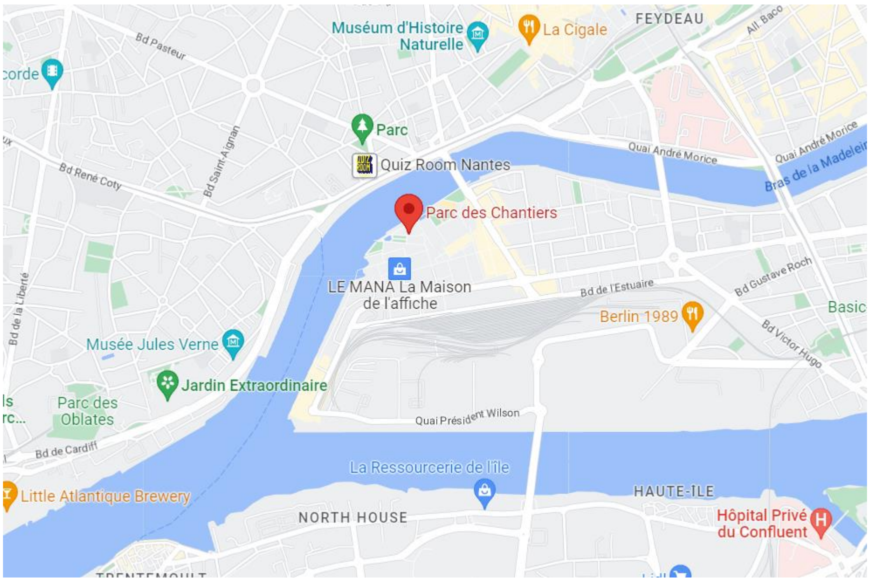


Figure 40: Parc des Chantiers in Nantes (source: Google Map)

DESCRIPTION

The first use case focuses on the establishment of the needed infrastructure in the area mentioned above to store goods during the day and deliver them with cargo-bikes. The idea would be to have a small container (approximately 120m²) operated as a hub by a cargo-bike company and shared with other actors. There is space next to it for an unloading and turning area, outside of this surface.

The Micro hub can be either static or mobile, which can become permanent after it proves its usefulness. The main goal will be to remove trucks from the pedestrian area of Parc des Chantiers, as cohabitation between trucks and pedestrian is dangerous.

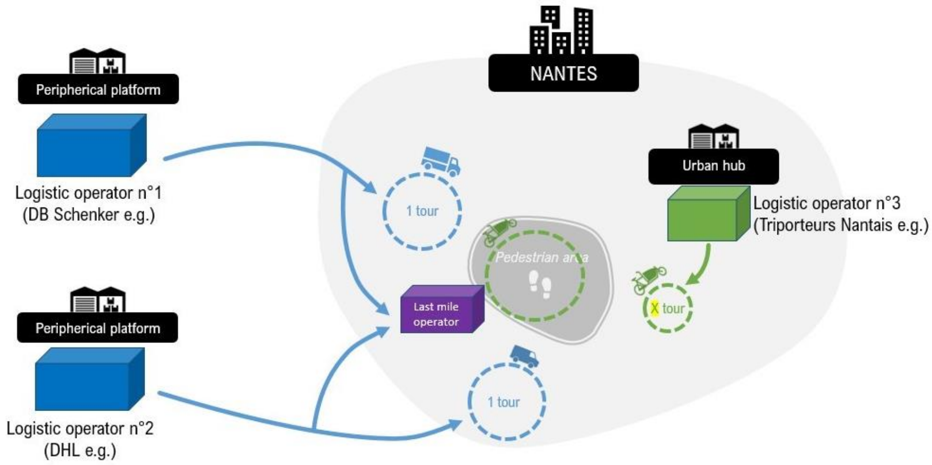


Figure 41: Pilot situation for use case 1 - consolidation of parcels to the pedestrian area via light hub, last-mile with active transportation modes only (source: IT)

Such mobile micro hubs, suitable for DECARBOMILE needs, have been already developed by SOGARIS in a different project. It has been proven successful, despite the two main challenges: price of the location and admin regulation, which would already be tackled here as Nantes Metropolis is providing the real estate and is part of the use case (for political and regulation support).

Potential added services in this use case can be cardboard waste collection via cargo-bikes, taking it to a barge which goes to the waste plan. This, however, is very hard to implement because of river tides

(6m difference between lowest and highest water level). Despite the politic will, there is at the moment a lack of economic actors to operate the boat, etc. and of sustainable business model.
Based on the Interface' study from 2021, the island of Nantes' location has been proven relevant in terms of accessibility from peripheral hubs, and to the city centre for last-mile parcel delivery. Indeed, the City of Nantes represents up to 45% of the logistic flows from the Metropolis, while the island of Nantes account for 3% of the Metropolis logistic flows.

CHALLENGES

- 2028: new tram plan, new bridge, hospital building, etc. A lot of construction flows to anticipate.
- Very touristic area, only pedestrian and authorised vehicles can access. It may be difficult for cargo-bike operations.
- Feasibility of cargo-bike delivering for heavy goods such as beer kegs for the bars.

NEEDS

- Figure out the local business' needs (bars, shops, university, schools, hospital in the near future, etc.)
- Call for Public Services to operate the hub.

USE CASE #2: Mobile hub

LOCATION

In the target are public parking areas, since enough space is needed to park and unload the mobile hub, which in this use case would be a truck. Right now, the parking located alongside Allée Baco, close to the bus station of Nantes, is considered as the most appropriate available site.

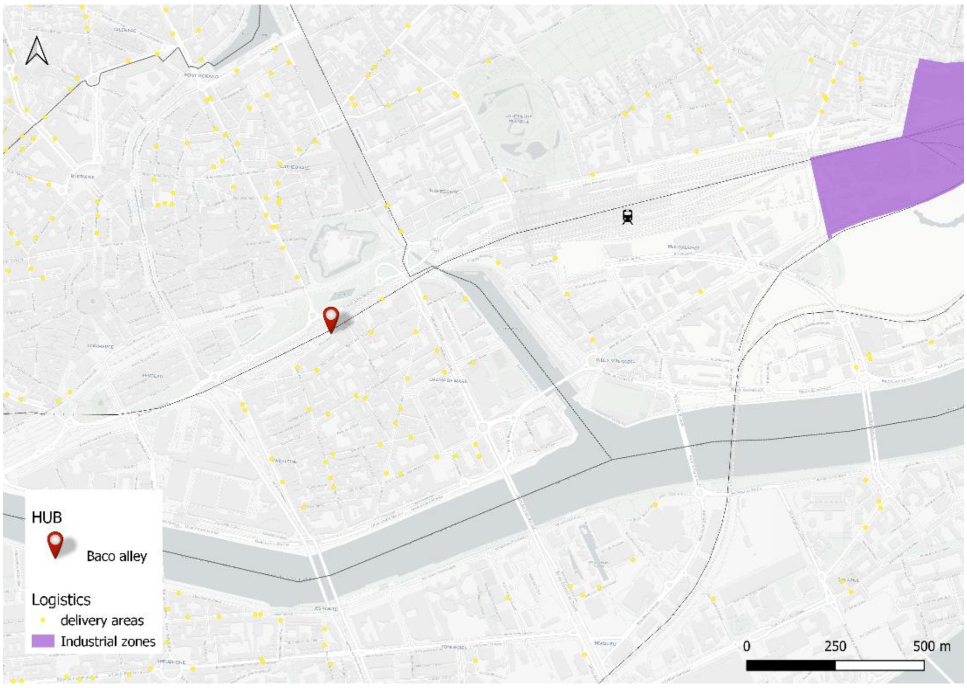


Figure 42: Baco alley in Nantes (source: IT)

DESCRIPTION

This use case would combine a dedicated vehicle/truck (with microcontainers inside), bringing parcels into the city, with cargo-bikes delivering them on the last-mile. The truck will remain static while parked in the mobile hub site. The microcontainers will be transloaded from the truck to cargo-bikes for final distribution of the parcels in the dense city area. The interest is to massify flows of different operators to enter the city and use a unique container that fits both the trucks and cargo-bikes.

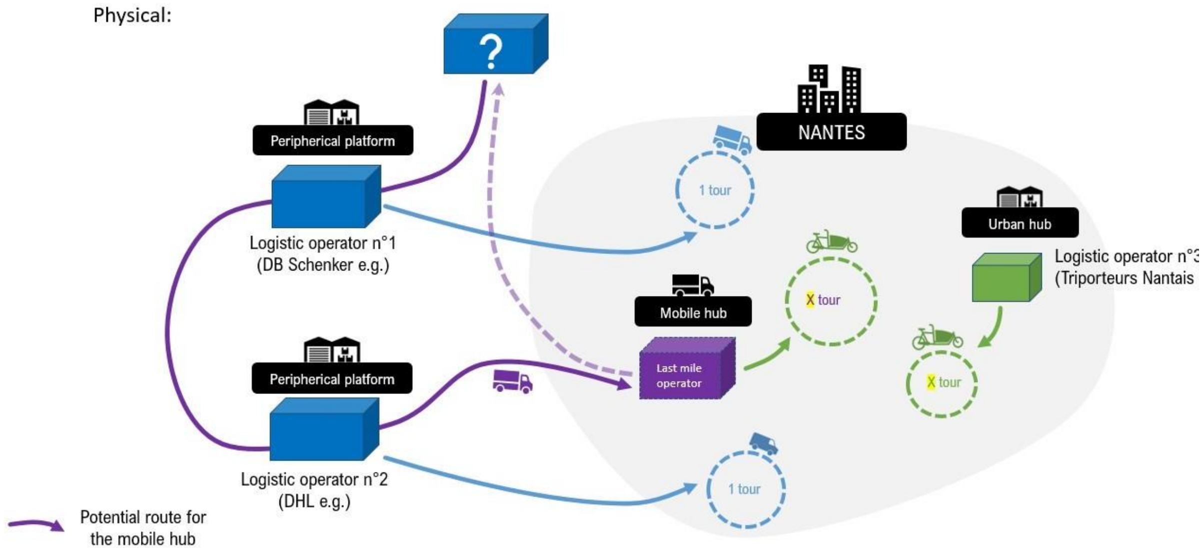


Figure 43: Pilot situation for use case 2 - consolidation and mutualization of parcels via a mobile hub (source: IT)

Starting on April 1, the City Progress will experiment in that same area (parking Allée Baco) for twelve months running a mobile hub with an HGV tractor unit + one trailer, which remains stationary. Two return trips are foreseen per day: arrival 6am – departure 1pm; arrival 2pm – departure 8pm. A transfer of city pallets is planned, and the electronic means and hardware are already developed. The challenges identified in this project are economic sustainability (need for a strong partnership with a logistics operator to guarantee 50% of the good flows and staff management), and technical feasibility (strong hardware innovation challenge, development of a dedicated vehicle, etc.).

CHALLENGES

The interests and needs of local shopkeepers in having a UCC in this location should be examined (maybe via a survey).

USE CASE #3: Bus depot

LOCATION

This use case assumes placement of micro hubs in several bus depots in the city. Some of these depots are away from the centre, but are still well connected to the centre.

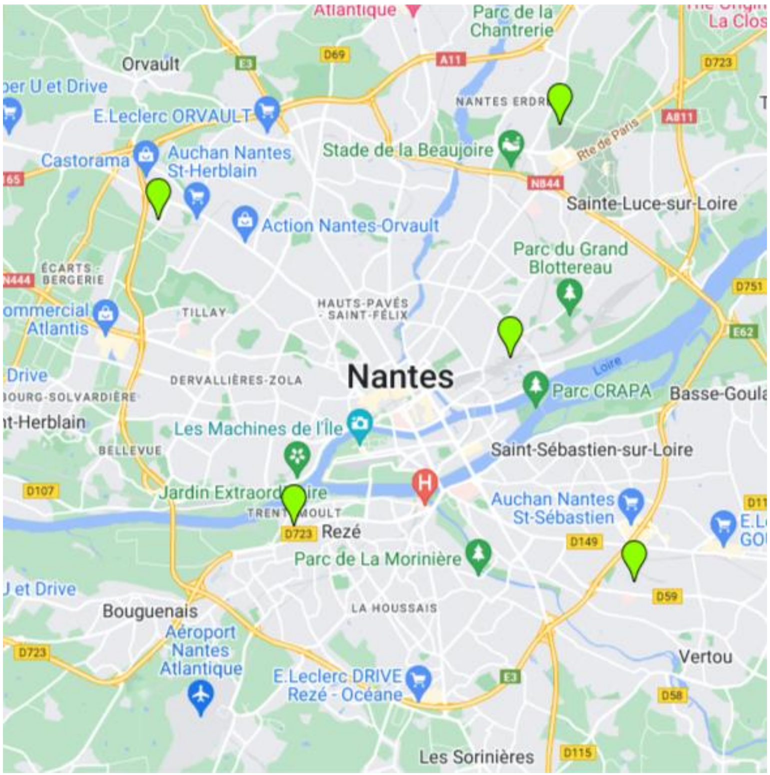


Figure 44: Localisation of bus depots of Nantes Metropolis (source: Google maps)

One depot in Saint-Herblain (part of Nantes Metropolis), Route de Vannes, is identified as potentially interesting. It is located in a big commercial area where some shopkeepers expressed their needs for extra storage spaces.

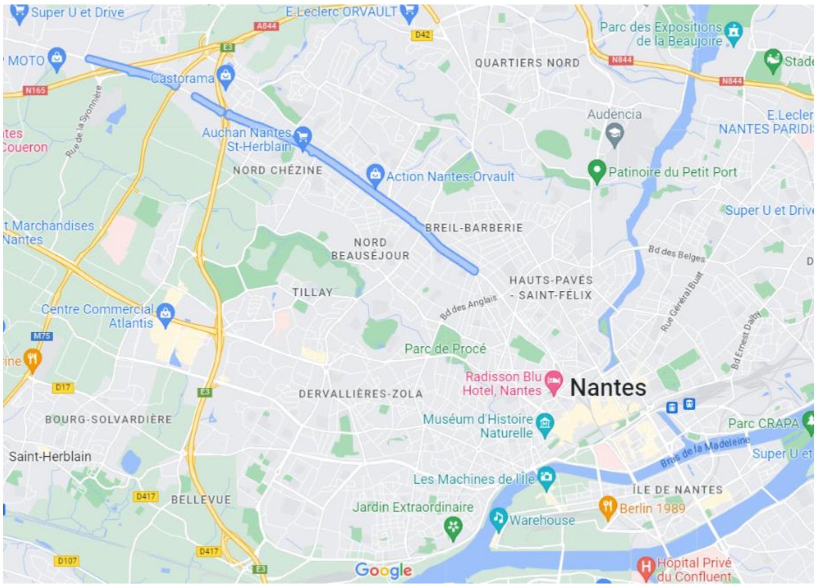


Figure 45: Route de Vannes in Saint Herblain (source: Google maps)

DESCRIPTION

The hub will offer temporary storage, mutualising the space during the day while buses are operating in the city. There would be the space for three to five trucks as temporary hubs, which would then allow delivery with cargo-bike or with light e-vehicles. This is still to be discussed with the public transportation operator in Nantes – SEMITAN (a similar case is already being executed in Paris). Here is a possibility to test FLEX containers.

CHALLENGES

- Surroundings of Nantes don't have last-mile cargo-bikes delivery options, which is an issue the metropolis would like to tackle.
- The city centre and the suburbs (commercial area, residential, etc.) have different needs. In the suburbs there are no restriction of vehicles, which diminishes the interest in cycle-logistics. However, the metropolis plans to develop pollution restrictive regulations (LEZ) to suburbs as well.
- The depot that is close to the centre was the first one identified by Nantes Metropolis. Its location is interesting for urban freight distribution, but this site is harder to access by trucks and there is less space for storage.

NEEDS

- Maps of the needs for the identified location: number of inhabitants, shops, economic actors, etc.
- Further information on the extra storage needs for the shopkeepers of *Route de Vannes* commercial area.
- If the city provides the data, ICT partners can design the tools within DECARBOMILE.

USE CASE #4: Floating hub

Using a floating hub is also discussed as a possible use case, but due to the many challenges associated with the water transport in Nantes (e.g. lack of actors eager to operate the hub / boat, water tides etc.) this use case is put on hold at this stage.

Key Performance Indicators

Specific KPIs for Nantes will be further developed, once the use cases are more specific. General indicators could include:

- Number of FLEX equipment deployed
- Allocation of public space for UCCs
- Weight of collected waste

Relevant use cases to build upon

PROMOCASH USE CASE

In Nantes' city centre, Promocash (big French retailer company for restaurants and the Hotels Restaurants and Catering sector, which can be called the HoReCa sector) and Carrefour opened on 02/06/2022 a shared loading dock, where they both get their truck deliveries (before 7 AM). Carrefour then supplies its side shop, and Promocash its retailer shop for restaurants.

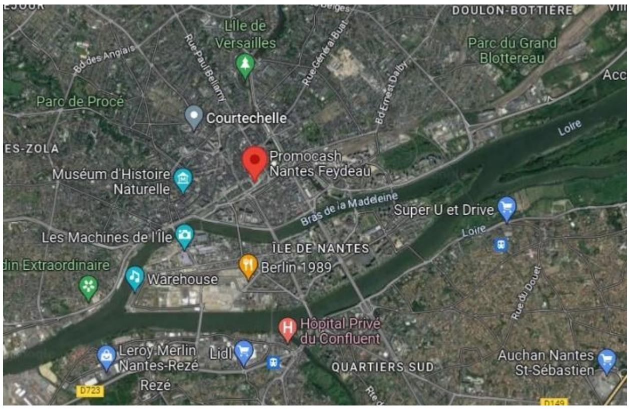


Figure 46: Promocash location and picture (source: Google maps and IT)

Promocash also offer B2B deliveries services (30-40% of their sales, where the restaurant keeper comes to the store, makes its own shopping, and asks for a delivery within the hour). Deliveries are operated by Promocash own staff, with e-scooters equipped with a refrigerated container.

- E-scooters are manufactured by LeClainche, which also takes care of the after-sales services.
- Three small models (up to 200kg of loaded goods) where the scooter and the trailer are indissociable, two bigger models (up to 370kg loaded goods) with the trailer pulled by the scooter, and one e-vehicle (combo).
- Batteries on e-scooters could last for a full half-day.
- In principle, it is usually one route = one client, and load pooling can be problematic for security and hygiene reasons, but as it is B2B, orders are usually quite big and heavy.

Figure 47: Small model of e-scooter used for delivery by Promocash (source: IT)

CITY PROGRESS

This project is interesting because it implies an innovative mobile hub. This mobile hub will carry parcels but also a small green vehicle that will carry out the last-mile deliveries. For more details see the next section for use case number 2.

The 0 barge

This project is interesting for the potential use case of implementing a floating hub. It was held by Atlantique Boissons Nantes but is currently put on hold. The idea of a floating hub is innovative but the regulations that are in place make it difficult to implement such thing. Many stakeholders need to be addressed: Nantes Equipment management (SEM), the Navigable Waterways of France, the Loire-Atlantique department, etc. Moreover, finding the perfect spot for the installation of the right equipment was very difficult (a place that respect regulations, with a great urban inclusion, near the city centre and cafés and restaurants…).

Urby Nantes
The project is working well and is developing a fluvial transportation system in partnership with the SOGESTRAN group. They are supposed to develop it in 2023 and maybe it can be a good experience to learn from for the DECARBOMILE use case currently on hold.

Based on the use cases identified, the additional following projects could be of interest for Nantes Metropolis:

- BCKlet: Supply to pharmacies from a decentralized hub, containerization distribution model, isothermal hardware development for the transport of medicines.
- CityDepot: Consolidated customized supply of products to customers (defining their preferred time and location for delivery), with reverse logistics and waste collection, offering storage services too.
- Ephemeral Hive: Use ephemeral public or private space (parking spaces, marketplaces, bus depot) as a consolidation and a breaking point of loads between different types of vehicles for urban deliveries activities; involvement of several actors of the last-mile, actors upstream, and users of the space (bus parking + maintenance + last km).
- FLUDIS: Boat delivery, with 4 checkpoints, with crane (un)loading, cargo-bikes for B2B last-mile logistics.
- River'Tri: Specially equipped barge and a pusher as an ephemeral waste collection centre, moored from 9AM to 5PM along a quay, offering exact same services as a traditional waste plan except for green waste and rubble) with up to 3 000 T / year, and return to its home port every night (new collection site on the next day).
- UPS HAM: Use of 4 swap bodies (20 ft containers) loaded with parcels at the branch on the outskirts of the city and transported to locations in the city centre, used as micro hubs, with 2 or 3 deliverers for deliveries in an area of 2km (max) around the micro hub (with 7 Cargo Cruiser XL (181 kg/ 2.7 cubic meter) and 4 electric cargo-bikes/handcars).

A more detailed document gathering information on the above projects will be shared with the LL to enhance collaboration on these topics.

1.3 Logroño Living Lab

CONTEXT

Logroño represents in DECARBOMILE the South Europe context, with its 150 808 inhabitants for a total area of 80 km² (1 895 hab./km²). The city is the capital of the autonomous community of la Rioja and accounts for approximately 50% of the population of La Rioja. The city is a centre of trade of Rioja wine, for which the area is noted, and manufacturing of wood, metal and textile products. Also, the municipality of Logroño has an agricultural and natural character, with most of its surface area occupied by these uses.

The city is divided into five districts (North, South, East, West, Centre). It has a historic centre, the oldest part of the city, where you can find the origins of the city, as well as the most famous

monuments, streets and squares of the city. This historic district is full of stores, tapas bars, and restaurants and is also crossed by the trail of Santiago de Compostela, so there are pedestrians on the streets all the time. The river Ebro also crosses the city.
In terms of mobility, the actions carried out in the city have the focus on pedestrianisation, road calming and improving the city's accessibility (see Figure 59 on page 73). Actions have also been carried out (and continue to be carried out) to promote public transport and the use of bicycles.

In Logroño, the modal shift consists mainly of passenger cars, which represent about three quarters of the total volume of vehicles in the municipality, followed by trucks and vans, and motorbikes. The municipality has more than 100 km of roads of all types and more than 19 km of railway lines. Other data: a study of daily mobility in Logroño from 2018 (Logroño calles abiertas), was indicating the modal distribution of mobility in the municipality (Figure 48 below). Considering the reason for the trip and the mode of transport, the study shows that the car is the most used means of transport for commuting to work and to walk for leisure activities.

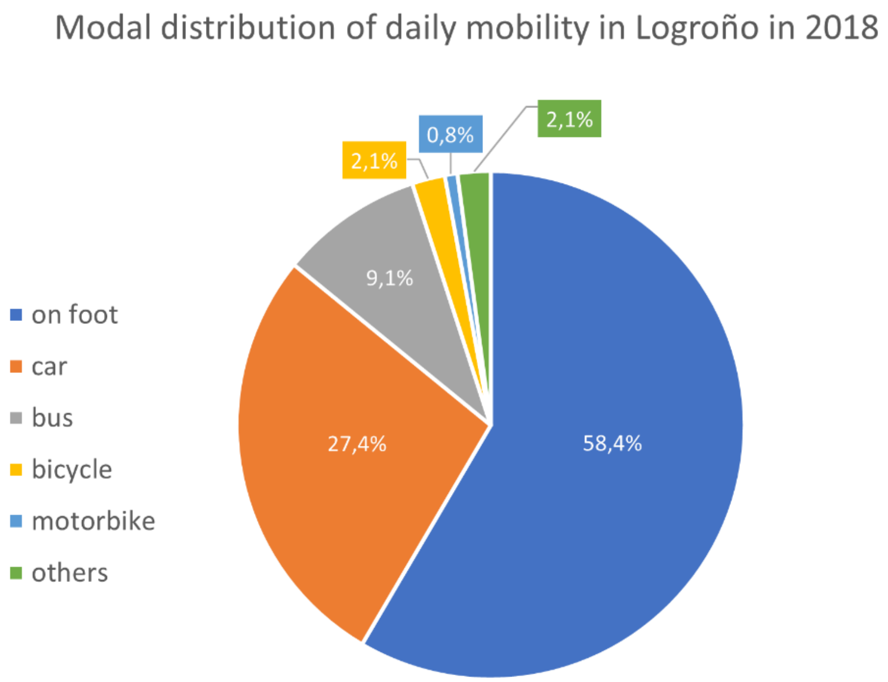


Figure 48: Graph of the modal distribution of the daily mobility in Logroño (source: Logroño calles abiertas, 2018)

On the map below, which represent the repartition of the city inhabitants, you can see a high concentration in the city centre. Indeed, in Logroño, 80% of the population is concentrated within a radius of 1 km. Also, the city is in full development and is expanding especially towards the south, with new residential neighbourhoods. It’s in the east of the city that are grouped the industrial estates.

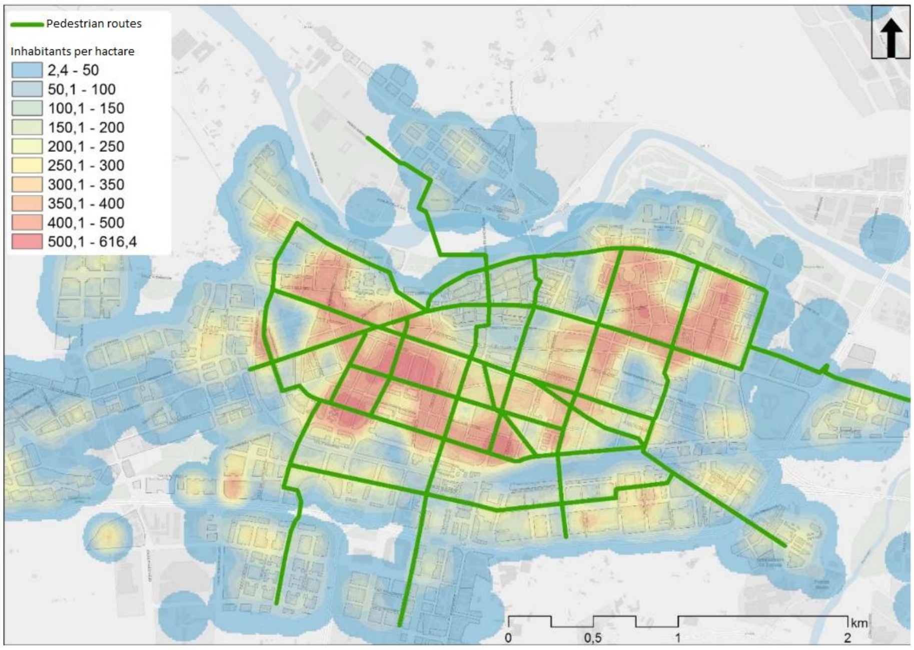


Figure 49: Map of the population density in Logroño (source: Logroño calles abiertas, 2018)

The successive urban plans that have been implemented in the recent decades have shaped a dense and compact city with a mix of uses, achieving an ordered urban grid that favours mobility based on active means (bicycle and foot). A revision of the General Municipal Plan is currently underway, which promotes a city model based on consolidation and urban regeneration through innovation, for a resilient development and social cohesion. The plan focuses on the efficiency of urban resources, avoiding urban sprawl and giving priority to action in the existing city and the built heritage, also focusing on improving the quality of life of all people and reducing the impact on the environment.

URBAN LOGISTICS

Economic activities and freight movements

In the city-centre (around San Blas market for instance), streets are very narrow, volumes of flows are very important (mix of deliveries to local shops, supplies of the market, inhabitants,…) and parking conditions are difficult, so many vehicles are parked in a chaotic way.

The Chair of Commerce of the University of La Rioja has completed a study about commerce in Logroño. The methodology of the study was notably based on surveys addressed to 158 shops and 852 clients, to collect their needs and opinions about their supplies and deliveries. The Chair of Commerce also has a map of the ground commercial locals with information on their activity and if they are occupied or not. The results of this study were shared with DECARBOMILE.

Some data on industry and services: the municipality of Logroño, has a total of 11 101 companies (half of the entire Autonomous Community of La Rioja) of which 626 companies are engaged in industrial production and 5 805 in the services sector (2021 data). Analysing the trend over the last decade, there has been a decrease in the number of companies in the commerce, transport and hotel and catering and construction sectors, in contrast to real estate, professional and technical activities and other personal services, which have grown.

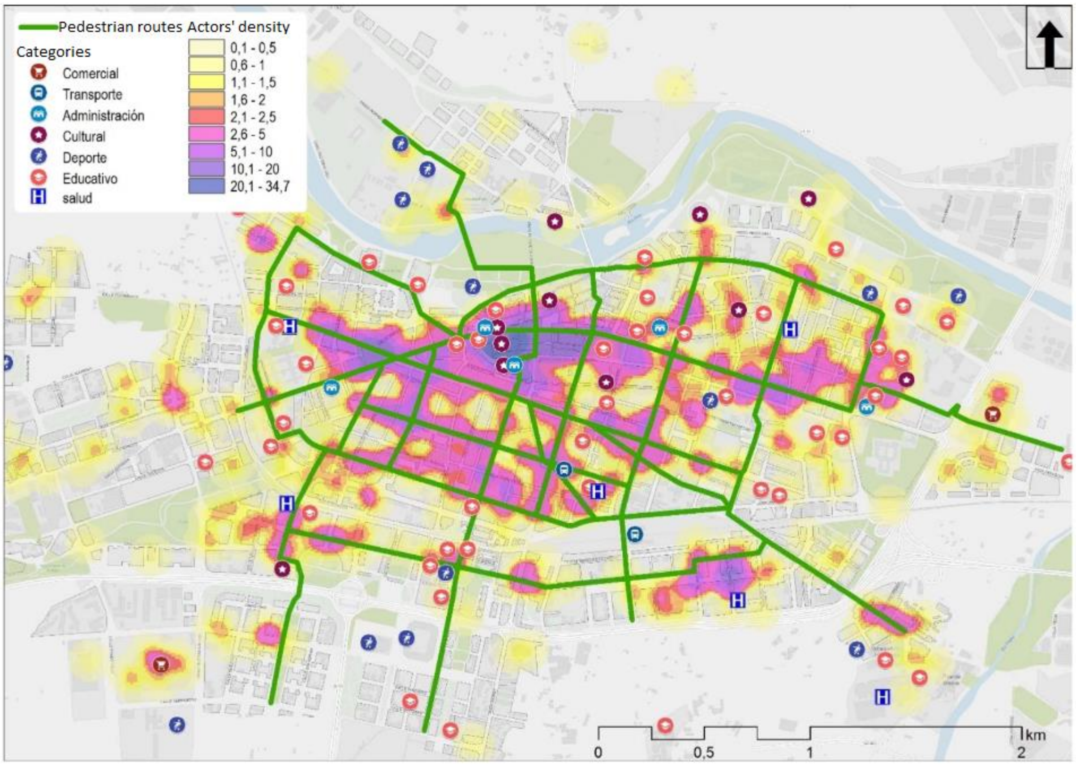


Figure 50: Map of the economic establishments of Logroño (source: Logroño calles abiertas, 2018)

Focus transports and distribution

The main logistics operators of the city are MRW, DHL and CORREOS. It has been possible to gather some specific information from DHL and MRW way of functioning.

Concerning the logistic operators of the territory, MRW is delivering by light vehicles only (~500kg capacity) with a distribution model of around 100 stops in one tour and one delivery per stop. To complete, MRW is using two cargo-bikes to deliver in the city centre (for parcels with less than two kg and an average frequency of 150 drops per hour). DHL for its part has also some trailers and trucks (freight delivered have higher volume than MRW). Trailers are used to collect parcels in big shops and industrial polygons. DHL delivers to the centre of Logroño with two trucks for around 400 deliveries and 40 pick-ups.

Focus on food products

In Logroño, there are different important markets that generate flows of food products. The focus is on the San Blas market (see Figure 51: San Blas market (source: deamstime)) and Merca Rioja (see Figure 52: Merca rioja (source: nuevecuatrouno)


Figure 51: San Blas market (source: deamstime)

Figure 52: Merca rioja (source: nuevecuatrouno)

It is usual for the merchants of San Blas market, to make 40% to 50% of their sales (in volumes) via home deliveries (deliveries made with their own vehicles). They do not use an IT solution to manage their deliveries, it is made “manually”, live or via online messaging. Each merchant does its own deliveries, without any concern about mutualizing with other merchants.
In the San Blas market, a try to implement a mutualized delivery service was made. It was a failure because merchants did not find economic stability with this model. One of the main obstacles for the merchants was the share of the costs for the service. Products of high value (for example meat) were transported with low value products with high volume / weight (for example salt). The weight of the delivery cost is not the same between these products so no rentability was found.

Merca Rioja is the wholesale fresh products market of Logroño. Products come from all over Spain (Madrid, Barna, Saragosa, Bilbao, ...) and they also import from outside the country (for example avocados from Peru…). This wholesale market is quite famous and 30% of the clients came from other towns (25 to 30 km around Logroño). Every delivery that is made is using the same distribution model as San Blas merchants, the orders are made without any help from an IT marketplace and the merchants do their delivery with their own cars, without mutualizing it. Although, not a lot of deliveries are made since most of the clients come to the market to see the products and negotiate.

Focus on pharmaceutical products

A current project that can inspire the DECARBOMILE use cases is the Riofarco cooperative that is doing the job of consolidating and mutualizing deliveries and logistics hubs to deliver pharmaceutical products in Logroño and La Rioja in general (77 stores are in Logroño for 500 stores in total in La Rioja). It is a success case, for Riofarco that provides 50% of the pharmacies stock. Riofarco has a logistic hub located in Villamediana de Iregua, consolidating and mutualizing deliveries to the pharmacies. It also has a marketplace associated to it that allows the final customer to collect its delivery in the pharmacy of his choice. In terms of knowledge that can be useful for DECARBOMILE in this project, we can focus on the feedback that Riofarco has with the implementation of a new distribution model via e-commerce, but also on the technologies behind the deliveries that are made with a continuous temperature control on the parcels. Moreover, Riofarco has managed to achieve the creation of a mutualized service with pharmacies that are facing an important level of competitiveness.

Infrastructures and main Equipment/assets

To introduce this section, below is a map representing the locations of the logistic operators of the city. They are mainly located in the industrial areas, in the outskirt (in pink). With this map, it can be seen that the city is well connected to the surrounding main roads. But there are also two rivers (with five bridges for each one) that limit the access to the city centre. In this map, the pedestrian area is shown with black dashed lines. Following the municipal ordinance on loading and unloading in the city, this area is a restricted area for delivery. Only trucks with less or equal GVW (Gross Vehicle Weight) of

3.5T are allowed and in a time slot between 7AM and 12AM and the parking time may not exceed 10 minutes.

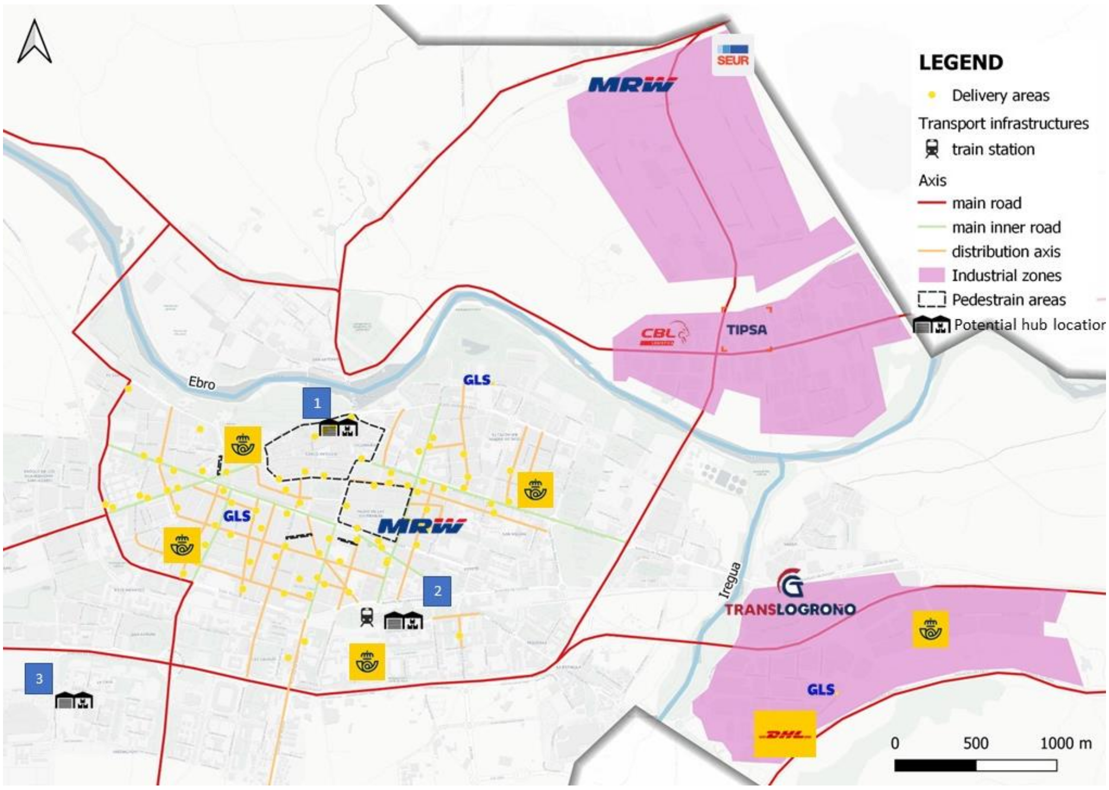


Figure 53: Map of the logistic operators of Logroño and potential locations for the DECARBOMILE hubs (source: IT)

In addition, several real estate locations (some owned by the city, some owned by private companies) have a strong potential for future consolidation hubs. They have been pre-identified and visited during the technical visit. The three possible hub location are described in detail below, with pictures and have also been numbered in the map above (1, 2 and 3, further detailed below).

In the San Blas market, a project of building a micro-hub in the basement of the market is ongoing (n°1 on the map, Figure 54). The construction is supposed to be completed in 2023 and this new micro-hub located in the city-centre would have a surface of approximately 300 m², with half of it dedicated to urban logistics, the other half would be used for storage only.

Figure 54: Micro-hub located at the -1 level of the market (source: IT)

Near the train station (operated by the ADIF, the Administrador de infraestructuras ferroviarias) and the new bus station (municipality of Logroño), it could be very interesting to implement a hub or a micro-hub (n°2 on the map above, Figure 54). This location is relevant because it is just at the entrance of the city and it is near some main roads. More specifically, the location that seems to be the best choice is an outdoor space (on municipality ground) that is near some bicycle lanes and not so far from the road (see picture below). On this parcel, we can imagine a service of smart lockers and for this it would be necessary to make a connection to the electrical network. Also, a connection to the main roads would be necessary. Other locations have been identified like a closed local belonging to ADIF (a tendering process is already ongoing to determined how to use it) or in the parking of the intermodal station (managed by the company Saba).

Figure 55: Exterior municipal parcel near the intermodal station (source IT)

ADIF, the public administrator of railway in Spain is developing a project called "ECOMILA" in Logroño (that they have already implemented in Madrid), that consists in using available capacities in ADIF's parking stations in order to promote sustainable transport practices by reserving some parking spots for electrical or shared vehicles.

Another location that could be interesting to use for the project is the "Parque of Servicios", owned and managed by the municipality. This place is already used for logistics purposes (storage, maintenance...) and is composed of three main buildings. Some space is still available and could be used for the project DECARBOMILE. What makes this location interesting is its localisation with an immediate access to the highway. It is also near a new neighbourhood of the city that is under development and where a lot of new residents come to live, even if it's a bit far from the centre.

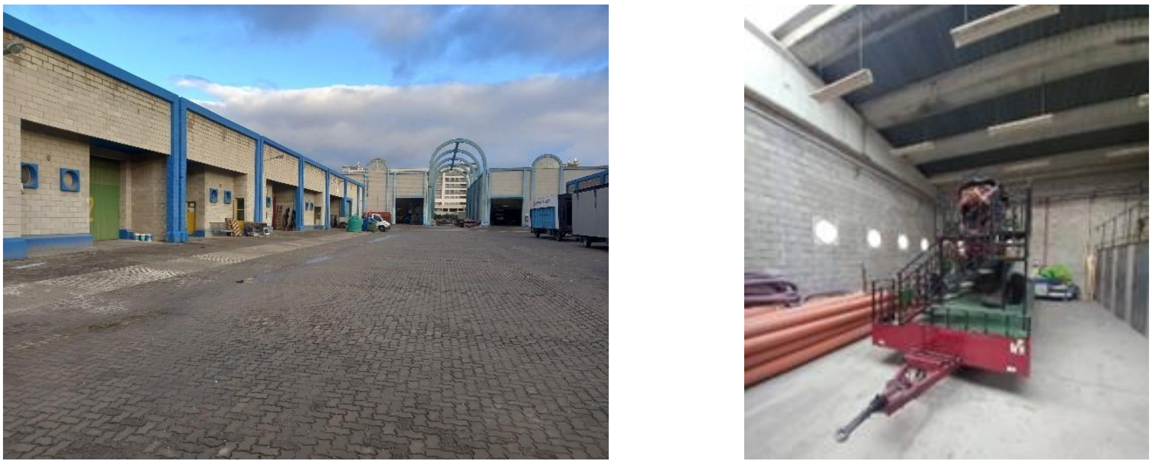


Figure 56: The "Parque de Servicios" of Logrono, with some free capacities for a hub / micro-hub (source: IT)

Another possible location are two locals in the Merca Rioja building (n°3 on the map above, figure 54) which have direct access to the quays and the ramps (see pictures below).

Figure 57: Potential free local of the Municipality located at the end of the building (left) and ramp for access with rolls or cargo-bikes for example (right) (source: IT

Public policies and regulations

A **Limited Traffic Zone** has been implemented on different streets, notably Portales and Bretón de los Herreros de Logroño. It also covers the eastern area of Logrono, between Avenida de Viana and Calle Portales (from north to south) and between Calle Rodríguez Paterna and Sagasta (from east west) since summer 2021. Currently, deliveries in the city centre are allowed from 7 AM to 12 AM for commercial vehicles and vans, otherwise, merchants have to call the police authority to ask for permission. The control is made via cameras and the police has a register of all the license plates that are authorized to go into the city centre outside of the timeslot. In the contrary, cargo-bikes are authorized 24/7.

The historical centre counts on a **car and truck access restriction** system at the heart of the city's most touristic area, enforced by traffic cameras, which is part of the **Low Emission Zone** (LEZ) Plan, planned for 2023. The municipality wants to extend it to a wider Low Emission Zone (LEZ) soon and is currently studying the definition of the perimeter and the regulations of this LEZ. It has the ambition to favour low-emission vehicles with, for example, giving access from 7AM until 12AM to low-emission vehicles and giving access from 8 AM until 11 AM for non-low-emission vehicles. The final objective is to reduce the number of motorized vehicles in the city and notably in the pedestrian area.

The main municipal policies regarding last-mile logistics are comprised in the Urban Freight Regulation Plan 2021.

The city is also involved in a process of updating its Sustainable Urban Mobility Plan (SUMP) with, among others, the ambition to reinforce infrastructures for cargo-bikes (bike lanes, parking spaces capacities...). The SUMP, in effect since 2013 is now to be complemented with a Local Urban Mobility Strategy study. Finally, a technical assistance has recently been contracted for the elaboration of a Local Urban Mobility Strategy. There are two extracts from the document that focus on logistics.

What can be sum up from these two documents is that the delivery regulations in Logroño state that parking time must be less than twenty minutes and deliveries are allowed within the time slots of 8.30AM-1PM and 3PM-7PM. In the historic city centre, as well as in the pedestrians' areas, vehicles with a gross vehicle weight of less than or equal to 3.5T are allowed to park for less than ten minutes within the time slot of 7AM to 12AM on working days.

Logroño does not have a large logistic centre in its perimeter (nearest one is located 68km away), however, the city can receive supplies through smaller consolidation centres located in the industrial areas of Portalada, and Cantabria (east of the city). There are no UCCs in the city centre except for logistics operators SEUR and MRW, which have relay points located in the avenue de la Solidaridad and the avenue General Vara de Rey, respectively.

On average, 131 000 parcels flow into the city each week, representing 0.874 parcels per inhabitant. This implies 18 000 delivery trips per day, which make up 3.9% of the daily mobility flow of the city on working days.

The SUMP has three clear objectives to improve the urban logistic of the city:

1: Improving urban freight distribution with measures to increase the control of delivery areas, promote green means for urban freight transport and maintain the same time slot for commercial vehicles in pedestrian areas and city centre.
2: Analysis of the regulation of night-time loading and unloading. Currently an experiment is led on night delivery in Mercadona. If the experiment is a success, it will be applied in the city, with respect of safety and with an impact acceptable for night-time coexistence with residents.
3: Creation of an Urban Freight Transport Forum.

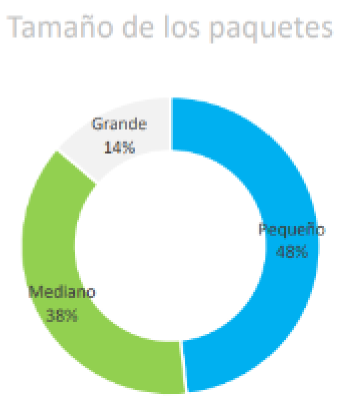


Figure 58: Graph of the seize of parcels in Logroño (source: Estudios y actuaciones sobre la estrategia local de movilidad urbana sostenibles)

A specific idea that can be useful for DECARBOMILE can be found in the study made on the size of the parcels delivered. This diagram above (figure 59) shows that implementing smart lockers would be a great idea since only 14% of the parcel are big ones. Also 51% of the population would like to see smart lockers in the city.

To advocate for more smart lockers, the study shows that 21 000 parcels are currently delivered in the future LEZ perimeter (with the majority of these parcels being small or medium sized). Other ideas are to create smart delivery areas (with IT solutions used to control the access of the delivery areas and avoid illegal occupation), an urban consolidation centre at the entrance of the future LEZ and update the municipal ordinance of the city (weight and size regulation, hourly regulation, night delivery, enforcement and reinforcement of access and loading rules and road charging systems).

In parallel, Logroño implements an 'Open Streets' strategy, as a response to the emergency situation of Covid-19, to transform the city's streets through a more balanced and fairer distribution of public space, improving the quality of life and promoting active mobility. The strategy is divided into the following six main intervention programmes to be developed and consolidated in the coming years:

- The healthy pedestrian network, which establishes a series of pedestrian routes that are safe and accessible.
- The healthy cycling network, ensuring safe cycling routes, establishing priority and secondary axes through traffic calming or segregated cycle lanes.
- Improved Environments, with specific improvement interventions in 20 school environments, as well as in other public facilities.
- Pacified areas in neighbourhoods, with adaptations of areas and neighbourhoods to calm traffic and improve road and health safety, via 30 zones.
- Support for public transport, with the treatment of stops to facilitate waiting times and the creation of bus lanes.
- Adaptation of regulations, by setting a 30 km/h speed limit, allowing cyclists to cycle in the opposite direction and revising traffic light phases.

It is planned to consolidate these actions through the implementation of actions linked to the urban transformation of the city. The overall aim is to:

- Reorganise public space, prioritising people's health, but preserving road safety on the streets.
- Achieve sustainable, safe and healthy mobility is the general framework beyond urgency.
- Design that takes care of universal accessibility and the needs of all people, with a gender perspective.

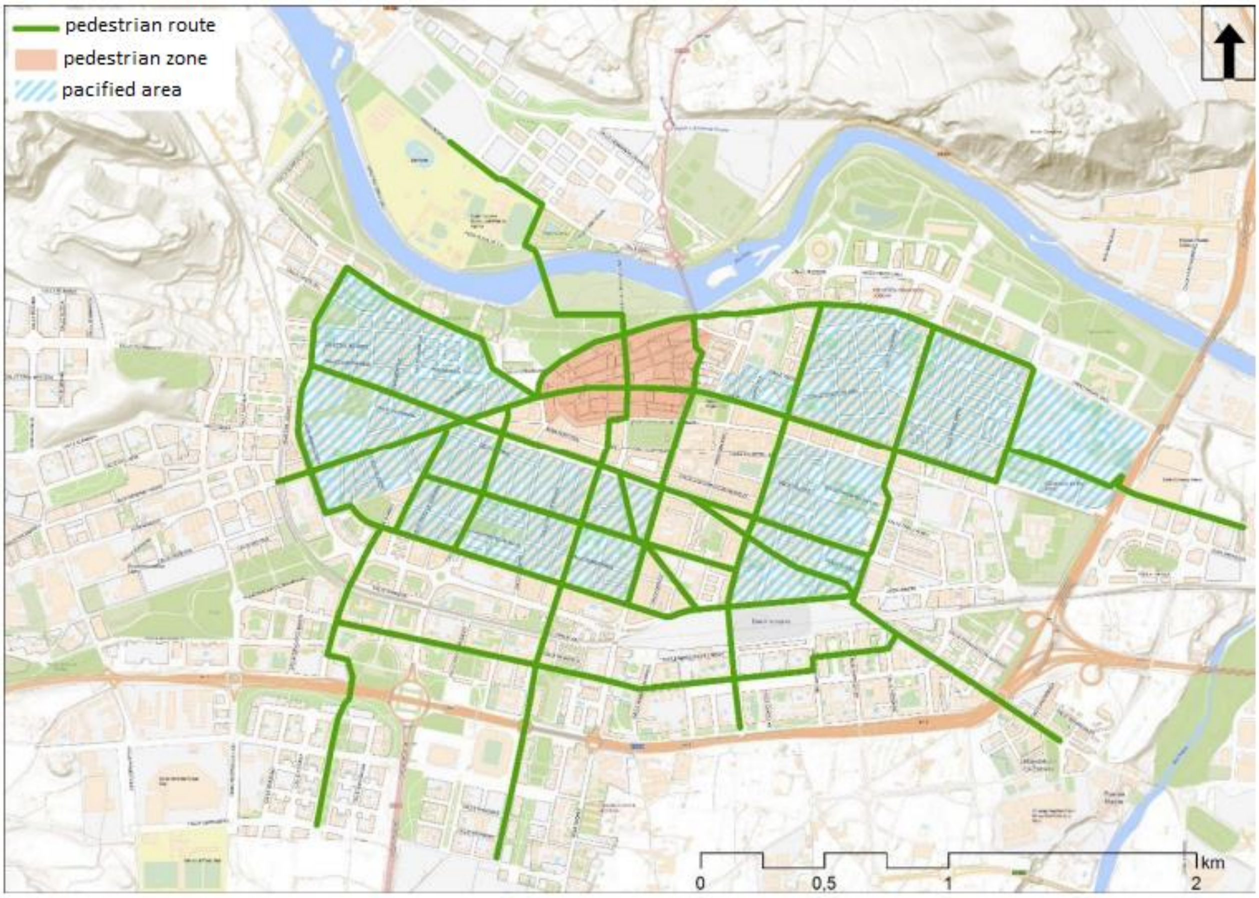


Figure 59: Map of pacified areas in Logroño and main pedestrian roads (source: Logroño)

Local stakeholders

Below, the list of the stakeholders:

Carriers:

Logroño en bici

Logistic operators:

DHL

GLS

MRW

Correos

Trans Logrono

CBL

SEUR

REVOOLT (start-up that delivers without carbon emission and uses new IT solutions)

TXITA (cycle logistic operator in SanSebastian)

For logistic operators DHL and MRW, that could be involved in the use cases of the project, they both have a logistic hub located in the industrial zones of the city. During the technical visit, these stakeholders have made comments on the implementation of the use cases and explained their concerns. For MRW, it is not possible to consider a collaboration with other logistics operators by mutualization of the parcels. The client has to know that he's been delivered by MRW who respects a certain standard. Moreover, MRW has some concerns about the operational and economical model associated with the introduction of cargo-bikes. Both of the logistics operators are willing to test new models with some micro hubs, cargo-bikes and smart lockers.

For Logroño, the stakeholders' mapping (figure 61) below was developed from the initial stakeholder mapping exercise done during the KOM combined with ranking exercise and the presentation during the technical visit. It shows pharmaceutical companies and markets having a key role in the existing delivery services. This set of actors are valuable stakeholders directly impacting the upcoming use-case intervention in the region.

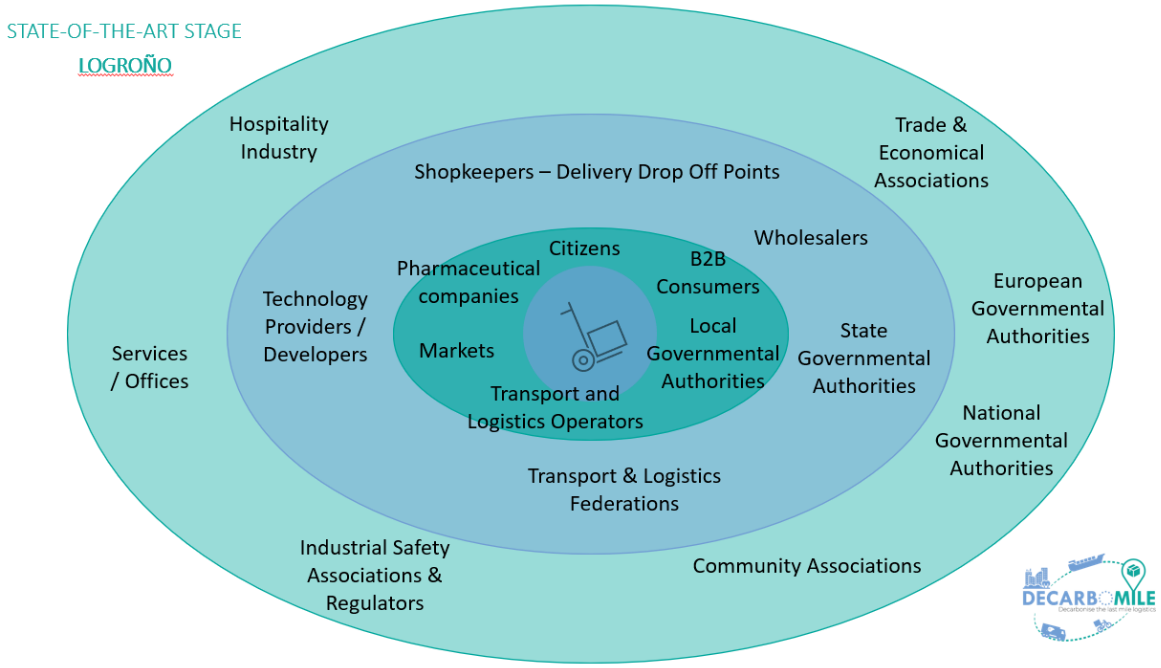


Figure 60: Mapping of l Logrono Living Lab demonstrating the current scenario's key sets of stakeholders (source: CBS)

Local authorities and real estate and infrastructures:
La Rioja Government
General Directorate of Public Space and Activities -Logroño City Council
Federations
CETM La Rioja: Confederación Española de Transporte de Mercancias (Spanish Confederation of Freight Transportation)
FER: Federación de Empresas de La Rioja (Business Federation of La Rioja)
Associations:
AECOC (The Manufacturing & Distribution Association)
PMLR (La Rioja's Mobility Platform Association)
Trades' Association of the Plaza de Abastos de Logroño - San Blas Market
Paseo de las 100 Tiendas Trades' Association
El Corregidor Market Traders' Association
ATRADIS (La Rioja Association of hauliers and logisticians)
Asociación de vecinos san josé (neighbourhood association)
Asociación de vecinos madre de dios (neighbourhood association)
Educational institutions:
University of La Rioja Business School

Existing IT solutions

The Municipality is involved in a "Smart City" project. Within the project, they started to develop a hub consolidating different sources of data and giving open access to them like data on traffic, economic establishments, etc. A local private company is working on these developments with the Municipality. The hub has a big potential for the project because of its high development capacity. This project includes the development of a marketplace that has just started (it will be used for the San Blas market in a first place, later they want to link it to a free-space parking system). Several questions emerge from this idea: first of all, the potential link between this project led by the municipality and DECARBOMILE and furthermore, how it can be possible to encourage the use of low emissions vehicles via this marketplace, what kind of regulations/incentives would be interesting to implement, etc.

SUMMARY OF THE SITUATION AND POTENTIAL USE CASES

Synthesis and knowledge

The stakeholders that participated in the technical visit raised several points of attention during a meeting. First of all, it will be very important to sensibilize the final customer about the associated impacts of the delivery option that he chooses. Also, the creation of an online marketplace should not encourage the final customer to abandon the local shops and in the contrary "click & collect" or the shop experience should be highlighted and encouraged (maybe via lower price, …).

During the first kick-off meeting of the project, the partners have identified some challenges and strengths. Here is a synthesis. First, according to the members of the consortium, in Logroño the main challenge will be the local stakeholder's engagement. Indeed, it will be a challenge to engage them in a common system for the last-mile and make connections between the local market and the "big" market. Moreover, the DECARBOMILE project requires a great resilience, and a lot of habits will have to change, from the logistic operators, to the shop owners and the final consumers. The second biggest challenge will be to build some safe infrastructures for active mobility, especially bikes, that are at the centre of the project. Moreover, it seems complex for the partners to activate three different hubs with three different activities.

As for the strength of the project, in the first place there is the city's configuration, its size and population density. The small size of the city and its high density makes it easy to connect the different stakeholders, as they are not so far away from each other. With smaller distances, it is easier to implement active mobility. Also, it will make it easy to define criteria of success and therefore, replicate the developed scheme. The second strength is the strong political commitment and finally there is an ongoing network of hubs and micro hubs with potential locations already identified (see section *Infrastructures and main equipment/assets*), which is the final strength of the living lab.

Based on this, below is a list of the use cases developed for Logroño.

Potential use cases

The **reference situation for our first and second use case** (showed below) corresponds to a classic distribution model for two logistics operators (that can be MRW and DHL for example) who have their hub located in the outskirt of the city, notably in the industrial zones. These operators do their deliveries using straight-truck or smaller motorized vehicles, equally in the city centre and in more remote locations. They offer home deliveries and pick-up point deliveries as well. On the other hand, we have the Riofarco cooperative (mentioned earlier) which is already doing flow consolidation for pharmaceutical products deliveries.

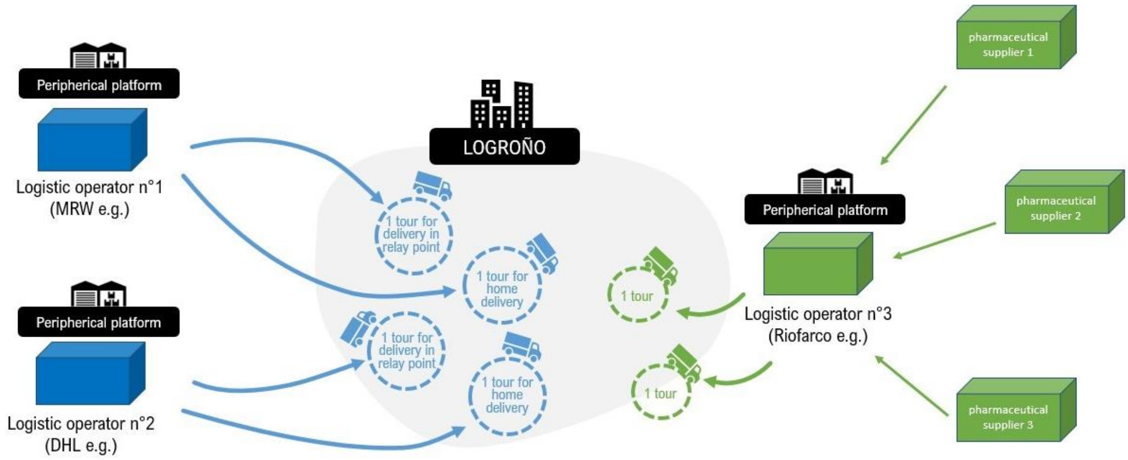


Figure 61: Reference situation for use cases 1-2 - consolidation and mutualization of parcels and pharmaceutical products deliveries (source: IT)

USE CASE 1: Consolidation of distribution of parcels (deliveries and pick-up) with cycle-logistics, for B2B and B2C

Different operators bring the parcels from their hubs to the hub with their own vehicles. Consolidation and deliveries / pick-ups take place with cargo-bikes and trailers. The vehicles of the operators continue their tour after they left the parcels at the hub. The interest in smart lockers as a complement needs to be confirmed.

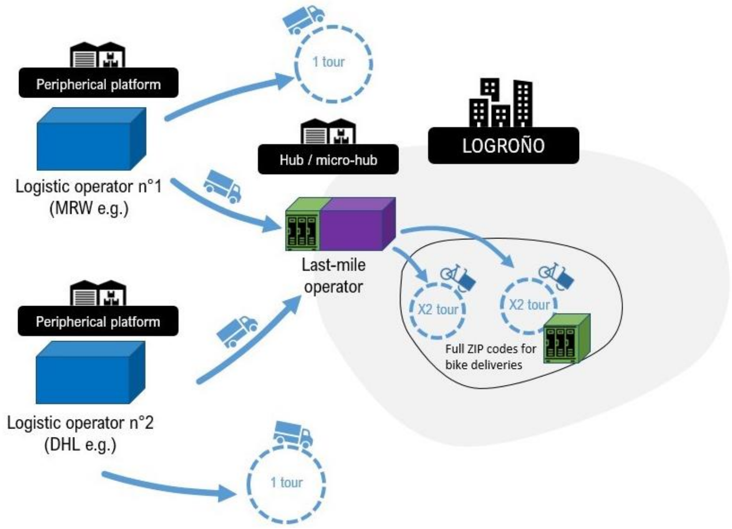


Figure 62: Pilot situation for use case 1 - consolidation and mutualization of parcels (source: IT)

The pilot situation for **the first use case** is mainly focused on the creation of MCCs, that would be located in the city-centre, on the entrance of the new LEZ implemented by the municipality to allow the delivery to be made by cargo-bikes. The subcontractor involved in the cargo-bikes delivery would be responsible for full ZIP codes of Logroño but this solution does not have the purpose to replace the truck delivery that will still exist. It would also be interesting to test smart lockers in addition of the deliveries made in pick-up points.

Possible local actors: DHL, MRW, DACHSER, GLS

USE CASE 2: Consolidation of deliveries of pharmaceutical products, with cycle-logistics, for pharmacies' e-commerce and their own supply

An operator (Riofarco) already mutualizing the e-commerce for 56 pharmacies of Logrono brings the products from its hub and with its own vehicles to the hub. Consolidation and deliveries are with cargo-bikes and trailers. The vehicle of the operator continues its tour after it leaving the products at the hub. The hub could be shared with the use case 1.

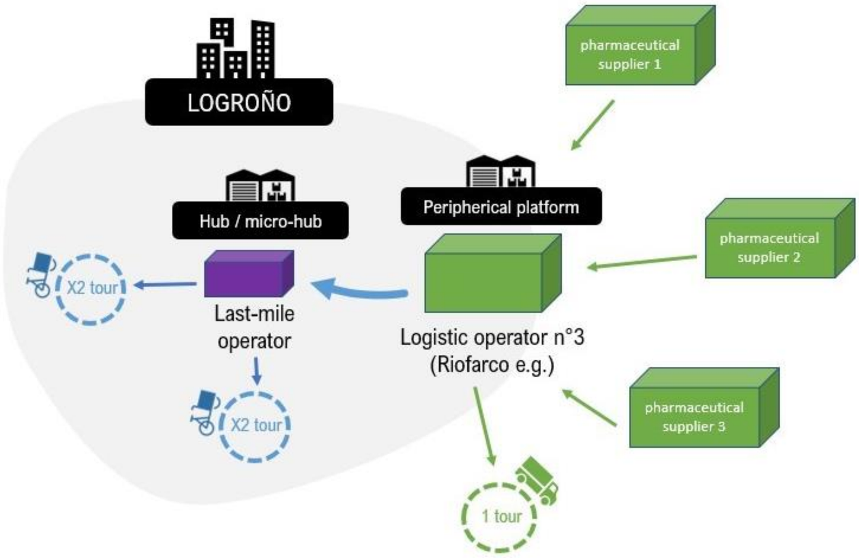


Figure 63: Pilot situation for use case 2 - focus on pharmaceutical product deliveries (source: IT)

Possible local actors: Riofarco

USE CASE 3: Services to local shops

Bring digital tools to local shops (marketing tools for them to know their clients better, marketplace and external database access starting with the touristic affluence), to improve their supplies and/or their pick-up/deliveries to their clients with the development of promotions and incentives.
Possible local actors: Clothing and accessories shops, Bookshops, Pharmacies, Hotels and Tourist housing associations, Businesses and Associations that connect local producers and clients (fruits and vegetables), Digital hubs suppliers (connecting local businesses and customers):

- Shop "El colletero" and group of consumers "Huertas del Iregua" (direct supply from local producers + baskets service picked-up in the shop)
- Ecologroño (initiative from "Amigos de la Tierra La Rioja" to group in a same web shop trying to differentiate their business with sustainability)
- Caperucitapp "Tu Cesta de Comercio Local", business connecting local commerce with clients, providing digitalization in sales and last-mile logistics (today: ten delivery drivers providing services to 30-35 local shops; combines sustainable delivery with conventional delivery (for larger distance); embark Logrono and small cities around like Alberite, Lardero, Villamediana de Iregua and Oyon).
- Planeta Limpio (doing home deliveries with a bike)
- Atypica (clothing local shop)
- Mikonos (clothing local shop)
- Summertime by Bianca (clothing local shop)
- Curtidos Dominguez (local shops)
- Santos Ochoa (library)

- Pharmacies (link with Riofarco) TSYS: local business (subsidized by the City) delivering food to dependent / older persons. Most of deliveries during the morning, from their hub -> see dedicated use case after
- Hotels and touristic accommodations associations:
    1. Actual logistic needs
        - + Supply
        - + Laundry
        - + Arrival and Departure of the clients to Logrono and to their businesses
        - + Others
    2. Interest to improve clients' experience
        - + Improve arrival and departure
        - + Improve City's stay
        - + Capacity you have to segment your clients to focus in a specific group
        - + Develop incentive and campaign systems, sectorial (individuals and/or collectives) and crossed with other sectors (for example commerce and restauration)
        - + Needs prevision associated to urban logistics

USE CASE 4: Consolidation of food deliveries to dependent / older persons (TSYS), together with other products and home services (pharmaceutical products, e-commerce, etc)

Grouping of deliveries to TSYS' clients through cycle-logistics. Take the opportunity of this urban distribution to consolidate other home deliveries to the same customer.
Possible local actors:

- TSYS
- Riofarco
- Local shop? Market?

USE CASE 5: Improve supplies and/or pickup/deliveries of fresh food flows

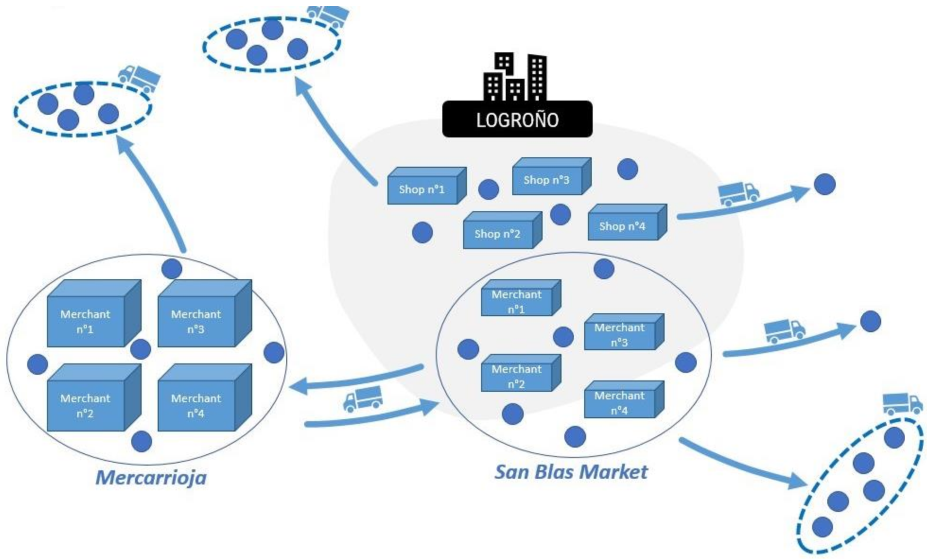


Figure 64: Reference situation for use case 5 - consolidation and mutualization of deliveries from markets and local shops (source: IT)

The fifth use case focuses on the main marketplace of the city: San Blas market and Merca Rioja. Following the technical visit, it appeared interesting to work on the link between the two markets and the distribution model that they use. Their deliveries to direct customers are made in the same way as the two logistic operators of the use case 1 with no consolidation method being used. They can as well do one delivery for one trip or organise a tour for many clients. What is special is that every merchant does its own deliveries (with their own vehicle) so in addition, it generates a lot of flows that could be easily mutualised. In this use case, we also consider the deliveries made by the local shops of the city.

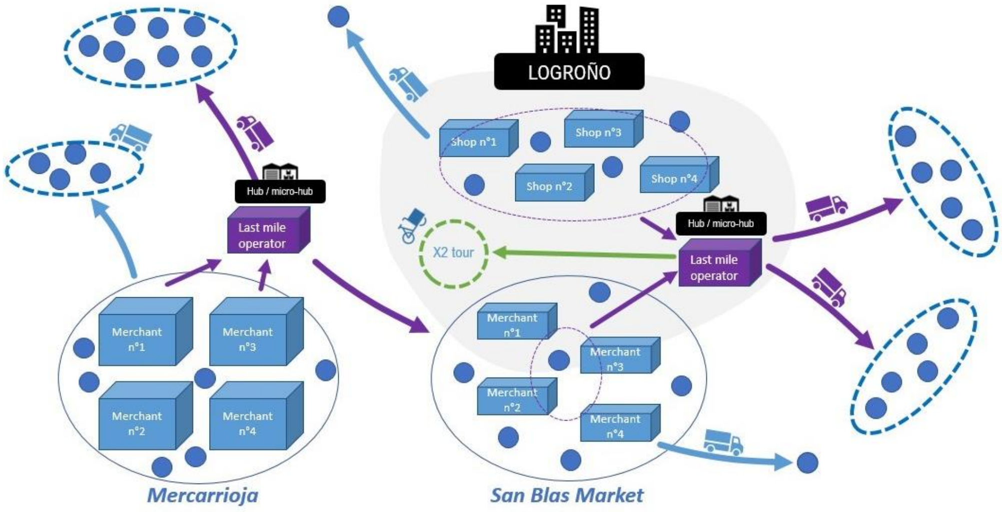


Figure 65: Pilot situation for use case 5 - consolidation and mutualization of deliveries from markets and local shops (source: IT)

This pilot situation aims to consolidate the delivery flows of the city. Although, it is not the point to completely suppress deliveries made individually by merchants. Here, we imagine the creation of two consolidation centres (one in the city centre, one near Merca Rioja) that would pool the deliveries and minimize the number of deliveries. The hub near Merca Rioja would be operated by a subcontractor. The one in the city centre would permit some deliveries to be made by cargo-bikes (as in the use case 1, for the area inside the LEZ) and will allow deliveries to be optimized so that one tour delivers more people.

Possible local actors:

- Merca Rioja (Fruits, vegetable, fish)
- Gourmet Shops,
- San Blas Market,
- Agro-ecological market

Use case 6: Optimization of logistics flows within the urban perimeter

Minimize the freight movements entering and leaving the urban perimeter: flows of operators between their hubs and the centre for example. Propose a transport service between different shops for shopkeepers.

Possible local actors: all local businesses *(Candy shops, Clothing and accessories shops, Bookshops…)*

Key Performance Indicators

Specific KPIs for Logrono will be further developed, once the use cases are more specific. General indicators could include:

- Number of freight units collected in smart lockers
- Handling loading/unloading time at the warehouse
- Allocation of public space for UCCs

Relevant use cases to build upon

Based on the use cases identified, the additional following projects could be of interest for Logrono:

- CityDepot: Consolidated customized supply of products to customers (defining their preferred time and location for delivery), with reverse logistics and waste collection, offering storage services too.
- KARGOPARK: smart lockers placed at Migros retail stores to enable customers to self-pickup their packages (orders from e-commerce sites, self-pickup, e-commerce cargo) while they come to do shopping.

A more detailed document gathering information on the above projects will be shared with the living lab to enhance collaboration on these topics.

1.4 Hamburg Living Lab

CONTEXT

Hamburg is the second largest city in Germany after Berlin. It is located in northern Germany on the river Elbe and is known for its large port. Almost two million people live in Hamburg.
Today Hamburg belongs to Germany and is a federal state in its own right. It is governed by the First Mayor and the Senate, which is the name of the government.
More than a thousand years after the port was founded, Hamburg and its neighbouring communities are now the most important trading and economic centre in northern Europe. The Port of Hamburg is not only Germany's largest universal port, but also an important distribution point for goods trade between the North Sea and the Baltic.

A few key figures on the Port of Hamburg

- 126.3 million tonnes of cargo, including around 8.5 million standard containers (TEU), were handled in 2020.
- The port is the third largest container port in Europe
- The port ranks 18th on the list of the world's largest container ports.
- The port is one of the most important employers in the metropolitan region.

Hamburg is a city with a lot of water and a lot of green. Apart from the river Elbe, three other rivers flow through Hamburg: The Alster, Bille and Este. A large part of Hamburg's urban area is harbour territory.
The Hamburg metropolitan region is one of the most competitive regions in Germany and Europe. Thanks to a great infrastructure, qualified skilled workers, innovative companies and research institutes known for cutting-edge research, the economy continues to grow. Supported by the high quality of life, the population is growing steadily. In 2022, 5.4 million people live in the Hamburg metropolitan region.

High-performance clusters have developed in various economic sectors in the Hamburg metropolitan region - from the traditionally leading sectors of maritime industry, logistics and port management to aviation, renewable energies and life sciences. The strong economy of the metropolitan region also includes the chemical industry, the food industry, automotive and mechanical engineering as well as media and IT. The cultural and creative industries and tourism also play an important role.
A number of highly specialised research facilities and institutes complement the diverse public and private teaching and educational opportunities in the Hamburg metropolitan region. More than 10 000 researchers contribute with their ideas and their work to the creation of innovations and new findings that can be used by companies.

Figure 66: Hamburg metropolitan region (source: Hamburg invest)

Hamburg Municipality (HAM) is involved in the project through the Senate Chancellery (SC), the Ministry of Economic Affairs and Innovation (BWI), the District Office of Hamburg Mitte and New Mobility Solutions Hamburg GmbH, a worldwide congress dedicated to smart mobility (ITSHH). Further local partners are Logistik-Initiative Hamburg (LIHH), Hamburg University of Technology (TUHH) and Deutsche Post DHL (DP DHL) as logistics service provider.

URBAN LOGISTICS

Economic Activity and freight movements

Freight movements

Around 32 % of the traffic in Hamburg is commercial traffic with 1.1 million trips per day. The distribution of ways of the different vehicle classes are described in the figure below (Figure 67).

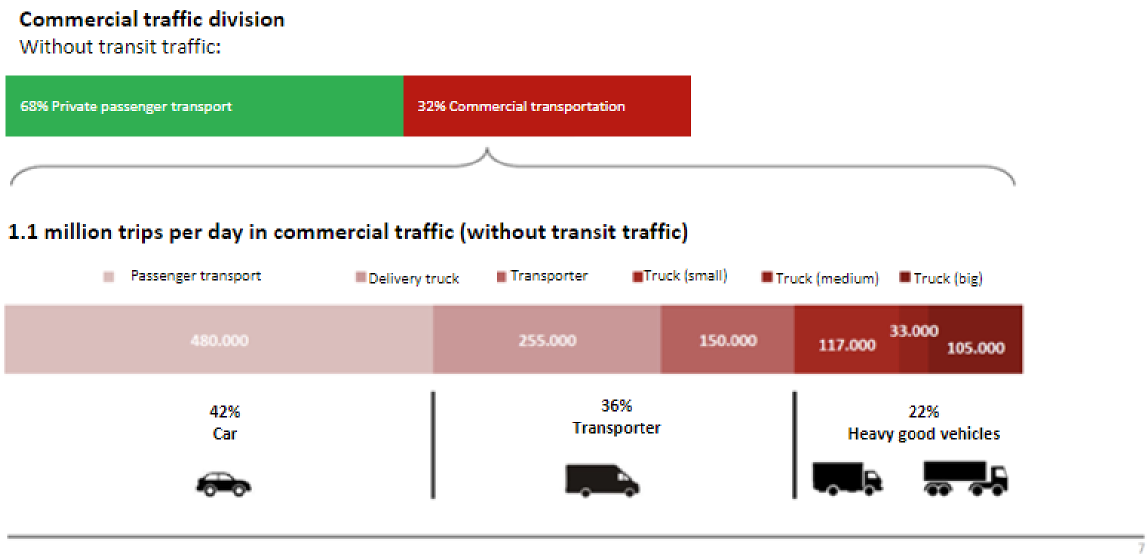


Figure 67: Overview of the distribution of commercial traffic in Hamburg (source: Mobilitätsbeirat 2019)

42% of the vehicles are cars, 36% transporters and 22% heavy goods vehicles. In total, the passenger economic traffic with cars makes 480 000 trips per day, the delivery trucks 250,000 trips/day, the transporters 150 000 trips/day, the small trucks 117,000 trips/day, the medium trucks 33,000 trips/day and the big trucks 105 000 trips/day (Mobilitätsbeirat 2019).

In 2017, the shipment volume was 95 million items, 46% of which went to private households (X2C) and 54% to businesses and other institutions (retail, industry, service providers, public authorities, etc.) (Altenburg 2020).

Freight movements: focus on DP DHL

With regard to Hamburg's use case, the following section focuses on facts and figures from DECARBOMILE partner DPDHL, the only freight and logistic operator in the pilot phase.

The DP DHL's delivery base in Hamburg Billbrook has an average of 60 delivery routes. However, depending on the volume of shipments, it is also possible to plan for around 70 delivery routes per day. The delivery area mainly covers the core of the city of Hamburg.

Deliveries are made to more commercial and industrial areas of the city, such as Billbrook or the Steinwerder district south of the Elbe. In Steinwerder imany port operations and large company sites are located.

The delivery area also includes areas north of the Elbe, with many office locations, retail shops and private residences: HafenCity, where the well-known landmark, the Elbphilharmonieis located, as well as the densely populated areas in St. Georg. But also, Neustadt, which is bursting with elegant shops in the area of the "Neuer Wall" as well as the "Jungfernstieg", is in the delivery area of the Billbrook delivery base.

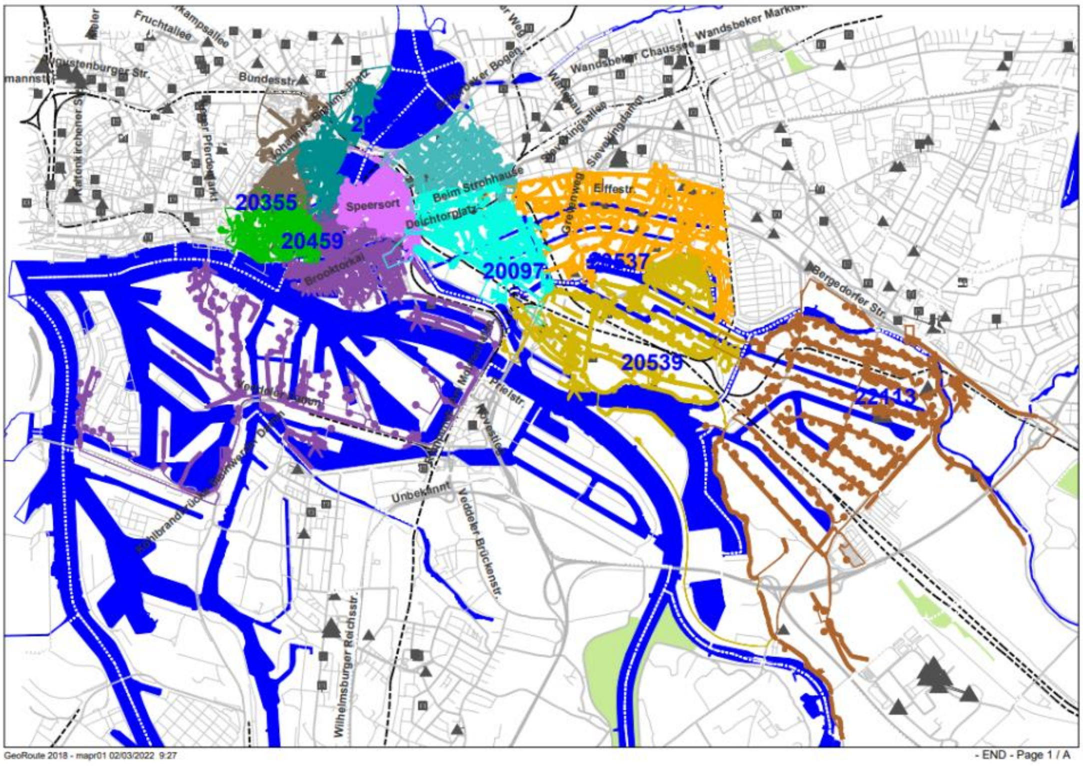


Figure 68: Overview delivery area Deutsche Post Hamburg Billbrook (source: company data Deutsche Post DHL Group)

Average for the year, 7 000 – 9 000 parcels per day are handled at the delivery base. However, these quantities vary on a daily basis. In the summer, during the holiday season, the amount of parcels is lower, and in the last weeks before Christmas, the volume can almost double. In December, for example, parcel volumes of 11 000 to 12 000 parcels per day can be estimated. However, on peak days, up to 16 000 parcels can be expected.

Freight movements: focus on traffic road

Traffic counts from the Hamburg Ministry for Transportation and Mobility Transition (BVM) show that in **Hamburg Billbrook the road networks are highly frequented by transporters as well as light and heavy trucks** (Figure 69). This is not only due to the proximity to Hamburg's port, where many freight transports start or end. Additionally, in the industrial area in Hamburg Billbrook many companies and in particular logistics service providers are located, that induce considerable flows of goods and thereby road transportation. The (in- and outbound) roads between Billbrook and Hamburg's city centre are congested, in particular, as their capacity is limited due to space constraints.

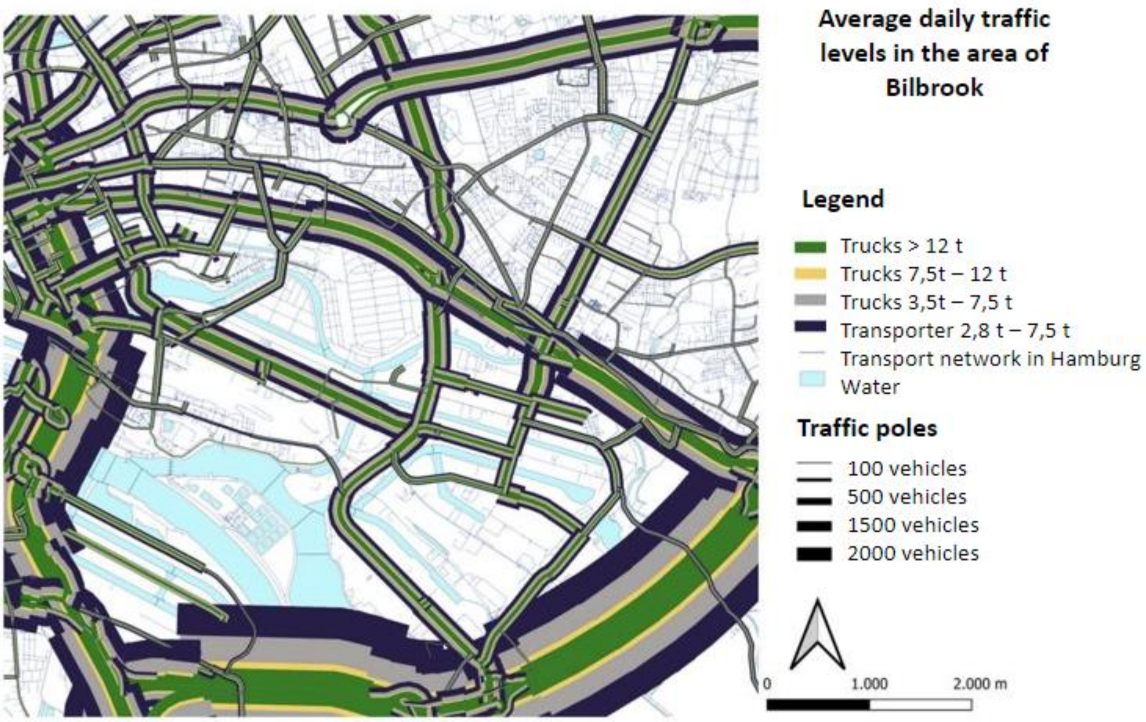


Figure 69: Illustration: Average daily traffic levels for transporters and trucks in Hamburg (source: Fiedler et al., 2020)

Infrastructure and main Equipment/assets

The Living Lab focuses on using the waterways and canals from Billbrook area, where one of the delivery bases of the project partner DP DHL is located, to the city centre of Hamburg. Today, these waterways are not used for commercial transport. Indeed, only tourist connections are using these waterways in Hamburg.

Focus on existing data and study on Hamburg's waterways: the WaCaBa study (2021)

The Ministry of Economy and Innovation (BWI) commissioned the study "Water Cargo Barge (WaCaBa)" in 2021. This in-depth study serves the Living Lab as guideline with its analyses of the local waterway system.

It shows which waterways and canals are navigable and the water depth of the Bille waterways (Billbrook area) measured by sounding. The following analyses shows the structure of the waterway banks and thus gives important information on which structures might need to be set up for the project.[1]

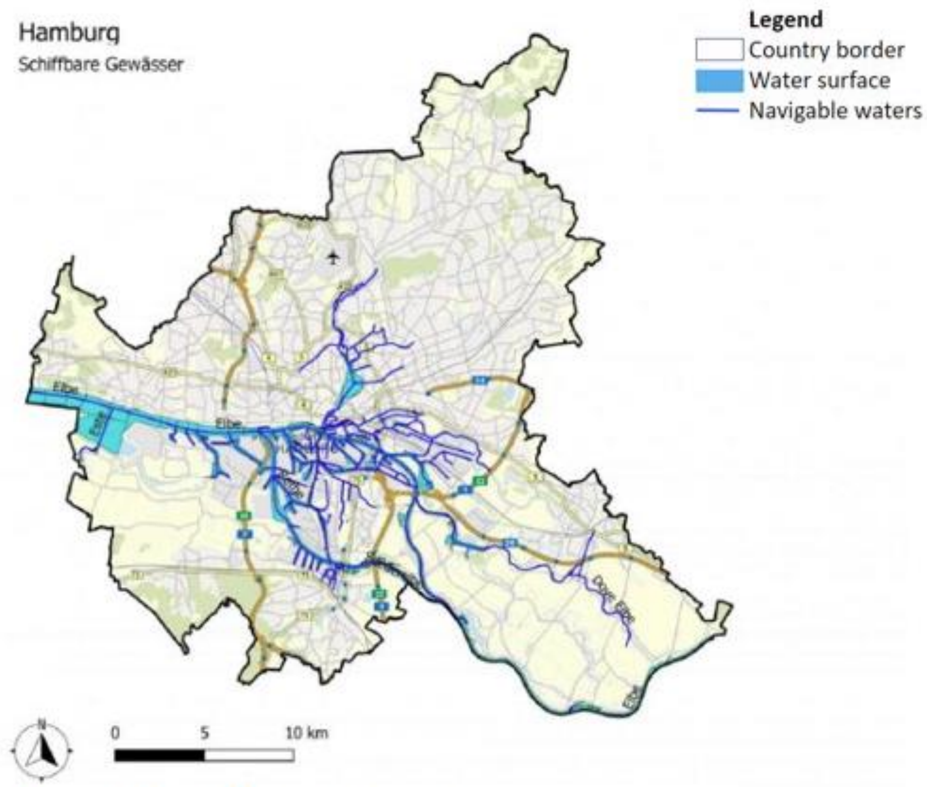


Figure 70: Illustration: Navigable waterways in Hamburg and water depth of Bille waterway (source: WaCaBa study)

Furthermore, the WaCaBa study shows the tidal dependencies of Hamburg's waterways, locations of locks and illustrates the zones of nature reserves. The study also gives a detailed overview of the responsible authorities for the corresponding waterways. Some of these authorities will be important stakeholders for the Living Lab.

The WaCaBa study also proposes one location as possible landing stage. The Living Lab partners identified this location for their use case as a possible unloading point of the vessel, see section *Potential use cases*.

Main equipment / assets in the use case

For deliveries on waterways by vessel, the Living Lab plans to collaborate with the project partner OHB from Ghent. Details of the vessel can be found in the dedicated section of Ghent's baseline.

Current deliveries by the project partner DP DHL to the city centre of Hamburg are carried out as follows:

- Approximately **90% of the parcels are delivered via mostly e-vehicles.**
- The remaining **10% of the items reach the customer via the mail carriers**. These are mainly small items that are sent as parcels but usually fit through the letterbox.
- Classic cargo-bikes have not yet been used in the area of the Billbrook delivery base, as the volume of parcels and the mass of parcels is too large for the economic operation of cargo-bikes.
- **DP DHL centre in Billbrook has only one cargo-bike**. An updated version developed by Rytle is used in Berlin. The updated version can transport parcels or one pallet- if necessary - as its container and loading is flexible (possibility to remove the container to use another

one). It is planned to use 6 of these updated versions of cargo-bikes in the DECARBOMILE's use case of Hamburg.

Public policies and regulations

For the Hamburg Senate, sustainable action is an extraordinary priority. Government policy is guided by the principle of sustainability. This path is consistently pursued with the resolution on the implementation of the United Nations Sustainable Development Goals in Hamburg which was adopted on 4 July 2017 with the Agenda 2023.

Hamburg Climate Plan policy

Hamburg city legislated an ambitious climate protection law in 2020 (Hamburgisches Gesetz zum Schutz des Klimas, (landesrecht-hamburg.de), which sets ambitious goals for the reduction of carbon dioxide emissions until 2030 (-55%) and 2050 (-95%) compared to 1990 levels.
Climate protection is defined as a cross-sectional task in the Hamburg Climate Protection Act and must therefore be considered in all planning, measures and decisions of the Free and Hanseatic City of Hamburg and its state-owned corporations, institutions and foundations under public law. The Hamburg Climate Plan is updated every 4 years.
The law is accompanied by a climate protection plan, which includes many concrete measures for archiving these goals in all sectors, including a Sustainable Urban Mobility Plan (SUMP).

In 2021, Hamburg also announced its strategy for decarbonisation in the urban logistics sector (senate document 22/5939 https://www.buergerschaft-hh.de/parldok/dokument/77388), which sets forth measures aimed at increasing sustainability and lowering emissions on the last-mile logistics by 40% until 2030 in comparison to 2017 levels. This includes the establishment of a narrow network of urban consolidation centres (UCC), from which parcels and other goods are delivered by cargo-bikes, and regulatory measures, which will incentivize logistics companies to use more sustainable modes of transport.

Green subgoals for the CEP sector (Courier, Express, Parcel) in Hamburg

The strategy for sustainable urban logistics also includes certain sub goals that have to be achieved in order to reach the ambitious greenhouse gas reduction targets for the CEP sector in Hamburg:

- at least 25% of the parcels delivered in Hamburg shall be delivered by alternative modes of transport like cargo-bikes by 2030.
- 30% of all B2C-deliveries shall be delivered to pick-up points instead of household deliveries.
- of the remaining CEP delivery vehicles in Hamburg, at least 95% are supposed to be emission free by 2030.

Green subgoals for mobility in Hamburg

Hamburg has set itself ecological, economic and social/health-related action targets with dedicated indicators in the field of mobility in Hamburg. Within the framework of the ecological action targets, for example the inner-city commercial traffic is to be optimised. The reduction of traffic-related emissions of climate-damaging greenhouse gases, the limitation of the additional use of traffic areas or the promotion of vehicles with low-emission and emission-free drives are among the ecological action targets.
The social and health-related action targets include the reduction of traffic-related air pollutants and noise pollution and the increase of traffic safety (Bürgerschaft der Freien und Hansestadt Hamburg 2017).
Linked to theses targeted actions, Low Emission Zones have been created on the Max-Brauer-Allee between Julius-Leber-Straße and Holstenstraße (only diesel cars that meet the Euro 6 are allowed to

circulate) and on Stresemannstraße between Kaltenkircher Platz und Neuer Pferdemarkt (only diesel lorries that meet the Euro 6 standard are allowed to circulate).

Focus on development of cargo-bike solutions in the City of Hamburg
According to the Alliance of bicycles and pedestrians of 2022, the cycling infrastructure should enable an increased use of cargo-bikes through sufficient dimensioning both in urban areas and in the periphery. The aim is to design urban-compatible freight and delivery traffic through new transport and logistics structures. Cargo-bikes should establish themselves as a fast and economical alternative or supplement to motor vehicles through a barrier-free and well-developed infrastructure for stationary and flowing bicycle traffic over short and medium distances and become a relevant means of transport for last-mile delivery processes and logistics processes (Hamburg 2022).

Local stakeholders

The overall local stakeholders that were analysed in this Living Lab are either individuals, a group of people or companies that are indirectly or directly affected by the actions of the Hamburg Living Lab. The local stakeholders can consist of the end consumers, local economic actors, such as supermarkets and industries, transport and logistics operators such as DPDHL, and various associations and organizations such as NGOs like the Naturschutzbund Deutschland (NaBu) and environmental groups. Additionally, local governmental authorities such as the Ministry of Economy and Innovation (BWI) or the Ministry for Transportation and Mobility Transition (BVM) and inhabitants of the community.
Out of the overall local stakeholders in this Living Lab the most important ones were identified as the Deutsche Post DHL (DPDHL) as an important logistics operator in the City of Hamburg, the company OHB Ghent that manufactures the use case vessel, the Logistics-Initiative Hamburg that has a wide network of logistic partners in Hamburg, authorities, and government entities like the BWI and the district of Hamburg Mitte that will provide necessary information about statutory provisions but also research institutes like the Hamburg University of Technology (TUHH) and the Fraunhofer CML that provide crucial information and details about the market, and the infrastructure.

For a perfect collaboration, the main stakeholders should be informed about the rough project process and should come together and discuss the current state of the project regularly - the goal is to reach a consensus for further procedures.

The current status of delivery services in Hamburg is indicated in the stakeholder mapping visualisation (Figure 72), where Logistic Service Providers (LSP) and city actors are having to rethink their offers and methods. The LSP need to adjust and adapt to changes in the city, due to changes in mobility and access – it's these aspects that set the basis for the upcoming use cases, looking at alternative modes of delivery and pick-up services. Figure 72 was developed based on the initial stakeholder mapping and subsequent rating exercise done during the project KOM and following months, combined with the knowledge acquired during the technical visit. In this visual the centre indicates the core of the services – meaning the most direct/high impact stakeholders in the centre and the further out you reach, the more indirect stakeholders are listed.

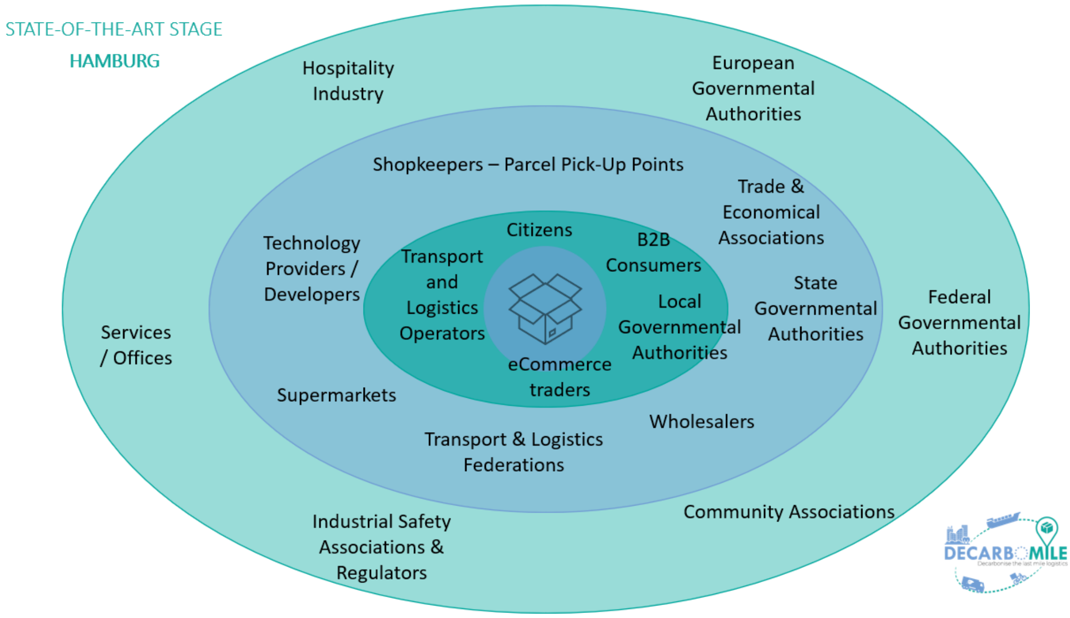


Figure 71: Mapping of local stakeholders in Hamburg Living Lab current scenario (source: CBS)

Focus on workshop with local stakeholders

A first workshop with stakeholders has been held on the 20th February 2023 with 18 attendees representing 7 groups :

- Fraunhofer CML: ran the WaCaBa study that is used as a basis for the use case
- Quartiersmanagement City Süd: potential customer
- BUKEA (Ministry of Environment, Climate, Energy and Farming): Responsible for water regulations, ecological aspects of water, water and shipping matters of the Alster Lake
- Otto Wulff BID GmBH: represents shop owners and local businesspeople in Hamburg Mitte
- HPA (Hamburg Port Authority) is a public institution responsible for many waterways in Hamburg around the harbour
- Gustav Seeland GmbH: potential transhipment site in Billbrook
- DP DHL: freight operator of the pilot

The next steps identified are as follows:

- Engage more public in the next workshop(s), for example water regulations
- Advertise solution and showcase results
- Identify two alternative routes in detail and exchange with stakeholders
- Check responsibilities within the team

Existing IT solutions

In general, stakeholders of the Hamburg Living Lab use the Microsoft Office packages including the Microsoft SharePoint to share information to partners within the DECARBOMILE project. While doing so the stakeholders do not comply with any information standard (ex. for metadata: DCAT-AP or for content: FIWARE, GS1).

The data generated in this Living Lab within DECARBOMILE can be used for follow-up projects that are dependent on the data generated through this project. However, no additional data or specific tools are required to collect this information.

Tools and data of the City of Hamburg

The City of Hamburg has a LORAWAN architecture (LOng RAnge Wide Area Network) for a wireless network / IoT network which is used in several city-wide projects like SmaLa (Smarte Ladeinfrastruktur) for smart parking and smart charging infrastructures within the City of Hamburg.

The City of Hamburg supports and maintains an **open data hub to gain further information about traffic behaviour within the City of Hamburg:** Verkehrsportal (geoportal-hamburg.de) and the catalogue for meta data MetaVer. The data can be used in a technical and economical consent4 without any additional approval from the authorities of Hamburg.
One representative of the Urban data hub of Hamburg made a presentation of this open data hub during the technical visit (10th January 2023). They manifested an interest to share useful data and the possibility to store data that could be collected by the vessel.
A warning point has been raised with DECARBOMILE's IT partners (TMTX and Capillar) to contact agencies of Hamburg in order to know which tools can be used to collect air pollution data by sensor captor.

DP DHL tools and data
On the other hand, private companies like DP DHL use several other tools to generate, analyse and use data for their daily business. The DP DHL does use ISBT (internal delivery management system) to control the delivery management to delivery hubs, parcel centres, and letter centres. For the planning of delivery tours of packages and letters DP DHL uses IBIS and several other applications such as "GO!". The control of shipment quantities happens with ISBZ and the software of the hand scanner of the delivery workers runs on the system Hasci. DP DHL uses the iSTM portal for the use of dashboards and analyses for the integrated control model Post & Parcel. The STELN portal informs mail centres and depots about transports, quantities and supports warehouse control.

SUMMARY OF THE SITUATION AND POTENTIAL USE CASES

Synthesis and knowledge

The project partners of the Living Lab Hamburg are covering already a wide knowledge about local urban logistics and offer also administrative power in the City of Hamburg. This will enable the carrying out of the project on public spaces, receiving official permits and supporting the (public) acceptance of the project. Several urban logistics projects have been or are being conducted in the city already.

Within the dialogue process with CEP (courier/express/parcel) service providers in preparation of the DECARBOMILE project, several advantages of the project's approach were identified. As Hamburg is a very dense urban area, central areas for logistical use are scarce and a shift of transport flows from road networks to waterways can mitigate this land use conflict. The relocation of transports can furthermore reduce both local emissions of air pollutants and greenhouse gas emissions, when conventional diesel trucks are substituted with a barge with an electric drive.

Focussing on the Living Lab's aim of using the city's waterways for transport, further main strengths are the city-wide interest in finding innovative logistic solutions due to land use conflicts and traffic. Thus, using the water as space for micro-depots is of big interest as well as the will to support local low-emission or emission-free deliveries.

Nevertheless, the special features of this mode of transport evoke some concerns such as tidal dependence, transport time and costs of feeder transports, conditions of riverbanks and canals and access to waterways and environmental protection.[2] Indeed, data regarding waterways has already been collected in the WaCaBa study, but further investigation must be conducted and precise sets of data (files in GIS or CSV format, not only final global maps) need to be shared in order to validate the vessel route(s).

Potential use cases

The Living Lab focuses on using the waterways and canals from Billbrook area to the city centre of Hamburg with only one operator in the pilot phase, DP DHL.
Moreover, in the pilot phase, only one route for the vessel with 2 landing locations – starting point in Billbrook and ending point in Alsterfleet- are planned. Another mobile landing point in this route could potentially be in CitySüd.

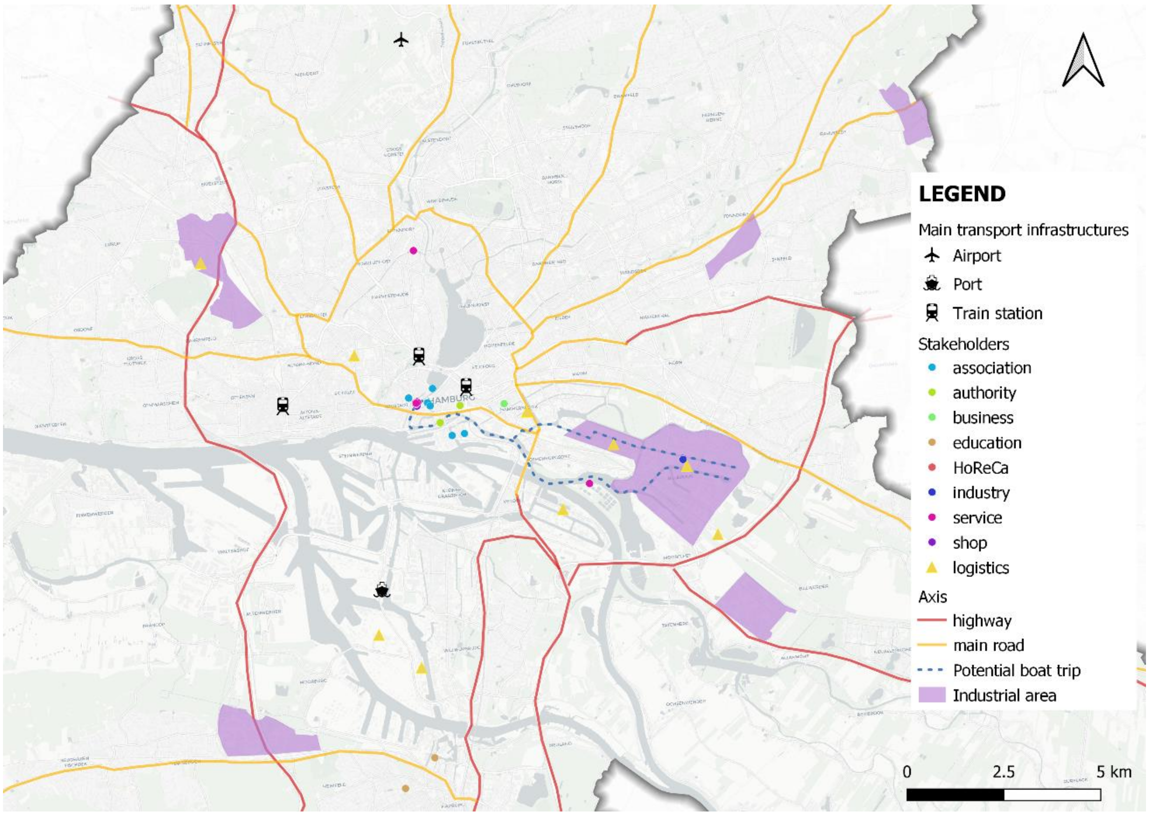


Figure 72: Map of Hamburg (source: IT)

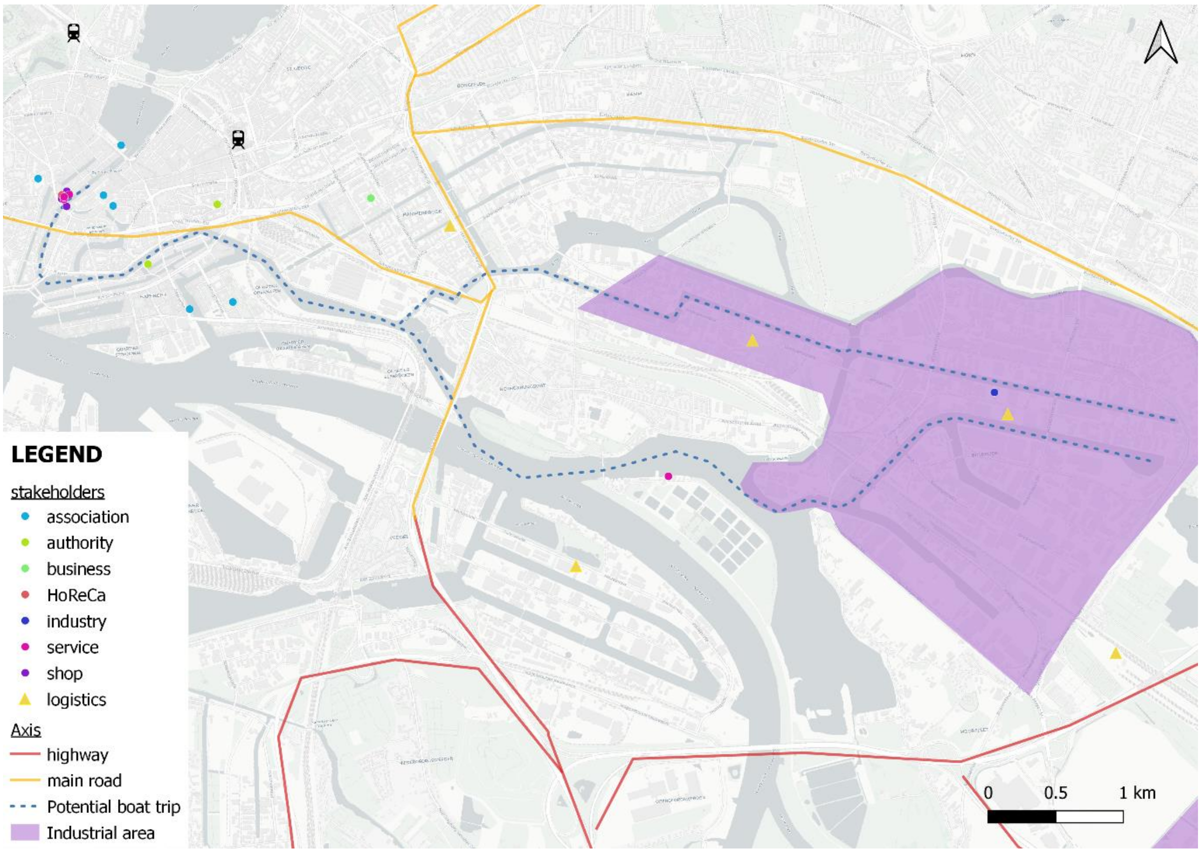


Figure 73: Zoom on the vessel trip (source: IT)

Focus on landing locations and route of the vessel

The loading and starting point of the vessel shall be close to DECARBOMILE's partner DP DHL 's delivery base in Billbrook. A possible unloading point and location for a floating mobile micro-hub could be an identified landing stage at "Am Alsterfleet", close to "Graskellerbrücke" (see pictures). This route was proposed in the WaCaBa study, and will need to be further analysed during the project.

This analysis will have to include among others the following topics:

- Navigation on the waterways:
    - which is the most suitable route and landing site, considering tide, locks, waves, etc.
    - Permissions for navigation and landing
- Infrastructure at loading and unloading point, handling of delivery units

In general, direct and indirect stakeholders, especially the City Management, need to be addressed to generate acceptance of the project.

Figure 74: Possible waterway route from Billbrook area (DP DHL delivery base) to city centre (source: City of Hamburg)

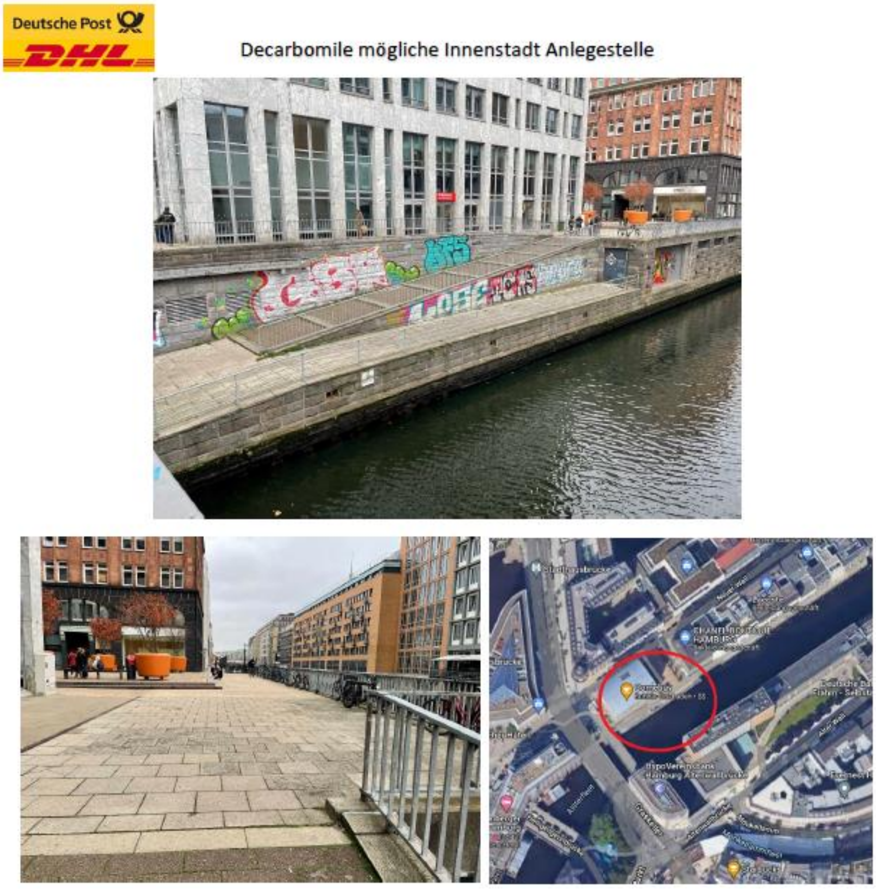


Figure 75: Possible landing location for vessel unloading and micro-hub in the city centre (Alsterfleet) (source: City of Hamburg)

As shown on the pictures, the proposed landing site does not provide the infrastructure for unloading. Thus, possible challenges might be to set up this infrastructure for (un)loading, as well as for (un)loading the vessel at the starting point in Billbrook. The construction of pontoons or the usage of cranes could be an option.

After the technical visit, the option of using a hydraulic elevator is also studied. In this possible landing location, cargo-bikes will have to leave the docking area through an inclined lane. Nowadays, this lane has steps and is used by pedestrians going in or out of a metro station. Moreover, the storage of cargo-bikes in this location must be studied further.

For the initial starting point of the vessel in Billbrook, a location near the distribution centre of DP DHL had been identified. But after further investigation of water's depth, this location was not considered suitable, and another starting point on the other side of the road is currently being investigated. Discussions and negotiations are taking place with Gustav Seeland GmbH, a heavy and special transports company that possesses the land across the road and cranes that could be made available for transhipment in the starting point in Billbrook.

Focus on the vessel

The vessel "AVATAR" that shall be used, will be provided by the DECARBOMILE partner OHB from Ghent. This electric barge which is currently under construction is planned to be piloted not only in the Living Lab Hamburg but also in Ghent (satellite city).

Figure 76: AVATAR vessel being equipped in Ghent, BE, current status of construction (as of July 2022) (source: LIHH)

Its predecessor vessel the "Green Wave" is already in the Ghent waters for pilots and tests.

Figure 77: Pictures of the boat (source: LIHH)

Focus on cargo-bikes and storage

Options to save (short-term) storage especially at the unloading point must be analysed. The integration and usage of DP DHL packing-station (smart lockers) as micro-hub will be evaluated by the LL as well.

Moreover, at the unloading point, to be in accordance with social and labour law, some dedicated spaces for drivers on cargo-bikes must be planned too.

Focusing on the final last-mile delivery to the end-customer, after unloading the vessel, the Living Lab considers using six cargo-bikes. The project partners will analyse the most suitable options out of the portfolio of DP DHL or contemplate further options. For now, DP DHL plans to use the same model of cargo bike from Rytle as in Berlin.

Finally, a smooth, robust delivery process needs to be set up to allow quality and on-time transport and delivery in the most economical way possible.

To illustrate this use case, here are two visuals for a better understanding.

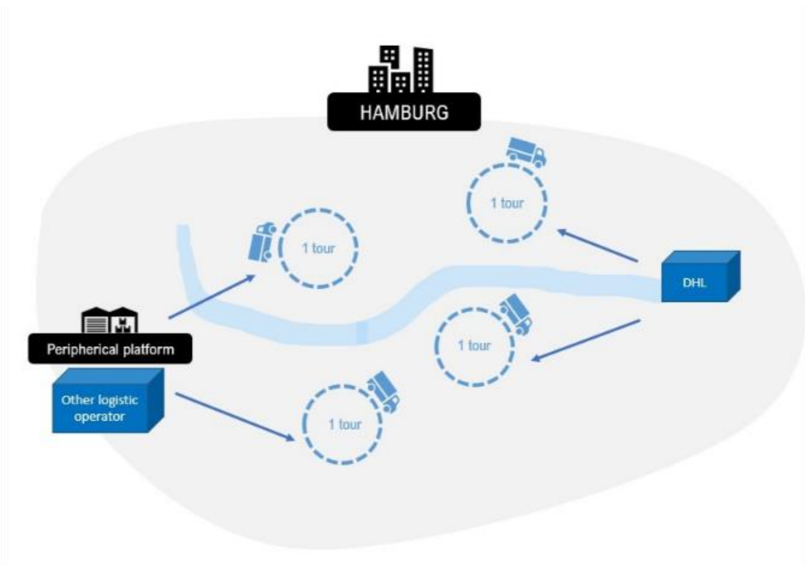


Figure 78: Reference situation for Hamburg use case (source: IT)

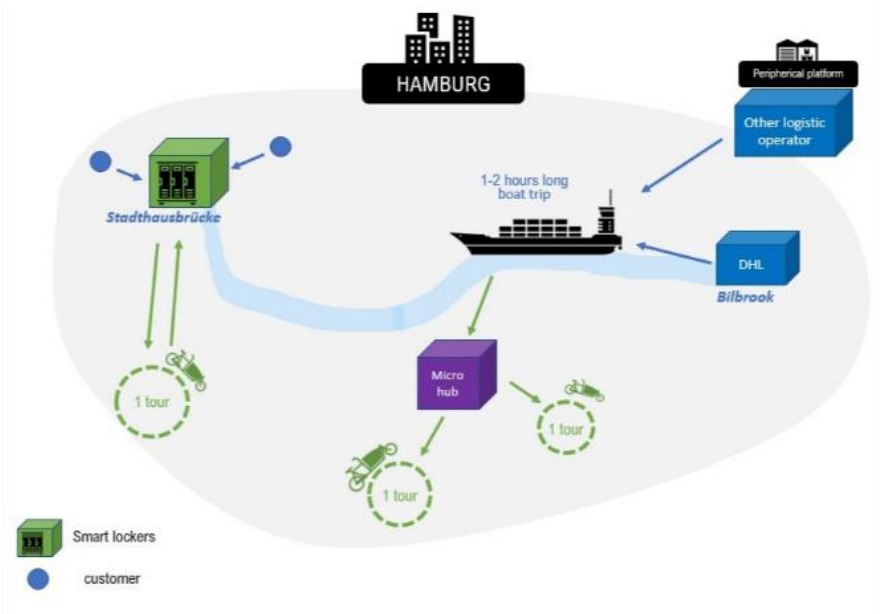


Figure 79: Pilot situation for the Hamburg use case (source: IT)

Focus on the reverse logistics
It may be considered for this use case to study how the return trip of the boat can be optimised. Therefore, reverse logistics might be interesting. In Nantes, a call for expression of interest was able to put forward a reverse logistics project which consisted of delivering products for vending machines and retrieve waste at the same time. Maybe this can inspire the same type of logistics in Hamburg.

Key Performance Indicators

In the case of Hamburg, there isn't a freight operator using the waterways of Hamburg, so most of KPIs are set to 0 at this moment. After the pilot phase, KPIs will be refined, specified and valuated. Other specific KPIs to Hamburg can be:

- Number of freight units collected in smart lockers
- Number of truck kilometres substituted by the barge
- Handling time to load/unload at the warehouse

Relevant use cases to build upon

For Hamburg, as a Hanseatic city with one of the most important ports in Europe, and a wide canal system throughout the city, especially in the city centre, the usage of these waterways for city logistics is an important field of study for several years now.
The Fraunhofer Centre for Maritime Logistics (CML) and Fraunhofer Institute for Material Flow and Logistics (IML) conducted the feasibility study **"Water Cargo Barge" (WaCaBa)**, commissioned by the Ministry of Economy and Innovation (BWI), in 2021. This study describes the canal infrastructure of the city and names responsible authorities. It serves as basis for further waterborne transport-related projects, such as AVATAR and DECARBOMILE.

Furthermore, one of DECARBOMILE's predecessor projects is the **AVATAR project**. This Interreg NSR project aims to test innovative and sustainable urban freight transport concepts with autonomous and emission-free vessels in order to achieve a modal shift from road to water (e.g. fleets, canals, waterways) in an urban context on the last-mile.

Cargo-bikes and micro depots are already used in small scales, notably through the projects **MySmartLife, MOVE21** and **RealLabHamburg** project.

Additionally, the following projects will be of use for the Living Lab:

- **DHL Solarship Berlin**: loaded with up to 250 parcels in four to five parcel wagons brought by a truck for delivery in 100 minutes, combined with electric cargo-bikes for the last-mile delivery.
- **AUTOBarge**: build-up a highly skilled workforce for the autonomous inland waterway transport sector and address the many other socio-technical, logistic, economic, and regulatory conditions that need to be met for the successful and future-proof implementation of autonomous vessels in the inland-waterway transport sector.
- **Medifly**: unmanned aerial vehicles (UAS) used in urban airspace inside and outside the control zone of a commercial airport, to transport quickly urgent medical samples.
- **SPICE**: assist public procurers to use smart procurement to facilitate fast adoption of innovative sustainable transport and mobility solutions.
- **Snacks Schwerin - Parcel transport by tram**: the delivery of the consignments to the depot, where the parcels are loaded onto the tram, is carried out in a CO2-neutral manner by eco-

powered StreetScooter (E-Vans). The parcel tram then stops at city stops with DHL packing stations.

- **HANSEBLOC**: IT-system and application based on the blockchain technology to support small and medium-sized enterprises in the usage of this technology.
- **Tabula-LOG**: knowledge of approval procedure and implementation for automated transport robots in a combined passenger and freight transport.
- **Wirtschaft am Strom (WaS)**: use of electric vehicles and light commercial vehicles in commercial transport (primarily carriage of persons in commercial context and mixed forms).
- **UPS Hamburg Fleximodal**: centre storage containers functioned as micro-hub depots enabling a last-mile delivery by (electric) cargo-bike or handcart; analyses the effects on traffic, environment, urban space and acceptance of the delivery model and gives recommendations.

1.5 Satellite Cities

In DECARBOMILE, four satellite cities are involved to ensure the replicability potential of the solutions developed: **Getafe** (Spain), **Ghent** (Belgium), **Sarajevo** (Bosnia Herzegovina), and **Tallinn** (Estonia). They will investigate specific aspects of the urban consolidation logistics framework and associated governance models, some of them will go as far as pretesting some innovations and they will serve as proofs of concepts providing small scale replicability in the framework of the project.

Getafe

Getafe is a municipality with more than 185 000 inhabitants, located in the southern part of the Community of Madrid, and one of the most industrialised city in the metropolitan area of Madrid, to which it is connected thanks to a train and subway network. Taking advantage of its geostrategic position and reinforced by its powerful and extensive network of infrastructures, it allows the companies located there to have a global connection with any part of the country and the world. Getafe has 14 000 000 m² of industrial land (over 3 000 stores), representing one of the most important engines of economic growth and generator of job creation policies in the country. It is the strategy centre of Airbus, and several logistic companies have operation centres there (SEUR, AMAZON, DHL, etc.).

The last-mile logistics is mostly implemented through motorized vehicles and only SEUR (logistics provider) is using cargo-bikes for delivery. A local cooperative has also recently been created (Bike Xpress). Getafe is currently developing a 125-hectare **low-emission zone** whose legal framework will support last-mile freight delivery and zero emission logistics. The involvement of the main logistic companies in the city and the involvement of GISA (Getafe's Local Development Agency) is meant to facilitate the synergies.

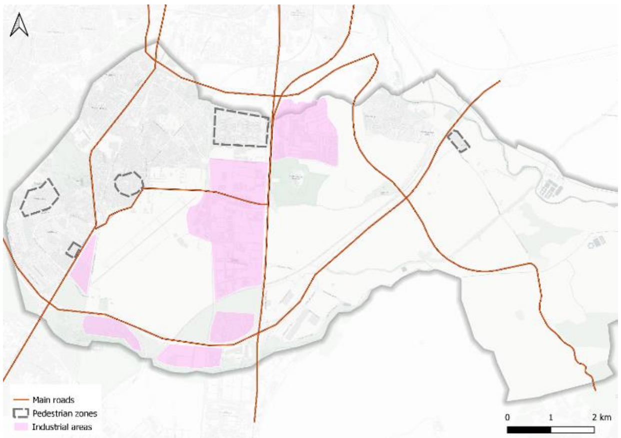


Figure 80: Map of Getafe (source: IT)

In addition, the creation of a **pedestrian priority** and **restricted traffic zones** in the city centre is underway through the installation of bollards that will physically prevent general access for 4-wheeled vehicles and restrict the hours of goods delivery by 4-wheeled vehicles.

As goods deliveries account for about 35% of the overall traffic, the aim of both measures will be to reduce car traffic and support the transition to cycling and cycle-logistics. Most of the small businesses, large supermarkets, bars and restaurants in the municipality are concentrated in a radius of approximately one kilometre from the city centre of Getafe, generating high traffic, pollution, and commercial flows.

With DECARBOMILE, the city will introduce cycle-logistics as an alternative to motorised goods delivery, while pre-testing smart lockers developed by INT to assess the best approaches for their integration with cycle-logistics. With support from the local development agency of the Getafe City Council (GISA) and building on relations with the Carlos III University and other key actors identified (economic actors, transport and logistic operators, and related associations), Getafe will develop an innovative and sustainable last-mile distribution model. To achieve this goal, the City Council will have to adapt existing regulations, develop a low-emission zone, and encourage the use of bicycles and non-polluting means of transport to businesses as well as to the general public (run awareness raising campaigns, support jobs creation related to cycle-logistics, etc). In parallel, a logistics hub will be implemented, consisting of a storage space, a storage space for bicycles for logistic use, and another space for private users. It will serve as an intelligent loading and unloading area for goods to be distributed outside of the established timetable (from 8AM to 10AM during weekdays). It will have direct access from the main access roads to Getafe via an urban road that crosses the city. Six micro-hubs will also be installed at different points of the central ring, which delimit the area of action of the DECARBOMILE project in Getafe.

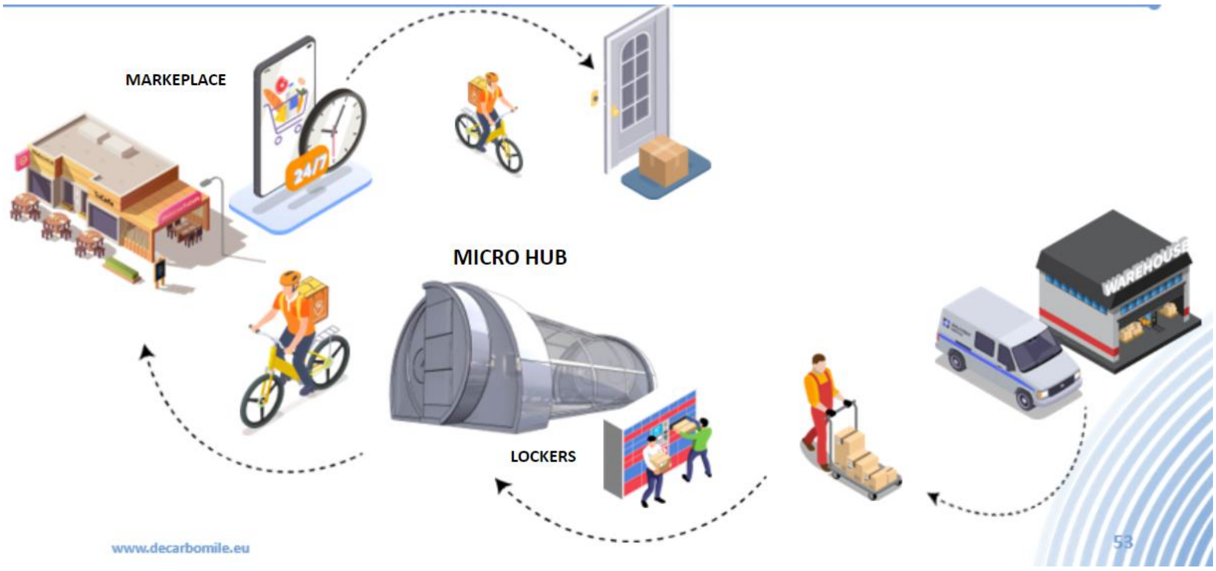


Figure 81: Local hub and market to be developed by Getafe in DECARBOMILE (source: Ghent)

Ghent

Ghent is a city of 250 000 inhabitants and 75 000 students, with an old medieval city centre and a fine mazed waterway system. The main economic activities in the City of Ghent are industrial activities (mostly in the harbour), as well as offices, retail and agriculture. Embedded in the North Sea Port, a central hub in Europe, the City of Ghent is ambitious in terms of the quality of life in its city centre. While there are several restrictions for entering the city area with heavy duty polluting vehicles, there are no alternatives today for heavy transport of goods as e.g., building materials or waste. Thus, trucks and vans remain the main delivery methods for the retailers. Some of them are starting to shift to e-bikes, mostly for food deliveries. In 2025, it is expected that all polluting transport modes will be banned from Ghent. Below is a list of relevant existing regulations and policies:

- The **Climate Action Plan of the Province of East Flanders** strives to a climate healthy Province in 2040 (net zero CO2 emissions in 2040 and climate adaptation). Among the 5 spearheads, one is called “Towards a smart mobility”, which includes the challenge “Creation of smart logistics and networks”.
- **Sustainable Urban Mobility Plans (SUMPs)** are a cornerstone of EU urban mobility. Ghent has developed a SUMP with a mobility plan, a traffic circulation plan and a vehicle parking plan for the circulation of vehicles in the old city centre.
- Since January 1, 2020, a **low-emission zone** prevents most polluting cars (EURO 4 and lower) to enter the zone within the city ring road (R40).

Figure 82: Red area constitutes the zero-emission zone in the city of Ghent (source: Ghent)

- A **Limited Traffic Zone** that divides the inner city and the historic centre into 5 sectors is in place. In some of these sectors (the historic centre and others), it is car-free. There are also traffic-free areas where bicycles are also forbidden. An exception has been made for deliveries for which a permit is necessary, and it can only be done in a specific time slot (depending on the sector).

During the DECARBOMILE project, Ghent will test and improve a zero-emission urban Electric Barge, that will also be used in Hamburg (powered with solar electricity), coupled with zero emission small vehicles, such as cargo-bikes, to operate as a mobile hub for urban logistics for various flows of goods, to reduce the trucks and CO2 and Nox emissions in the city. The urban Electric Barge was already prototyped and pre-tested in the scope of the EU project AVATAR. Additional use cases for Ghent include the test case of sensors developed by NGS, containers developed by FLEX, DHL lockers, and application scenarios developed by ITA.

The current method of transport is a multimodal model in which goods are transported from the producer to the warehouse with their own trucks or with trucks from others. In certain cases (e.g., with Knauf products) groupage loads are ordered from the producer and transported by an inland vessel to a city hub. The goods are picked up at the hub by the producer's own truck and delivered to the warehouses of the respective partners. Afterwards, the goods are transported from the warehouse to the end customer with their own truck. By using the urban boat in the logistics chain, it becomes a synchromodal model in which different types of transport modes are used in the logistics flow: trucks, urban boat, e-cargo-bikes.

Test cases have already been carried out in Ghent, with a view to testing the capacities of the urban vessel, the infrastructure of the city, the connection of the waterways, the placement of goods in pre- and post-logistics chains, the mapping of the loading and unloading areas and an overview of the last-mile problems. Key issues to keep in mind for successful implementation of this use case are timely involvement of the boat in the planning a skipper, organizing the unloading infrastructure, applying for a permit to use the unloading quay, coordinating with the water authority whether a private concession has been granted at the place of unloading, organizing the unloading of the boat and the last-mile deliveries. In the experience of OHB & the triple Helix consortium, the collaboration of city, water authorities & entreprises is key for the project in order to succeed.

Sarajevo

The Capital city of Bosnia & Herzegovina, Sarajevo has around 270 000 inhabitants, with a surface of 142km². Economic activities in the city are linked to the delivery of goods to shops, largely related to food production services, hotels and smaller craft shops. Currently in Sarajevo, especially in the city centre, logistics and delivery of goods take place with conventional heavy vehicles or vans that travel in the pedestrian zone. Very few Electric Vehicles (EVs) are used, leading to pollution, noise pollution and congestion. Green modes of transport should be introduced in the near future, which will change the way goods are delivered.

As a capital city that has not much developed yet its SUMP, Sarajevo is a perfect playground for the following and the replication of the results of DECARBOMILE. Sarajevo will aim to establish a greener logistics system for the delivery of goods via decarbonised vehicles, in order to reach a higher level of traffic safety in the city. It will study the potential for an Urban Consolidation Centre around the pedestrian zone supporting the introduction of green vehicles, such as cargo-bikes.

In the pedestrian area (0.47 km²) (marked in black dots in Figure 83), there are around 800 stores, and most of the urban logistic flows happen in the morning, with a peak time around 8:00 AM. Some of the entrances to the pedestrian zone can serve as micro pick-up hubs in order to consolidate the goods and to reduce truck traffic in the area.

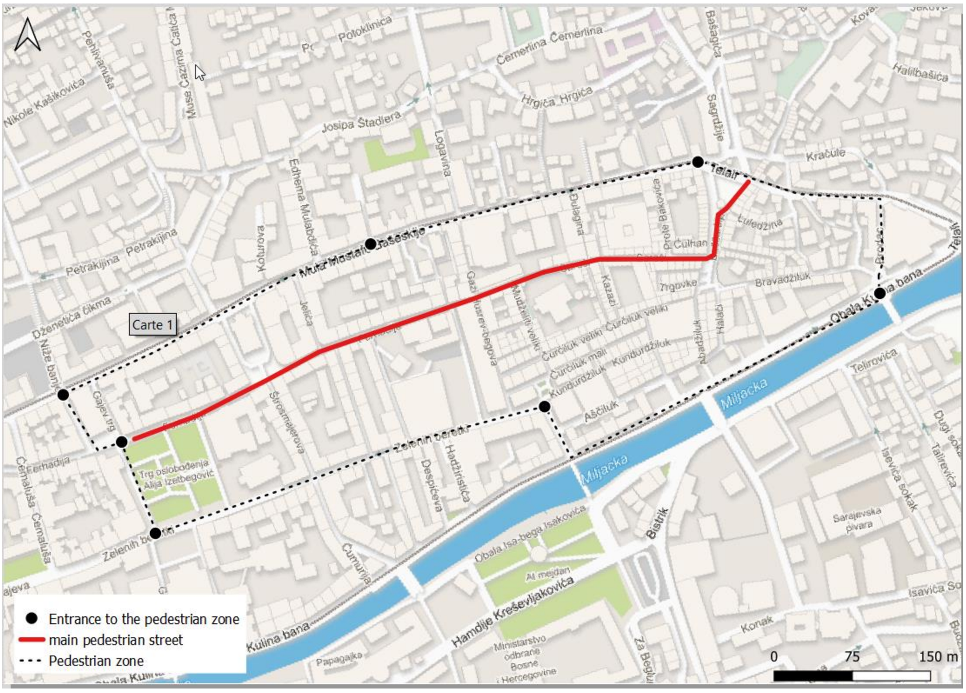


Figure 83: Pedestrian zone of Sarajevo (source: IT)

Tallinn

Tallinn Old Town has preserved its structure of medieval and Hanseatic origin, representing an exceptionally intact 13th century city plan, bordered by the Walls of Tallinn. Since 1997, the area has been registered in the UNESCO World Heritage List. Its area is 1.13 km² and there is a buffer zone of 2 253 ha. Most of the streets of the Old Town are covered with cobblestones. There are 4 939 residents living in the Old Town as of 2022, and over 700 000 tourists annually.

The main economic sectors in Tallinn Old Town are tourism related industries such as hotels, restaurants, pubs, shops etc. There is an average of four to five cafes/restaurants/shops per 100 meters in that area. While detailed information on the number and type of cargo vans serving Tallinn Old Town is currently not available, most deliveries are made by minibuses, which often create congestion due to their large number. Most of the average daily traffic in the Old Town occurs in the morning, when the pedestrian area is also open for service vehicles.

In 2017, a survey on freight deliveries was carried out among 59 businesses in the Old Town, that identified the main suppliers and potential problems. For shops, in-house transport is often used, while restaurant businesses mainly use suppliers' delivery (the largest delivery companies being A Le Coq, Saku and Prike), which in turn increases the traffic load, as each destination has to be reached by several vehicles. Cargo-bikes (produced by Estonian company VOK) are used only by a few companies; e.g. Tuul for e-scooter servicing, Wolt for food and grocery deliveries and Omniva to deliver shipments in high-density urban areas. Since November 2022, a cooperation agreement signed by the City of Tallinn and Clevon (an autonomous delivery technology company) allows unmanned robotic couriers to provide parcel delivery services (for DHL) in the Old Town outside the service hours. At the moment, some of the streets in the Old Town are restricted to cargo-bikes due to an increased velotaxi service for tourists.

In order to reduce traffic congestion, improve the living environment and the safety of pedestrians, a number of measures have been introduced to restrict the movement of motor vehicles in Tallinn Old Town**.**

- While there are currently no **Low Emission Zones** or **Congestion Charge Zones** in Tallinn, an area in the Old Town is a **traffic restricted area**, where motorized transport is banned for most cases. These are so called **pedestrian zones**, where motorized transport is allowed only on 3 occasions: 1) freight transport is only allowed during the morning hours (6 AM-10 AM); 2) residents can access their parking spots; and 3) when a permit is applied from the Transport Department for one-time entry. In practice, however, the time restriction linked to freight delivery is often not respected, as deliveries between 6 AM and 10 AM can be difficult and businesses are not prepared to start their working day earlier.

- In the **Logistic Plan Tallinn 2035**, Tallinn Municipality shaped its strong ambition to decarbonise its city centre. The city will investigate the potential of cargo-bikes as a way to authorize the delivery of goods in the Old Town area after 10 AM, with a limited impact on pollution and occupation/footprint of the area.
- In the upcoming **Sustainable Urban Mobility Plan (SUMP)** for Tallinn (will be adopted in 2023), the following elements are included:
  - reducing the speed limit of almost 80 streets in residential areas (from 50km/h to 30km/h),
  - 50% of the intra-city transportation of goods with emission-free vehicles by 2030,
  - importance of creating conditions for reducing emissions and traffic,
  - developing and implementing the concept of zero emission zones, including piloting a zero-emission policy for freight transport.

Figure 84: Tallinn city centre, outside and during delivery hours (source: Tallinn)

During the DECARBOMILE project, Tallinn will investigate the potential of cargo-bikes, automated vehicles, and robot deliveries together with their related regulatory frameworks, as a way to authorize the delivery of goods in the Old Town area after 10 AM, with a limited impact on pollution and occupation/footprint of the area. Relevant local actors to engage with that have been identified including existing networks and associations of economic, transport and logistics operators, the Estonian Chamber of Commerce and Industry, the Old Town Society that joins the Old Town residents and represents the interests of the residents, etc.

Synergies with the Living Labs

As the satellite cities will ensure the update and small-scale replicability of solutions and frameworks developed in the Living Labs, we have mapped below the potential synergies between the project cities, which will provide a basis for lessons learned and best practice exchanges.

Table 2: Synergies between Laving Labs and Satellite cities

	HAMBURG	ISTANBUL	LOGRONO	NANTES
GETAFE	Implementation of a Low Emission Zone Use of smart lockers	Implementation of a Low Emission Zone Use of smart lockers	Use of smart lockers and sensor trackers Marketplace	Future implementation of a Low Emission Zone Use of sensors to track and trace
GHENT	Use of the canal system to operate an electric barge, and optimised cargo-bikes			
SARAJEVO	Potential for an electric barge	Develop its own SUMP		
TALLINN	Implementation of a Low Emission Zone	Old town specificities (re. cultural heritage regulations, etc.)	Micro hub/consolidation centre implementation	Micro hub implementation Historical centre specificities (regulations, tourist area, cobblestone, etc.)

2. STATE OF THE ART AND BENCHMARKS

2.1 PROJECTS BENCHMARK

In order to collect best practices and key lessons learnt from relevant past or ongoing projects in Europe, DECARBOMILE partners provided detailed information on around 60 projects, which were then analysed, based on the five pillars of the project (collaboration, space management, added-value services, regulation, digitalisation). The analysis identified previous projects' failures and successes on technical, collaborative and business model aspects, including urban logistic consolidation models, multimodal experiences, cargo-bikes and smart lockers.

Figure 85: Map of the project benchmark locations (source: IT)

In total, 9 countries were covered by 49 projects and 12 additional projects were European-wide (with more than three different European countries involved). The following section seeks to highlight key elements in terms of use cases, methodologies and tools.

2.1.1 USE CASES

Among the analysed projects, the following use cases have been identified as relevant for the ones we are aiming to develop within DECARBOMILE:

- **Alternative mobility and deliveries solutions**
  - ADABIS: use of 100% electric bikes for package delivery of MIGROS grocery products given with slot orders or on phone, at Prince Island in Istanbul.
  - AVATAR: use of an electric vessel with a 25t loading capacity (combined heat power solution for green hydrogen energy supply) for urban freight distribution of building materials, parcels and retail supplies via inland waterways.
  - CARRETA: autonomous delivery robots (parcels from Amazon and fresh products).
  - D-Louve: innovative droids with "follow-me" technology, to provide both mobility solutions for people with reduced mobility and logistics solutions for craftsmen heavy materials.
  - FLUDIS: boat delivery at 4 checkpoints in Paris with crane to (un)load parcels and cargo-bikes for the last-mile deliveries.
  - Inland Waterway Transport Solutions: piloting waterway modal shift concepts including innovative barge-, waterway-, transhipment-, (un)loading-, freight flow mapping-, modal shift decision making solutions.
  - River'Tri: a specially equipped barge and a pusher as an ephemeral waste collection centre (up to 3000 T / year), which returns to its home port every night.
  - SOLAR BOAT: can be loaded with up to 250 DHL parcels and cargo-bikes for the last-mile deliveries within 100 minutes.

- **Consolidating hubs /smartlockers**
  - SOGARIS: removable micro hubs installed on parking places, located near the final consumer (2-3 km), meant to be mounted and dismantled in less than 24 hours, and optimised for delivery by cargo-bikes.
  - ELCIDIS: a 700 m² hub (the agglomeration rents a building to the SNCF and provides the space through a Public Service Delegation to a classic mobility operator for logistics services) in periphery of La Rochelle to link key operators from surrounding cities.
  - Ephemeral Hive: use of ephemeral public or private space (parking spaces, marketplaces, bus depot) as a consolidation and a breaking point of loads between different types of vehicles for urban deliveries activities.
  - KARGOPARK: a cargo operating company operates cargo vending machines at Migros retail locations for customers to pick-up their packages while coming for shopping.
  - WACABA (Water-Cargo-Barge): detail study on the navigability of urban waterways in Hamburg, for parcel logistics from a peripheral parcel consolidation facility to a (potentially swimming) micro hub in the city centre.
  - UPS HAM: swap bodies used as micro consolidating centres, loaded with parcels in the outskirt of the city and then transported and placed in the city centre.

- **Innovative IT tools**
  - GeoBT: a geo-localised traceable solution (system composed of sensors and software associated) to ensure real-time material and equipment management in hospitals.
  - HANSEBLOC: blockchain IT-solutions for transport/supply chain ought to function in an open-access & open infrastructure way (still lacking a viable business case and governance model, but technical feasibility has been proven).
  - ST4W: digital solutions for transport providing synchronization, automatic and real-time update of logistics unit status and an automated alert in case of delay or loading the wrong logistics unit.
  - IPRODUCE: novel social manufacturing hub to enable multi-stakeholder interactions and collaborations for cocreation ventures, establishment of local Collaborative Manufacturing Demonstration Facilities.
  - LDK: experimental deployment of a complete automation solution for the logistics chain, using interconnected sustainable transport systems.

- **Methodologies**
    - ACACIAS: new methodologies to evaluate the most environmentally friendly public policies related to mobility.
    - CityChangerCargobike: innovative tools for take-up and scale-up of cargo-bikes solutions and best practices from forerunner to follower cities.
    - CITIES4PEOPLE: mobility labs in cities to engage and empower local citizens in the innovation supply chain of their local mobility ecosystems.
    - ENTRANCE: development of a free online European Matchmaking hub (link) and complementary off-line services to mobilise financial resources and accelerate scale up of sustainable transport solutions, reducing CO2 emissions and pollutants.
    - LEAD: a simulation-based impact assessment environment and a Digital Twin Model, for evaluating alternative city logistics strategies and formulate a Roadmap towards PI-inspired zero emission city logistics.

2.1.2 Main Challenges Faced

Four main categories of challenges have been identified in this benchmark:

- **Situation-based challenges:** the first challenge are the existing limiting public regulations (on freight transports or other sectors) that can be a real obstacle to the development of an urban logistic project. Other challenges would be the lack of urban infrastructure or the topography (or geography) of the city where the projects are implemented.
- **Operational challenges:** in this category, the main challenge is the viability of the business model, once the subventions or grants come to an end. Other challenges identified are the lack of existing efficient tools or vehicles, the security of goods (if parcels are stolen or if transportation equipment is damaged), or the dependency on specific companies for business operations which can make the model quite fragile.
- **Social challenges:** the most important challenge in this category, surpassing any other challenge (all categories combined) is the stakeholders' engagement regardless of their category (end users, operators and logistic providers, authorities, etc.). Linked to this, is the challenge of the innovation or solution's acceptability, the communication and dissemination of its added value or the identification of common interest between stakeholders.
- **IT structures challenges:** main challenges identified here relate to connectivity or transferability of the solutions developed (integration of their IT tools into existing ones), as well as data management (collection, reliability, security).

2.1.3 Main Knowledge To Build Upon

Collaboration

As one of the main challenges identified, meaningful collaboration between stakeholders is key to ensure the wellbeing of a project. It is recommended to engage relevant stakeholders, final users, private and public partners, institutes, etc. from the very beginning of the project. In the benchmark, different methods of collaboration were mentioned.

Collaboration sometimes needs to be framed by a written document or a contract, such as a charter or an agreement (consortium agreement, partnership agreement, international program agreement, bilateral agreement, etc.). It is also possible to use an online hub (for example the matchmaking platform ENTRANCE) to ease the collaborative processes.

Collaboration is effective when a good diagnosis has been made beforehand to evaluate local needs and specificities and find the right stakeholders which should be engaged. For example, it came out from the benchmark that when public authorities try to implement an urban consolidation centre without proper analysis of the actors already involved in logistics and cycle-logistics locally, it is more likely that the model will not be sustainable. For massification of flows, it is necessary as well to have a good communication between logistic operators so they can evaluate precisely the volume that they have and that will need to be delivered. Here comes into play challenges related to data gathering and management.

Having specific contact "freight-persons" in the organisations can help with a good communication flow, to make the link between actors or even set up specific Committees. Having a thorough understanding of the way local stakeholders will be involved (formally and informally) is also very important. When it comes to interacting with local stakeholders, it is important to bear in mind that end consumers should be involved in the creation process, to help define, test and validate the use cases that will be implemented. When a public/private cooperation is necessary, a third neutral party can be useful, as good contact with public authorities and administration is key to success (to work on permits, regulations, overall impact and framework).

Value-added services, and business models

It is always complicated for innovative system to be economically viable from the beginning. While a way to develop the solution can be identifying potential public financial sources (regional schemes, national grants, research institutes, private industries, etc.), it is key to think about the afterlife of the project and its economic viability once the grant ends. Similarly, it is important to give a good thought about the legal structure of the project. In this project benchmark, for example, several projects are choosing a cooperative legal structure, which preserves neutrality and attracts all spectrum of customers. It is also important to have a solid business model first and value proposition before expanding to other cities and markets, and to phase out business and IT development through step-by-step detailed use cases.

Some good practices in terms of developing value-added services as part of the business model to complement last-mile freight distribution include extending delivery hours, offering home delivery for grocery companies, providing storage space with the possibility of on-demand deliveries of the stored goods, reverse logistics, etc.

Limits in the development of new logistics systems, however, can be that shops don't usually integrate logistics in their business plans, hence don't have budget for stockage or other services. Indeed, it has been identified that a proper binding legislative framework is necessary for the hub to be cost-effective and the business model to be viable.

Urban integration and space management

Installing consolidation centres necessitates to think about the location, the area needed, the facilities included (for example restrooms and electrical supply for drivers and courier), etc. When designing the hub, there must be a strong focus on creating a functional structure for the day-to-day operation. The pilot implementation needs to be at least two or three years to be properly implemented and tested.

More specifically, here are some specific points to focus on when designing the project:

- Evaluate the amount of electricity needed to recharge potential electric vehicles.
- Study where the vehicles will be parked, specific needs like electrical sockets, secure enclosed space, etc.
- Study how the creation of a new physical hub will affect the urban situation: how the generation of new logistic flows will affect the traffic already existing, the area of delivery for each new hub, etc.

For hubs that will receive Heavy Good Vehicle (HGV), it is easier to install the hub at the entrance of the city rather than putting it in the city centre and create access for those vehicles.

Having a good knowledge about the mobility network of the city and rely on the transport infrastructure already existing is a lesson learnt from the benchmark analysis.

Innovative ideas can use the tramway service or waterways to develop new systems. Mobile or removable hubs are another innovative way of saving money from buying land. The SOGARIS project and its removable hubs are taking advantage of the charter signed with the city of Paris to get a very low fee for places where they installed their hubs. For the UPS HAM project, swap bodies are placed on public sites.

Regulation

For projects with an online marketplace, it is necessary to look at the GDPR (General Data Protection Regulation).

For projects including mobiles hubs, the recurrent and long-term occupation of public space by a delivery vehicle requires a specific permit, also in some cities a monthly fee has to be paid.

For projects that includes food transportation, specific hygiene and public health regulations are at stakes such as the cleaning of transport boxes, the protection from the risk of contamination, the monitoring of the right temperature in the boxes, etc.

For projects that consider the use of waterways, it is important to have a good knowledge about which authority manages which waterway, as there are often several institutions responsible for different aspects. Several projects have shown that it can be difficult to implement river logistics, even though it is feasible.

For every project, a key element of success is support from public authorities, through the implementation of supporting regulations facilitating the implementation of innovative logistic projects (that is why a good communication with public authorities is crucial, as stated in the "collaboration" section).

Digital infrastructure

With digital infrastructure, possibilities are quite endless. In this benchmark, different categories of digital infrastructures have been identified.

For data collection and safe management: the GEOBT project developed a new sensors system and secured data collection for hospital use; data management through MIO for ADABIS MIGROS project.

Online marketplace and website for the user: creation of an app used for orders with the ADABIS MIGROS project; the Slot booking business model for the CLUSTER 2.0 project is a web-based hub that allows to book a time slot for deliveries or airport pick-up; a mobile app and a web-based user interface for the HANSBLOC project.

To involve citizen in the creation process: the CITIES4PEOPLE provided a Citizen Mobility Kit which gives a specific tool to involve citizens in the creation of their own logistic system.

Management of the supply chain and the delivery process: sensor boxes and remote control for partly automated vessel operation with the AVATAR project; the CluCS Business Model for the CLUSTER 2.0 project which creates a web hub to manage resources within a cluster; the D-Louve project developed a "follow-me" software (automated droids) to ease the deliveries of heavy goods and also helps disabled customers to carry their packages; for the Ephemeral Hives project an IT structure has been developed to share information in a fluid way between cycle-logisticians and the main stakeholders and also to calculate and track the delivery routes; the LDK project developed droids and robotization of freight barge.

Simulation system: ITWS project builds a simulation model for inland shipping and urban vessels on the marine simulator; simulation-based impact assessment environment and Digital Twin Model designed and developed by the LEAD project.

Later in this document, a more thorough analysis of cycle-logistics viability's main drivers and business collaboration frameworks have been identified, as part of the literature review.

2.2 REGULATION BENCHMARK

As a part of Deliverable D1.1 – ***Baseline situation for urban freight logistics in the living labs***, RCXB and UBC focused on benchmarking the regulations of urban distribution of goods in European cities. Target of the research were cities participating in the project but also other major European cities.

Dedicated surveys were shared with the member cities of the Union of Baltic Cities and different economic agents and logistic operators to get a higher response rate and more insights, best practice examples and existing challenges in the field of urban distribution of goods in cities. A rapid literature review was also provided, with data available on public websites to get more details on some examples in the areas not covered by cities and economic agents who completed the survey (e.g. City of London).

The regulation benchmark on the urban distribution of goods in cities specifically covered the identification of local logistics assets, needs and regulatory frameworks. For this purpose, two surveys were used to gather relevant information (e.g. on low emission zones, congestion charge zones, delivery fees, usage of cargo-bikes, etc.).

The first survey was open from December 21st, 2022 until January 23rd, 2023. In total, 16 European cities completed the survey. It aimed to gather detailed information about local logistics assets, needs and regulatory frameworks. A second survey was developed and launched on February 16th, 2023 (open until March 10th, 2023) with the aim to gather more representativeness and a better understanding of existing regulations in Europe, especially related to last-mile delivery. In total, the research covers 17 cities across Europe, from 11 different countries.

The table below summarizes the municipalities, organisations and economic agents, covered by the analysis, while the map (Figure 87) showcases their location.

Table 3: Stakeholders covered by the analysis

Nº	City	Country	Part of the project
1	Brussels	Belgium	No
2	Ghent	Belgium	Yes (Satellite City)
3	Sarajevo	Bosnia and Herzegovina	Yes (Satellite City)
4	Copenhagen	Denmark	Yes
5	Tallinn	Estonia	Yes (Satellite City)
6	Nantes	France	Yes (Living Lab)
7	Paris	France	No
8	Hamburg	Germany	Yes (Living La)
9	Berlin	Germany	No
10	Liepaja	Latvia	No
11	Logroño	Spain	Yes (Living Lab)
12	Getafe	Spain	Yes (Satellite City)
13	Barcelona	Spain	No
14	Valladolid	Spain	No
15	Karlskrona	Sweden	No
16	Istanbul	Turkey	Yes (Living Lab)
17	London	United Kingdom	No

Figure 86: Map of the countries in the regulation benchmark (source: RCXB)

2.2.1 Regulation on Low Emission Zones

A Low Emission Zone (LEZ) is defined as an area where access by some polluting vehicles is restricted or deterred with the aim of improving air quality.

As detailed in the graphic below (figure 88), among the seventeen cities analysed, seven are currently implementing a LEZ. Eight have it planned (with or without an implementation date), and only two are not planning on implementing a LEZ.

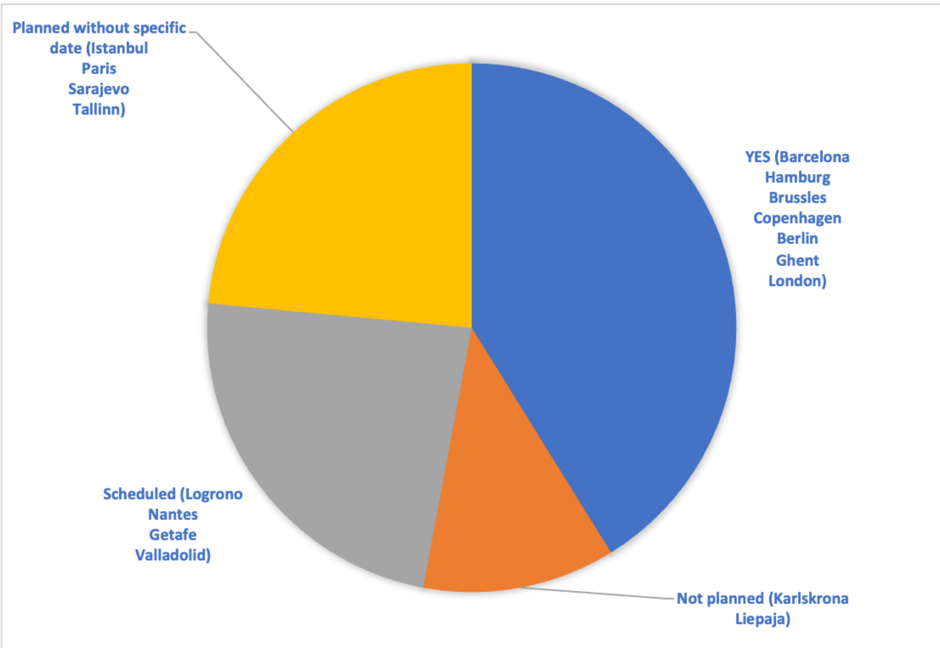


Figure 87: Cities regulations on Low Emission Zones (source: UBC)

In Barcelona and Brussels, the LEZ cover most of the city, while it usually applies to the city centre.

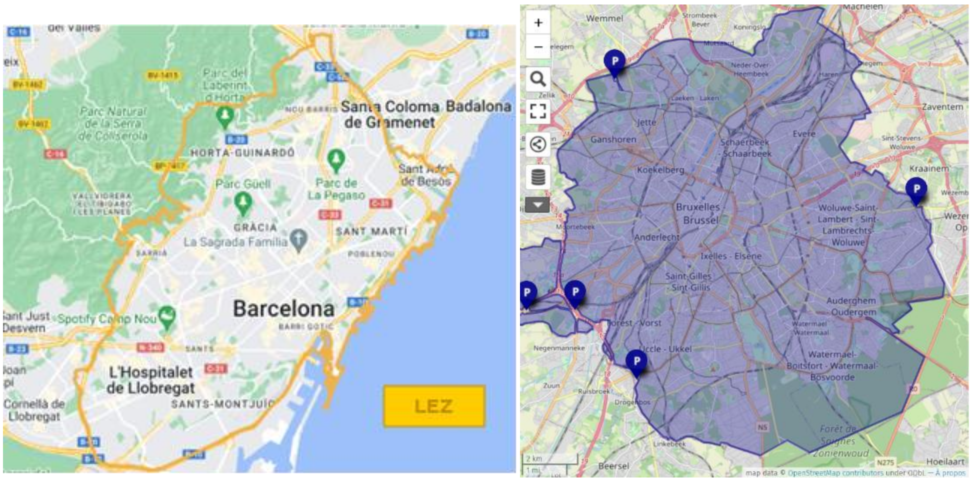


Figure 88: Maps of the Low Emission Zones in Barcelona and Brussels (source : Goggle maps)

The table below details the specificities of the LEZ regulations for each of the city covered by the analysis.

Table 4: Regulations in the different cities analysed

City (with link to the regulation)	State of the regulation	When it applies	Vehicles affected	Exemptions
Barcelona	Ongoing	Monday to Friday from 7 AM to 10 PM	Vans and trucks before Euro 4 (see details below)	
Berlin	Ongoing	Permanent	All diesel vehicles, petrol vehicles without a closed loop catalytic converter (Euro 1 or equivalent). A sticker is mandatory for all vehicles.	At national level: anyone having a professional or private destination where the Euro 6 LEZ is operating is exempt. This includes residents, businesses, customers and patients etc.
Brussels	Ongoing	Permanent	Vans only at the moment, trucks will be included from 2025 but already pay a kilometre charge (Viapass).	At the moment trucks are not concerned by the LEZ. The day pass costs around 35€ and there is a maximum of buying 24 day passes per year. To enter the LEZ, vans that don't meet the access criteria also need to pay, trucks will only need to meet criteria from 2025 on.
Copenhagen	Ongoing	Permanent	Ban diesel and petrol delivery vans, lorries and buses from 2023 and trucks from 2025.	If the diesel-powered **van** is in private use and if a particulate filter can't be retrofitted, the people may benefit from these **five exemption categories:** - resident (time limited) - six-entry punch card (time-limited), with six authorised access of 24 hours in the 12 months from

				the date that the vehicle became subject to the low-emission zone rules. - visiting a hospital or a specialist - disabled - night-time work
Ghent	Ongoing	Permanent	All motor vehicles, Vans and trucks	- mopeds and motorcycles - electric vehicles - hydrogen vehicles - plug-in hybrid vehicles with a maximum CO2 emission of 50g/km - vehicles intended for the transport of persons with disabilities - police cars, fire trucks, ambulances - vehicles of armed forces - mobile cranes (exceptional transport)
Hamburg	Ongoing	Permanent	Diesel cars and lorries	Residents and their visitors, clients and employees of shops/offices in these streets, ambulance cars, fire trucks, garbage trucks, delivery vehicles, public transport, craftsmen
London	Ongoing, will expend to a Ultra LEZ on 29/08/2023	Permanent	Restrictions based on the declared emissions of the vehicle rather than the age. Cars: EURO4 (NOx) for petrol engines and EURO6 (NOx and PM) for diesel vehicles. Specialist vehicles / vans (up to and including 3.5 tons) and minibuses (up to and including 5 tons): same standard as cars, in addition to the size limit.	- Specialist non-road going vehicles designed and built for mainly off-road use (agricultural and forestry tractors, mobile cranes, etc.). - Historic vehicles (constructed before 1 January 1973). - Vehicles operated by the Ministry of Defence.
Paris	Approved in 2015, strengthened in 2021	Permanent	Polluting vehicles (cars, vans, trucks, etc.) which have been operating before a certain date (between 1997 for gasoline and 2009 for diesel). A special sticker will have to be purchased by all vehicles circulating in the LEZ (to be stuck on the windshield). The price will vary according the degree of gas emissions of the vehicle.	Vans, trucks and private vehicles are eligible for a financial incentive for buying an electric vehicle and turning in the polluting vehicle.
Valladolid	Planned for October 2023	don't know yet		Residents in the LEZ; emergency vehicles; water-gas-supply companies in the city; taxi; public transport vehicles; delivery vehicles; low income people vehicles; tourists in hotels with

				parking lots; access to public parking lots, etc.
Istanbul	LEZ are provisioned in the current SUMPs, but not planned for a near future			
Tallinn	No LEZ at the moment, it will be planned when a new SUMP is agreed (next SUMP to be adopted in 2023)		Vans and trucks	Temporary permission to get the old town to robotic couriers.
Getafe	Planned for 2023, affecting all vehicles			
Nantes	Planed for 1st January 2025 (details not yet defined)			
Sarajevo	Planned but nothing concrete at the moment			
Logrono	Planned for 2023, favouring low-emission vehicles with time restrictions			

As a reminder, since 1992, European Union regulations have been imposed on new cars, with the aim of improving air quality - meaning a car has to meet a certain Euro emissions standard when it is made. European emission standards have evolved in recent years, and as of 2023, they do not yet include non-exhaust emissions – including particulates from brakes and tyres. However, this is being considered from Euro 7 onwards. The detail of the Euro emissions standard is as follows:

My car newly registered from:	Emissions standard
31 December 1992	Euro 1
1 January 1997	Euro 2
1 January 2001	Euro 3
1 January 2006	Euro 4
1 January 2011	Euro 5
1 September 2015 - but see important note below	Euro 6

Figure 89: Euro emissions standards for cars (source: RAC)

The analysis shows that when a LEZ is in place, it is usually permanent and applies every day and time of the week. We can also see that it is a good practice to enforce a first version of the LEZ, and review it over time, to have a more restrictive framework (first, only limited to a certain area, or the certain type of vehicles, before extending the restrictions).

In addition, exemptions are always implemented, either for specific people, specific vehicles or for a specific period of time. Usually, people-specific exemptions include local residents, health or public workers, people with disabilities, etc. Electric vehicles, public transport or specific delivery vehicles may also be exempted from the restrictions. Lastly, exemptions may occur within a given timeframe after the enforcement of the LEZ, to give people time to adjust and adapt.

Overall, Spain, Germany, France and Belgium have national general provisions for the implementation of LEZ.

Besides regulations to limit the emission of pollutants, all cities implemented night regulations to prevent the emission of noise pollution. Logistic operations are then prohibited from 10-11 PM until 4–7 AM, with exceptions being granted on a case-by-case basis. Hamburg has a noise regulation which frames the activities allowed at night (noise limit between 35 and 50 db at night[2]).

2.2.2 Congestion Charge Zones

As London is the only city from the analysis that reported implementing a Congestion Charge Zone (CCZ), it can be defined as a mean to alleviate unnecessary traffic by applying a fee to access to this specific zone.

London charging zone details are as follows:

- **Congestion Charge (CC):** Operates 07 AM-6 PM Mon-Fri, 12:00-18:00 Sat-Sun and bank holidays. No charge between Christmas Day and New Year's Day bank holiday (inclusive)
- **Ultra Low Emission Zone (ULEZ):** Operates 24 hours a day, every day of the year, except Christmas Day (25 December)
- **Direct Vision Standard (DVS) and HGV Safety Permit:** Operates at all times for lorries over 12 tonnes gross vehicle weight
- Exemptions:
    - Two-wheeled motorbikes (and sidecars) and mopeds
    - Emergency service vehicles, such as ambulances and fire engines, which have a taxation class of 'ambulance' or 'fire engine' on the date of travel
    - NHS vehicles that are exempt from vehicle tax
    - Vehicles used by disabled people that are exempt from vehicle tax and have a 'disabled' taxation class
    - Vehicles for more than one disabled person (for example Dial-a-Ride) that are exempt from vehicle tax and have a 'disabled' taxation class

2.2.3 Limited Traffic Zone

A Limited Traffic Zone (LTZ) is a restricted traffic area found in many historic European city centres where non-residents and unauthorized vehicles are prohibited from driving at certain times. National traffic regulations are usually the ones setting such a regulation.

From the benchmark, it came out that all cities have restrictions to limit traffic in specific areas, namely the city centre and/or the old town.

Again, exceptions to traffic restricted areas are reported in almost all cities that were analysed. Most of the time, there are morning time slots for logistic vehicles for the purpose of loading/unloading with

[2] https://www.verwaltungsvorschriften-im-internet.de/bsvwvbund_26081998_IG19980826.html

some additional restrictions related to the total weight of vehicles (up to 3.5t). Istanbul reports exceptions for official, touristic, logistic vehicles and commercial taxis for entering this area during the day (7 AM – 9 PM) while Nantes makes the exceptions for gas, hydrogen, and electric vehicles. In Brussels it's possible to ask for exceptions to enter these zones if the workplace is located within the zones, while in Hamburg only residents are allowed to get these permissions. Getafe allows only entering these zones for the purpose of loading and unloading together with authorized vehicles, residents, emergency security vehicles and public service. Tallin and Liepaja have restrictions that apply only to trucks and vans. Regulations in Valladolid apply to all vehicles with a series of exceptions including public transport, bikes, emergency vehicles, residents' vehicles, vehicles of people with reduced mobility, public services vehicles with 'ECO' and 'cero emissions' sticker.

Paris will implement a LTZ in 2024. No traffic will be allowed with some exemptions including emergency services and public transport without any additional permits. Entering the zones will be also allowed for residents' vehicles, "mobility inclusion" card holders, vehicles of traders/companies/stores located in the area, parking subscription holders and driving school vehicles. With the special permit entry will be allowed for the vehicles of customers and visitors to local shops, businesses, museums, theatres etc. in the area. This rule also applies to visitors and residents' guests together with the vehicles of people accompanying children or people with reduced mobility. Professionals working in the area - including delivery people and holders of a temporary occupation permit (moving, dumpster depot) will also be able to ask for this kind of permit.

2.2.4 Tax for delivery companies

While 70% of the cities analysed do not have a tax for delivery companies policy planned, only two of them (Paris and Barcelona) already have such a policy and Tallinn is considering the possibility.

When implementing a tax for delivery companies, the aim is to decrease the number of polluting vehicles, hence decreasing CO2 emissions, and fostering sustainability on the last-mile logistics. Indeed, targeted companies are usually logistics companies, or more broadly all companies operating CO2-emitting commercial vehicles, thus excluding hydrogen or electric vehicles.

Table 5: Cities implementing, not implementing, and planning on implementing a tax for delivery companies policy

City	Status of tax for delivery company policy
Berlin	Not planned
Brussels	Not planned
Getafe	Not planned
Hamburg	Not planned
Istanbul	Not planned
Karlskrona	Not planned
Liepaja	Not planned
Logroño	Not planned
Nantes	Not planned
Sarajevo	Not planned
Valladolid	Not planned
Copenhagen	Not sure
Ghent	Not sure
Tallinn	Planned
Barcelona	Yes
Paris	Yes

2.2.5 Data and Management

In most of the cities analysed, there are no public data on city logistics. Three cities (Barcelona, Brussels, and Tallinn) reported that they have access to local logistics data, via either public sources (regional administrations for Brussels) or private ones (through contracts and agreements).

Table 6: Cities implementing or not a public data space on city logistics

Yes	No
Barcelona	Karlskrona
Brussels	Logroño
Tallinn	Hamburg
	Nantes
	Liepaja
	Getafe
	Tallinn
	Istanbul
	Paris
	Sarajevo
	Valladolid

While most cities do not have public sources of logistics data, some of them do have an open data / smart city / MaaS hub, but not strictly limited to logistics:

- **Logroño:** https://opendata.logrono.es/
- **Hamburg:** https://geoportal-hamburg.de/urbandataplatform/HH_UDP-Schnittstellen.pdf
- **Nantes:** https://data.nantesmetropole.fr/pages/home/
- **Tallinn:** https://avaandmed.eesti.ee/datasets?ih=tallinna-linnavalitsus&pageSize=75
  (Tallinn's transport department is using the urban traffic modelling hub)

When cities do have a public data space on city logistics, it usually monitors the following elements: number of vehicles, vehicles emissions, fleets of logistics services providers, deliveries & pick-ups volumes per area, etc.
When asked about the kind of data needed to take better decisions, cities responded that they need real-time data on loading & unloading areas, on the composition and movements of logistics service providers, and on traffic flows.
Barriers identified to gather the needed data include legislative and political constraints (as well as a lack of collaboration and management hub), but most cities do not consider enforcing policies to support the access to the required data.

Almost half of the cities who responded to the survey have a management system for loading and unloading places, which offers the possibility to book loading and unloading zones, with time-control. This management system to use the loading and unloading parking areas usually does not apply to cargo-bikes, which don't have specific areas to load and unload their operations. Only Tallinn included in its Strategy 2035 provisions at the national level on the management of data related to last-mile logistics.

2.2.6 Cycle-logistics regulations at EU level

At the moment, there are no specific regulations for the commercial use of cargo-bikes in cities that responded to the survey. Only Barcelona has a record of the commercial cargo-bikes operating, as they have to register in a council database. In most cities, cargo-bikes are permitted everywhere, while other delivery vehicles must respect the pedestrian or restricted traffic areas limitations (with loading and unloading at specific times, during a limited amount of time, etc.).

The weight of bicycle trailers is regulated in most cities, with the general rule that it should not exceed half of the weight of the bicycle. Brussels recently updated its policy to authorize bike trailer above 1m20 length for professional use only.

While there are some restrictions in the use of cargo-bikes and trailers in cities in Europe, there are no similar regulations on the management of cycle-logistics micro hubs. However, four cities declared that a strategy for territorial organization and quantification of the micro hubs is necessary to provide proper coverage of the urban area of the city, and is being developed (in Barcelona, Hamburg, Nantes and Tallinn). In Istanbul, it is planned that primary and secondary consolidation centres will be established, and especially secondary consolidation centres are going to be connected to micro consolidation centres.

At national level, only France reported a strategic plan for the management of the last-mile in urban areas with micro hubs that incorporate cycle-logistics solutions. Overall, there is very limited regulations on parcels consolidation last-mile cycle-logistics with a third operator, and public support for cycle-logistics companies to operate a hub is limited.

At European level, we have benchmarked the regulation of trailers and the following elements came out:

- Trailers are not yet introduced in the legislation in most of the municipalities.
- Workgroups have been assigned to help to advance properly the trailer legislation at European level.
- There is a working progress of normalisations TC333-WG9 to formalize a new European regulation for cargo-bikes and trailers.
    - This EU standard for (e)cargo-cycles was launched in January 2020. Up until now, the work has mostly been focusing on determining the scope and categorization of (e)cargo-cycles (mechanical aspects of lightweight and heavyweight of single and multi-track carrier cycles, electrical aspects,), and preparing the harmonization of the future standards. Their harmonization will allow presumption of conformity with the said directives and serve as a powerful tool to comply with the law.

In the table below, we detail the regulation of urban distribution of goods using trailers first in countries where the DECARBOMILE project has LLs and then, other countries, as contrast information.

Table 7: Regulation of urban distribution of goods using trailers in European countries

Country	Permission	Lighting	Dimensions	Weight
Belgium	Yes	Two red reflectors at the rear. Red light whenever their charge hides the bike's light.	Maximum width is 100 cm but the national parliament has given authority to the regional parliaments (Flanders, Brussels, and Wallonia) to decide whether they want to allow up to 120 cm wide trailers (for pilot projects notably). This has been implemented in Brussels since 2018 and since 2023 in Flanders (Ghent). Discussions to implement this in Wallonia are underway.	Cannot exceed 80 kg, load and passenger included. However, a heavier trailer can be used if it has a braking system that automatically activates when the cyclist brakes (as FlexiModal's trailers). No specific restrictions regarding timetables or where to circulate.
Germany	Yes	Lightings must be accredited by the German Legislation for Road License (STVZO). Trailers wider than 100 cm must have one white light on the left front and a red light at the left rear, two white reflectors on the front (max 200 mm) from the external edge and two red reflectors (wide range reflectors) at the rear. Trailers with an inferior width must have two red STVZO-approved reflectors and two white reflectors.	The maximum external dimensions for a bike trailer are the following: 1200 cm length, 400 cm height and 255 cm width.	There is no limit.
France	Yes. However, no specific regulation for trailers in cycle-logistics so the one used now is the highway code for motor vehicles.	Trailers must wear front and lateral lights (white or yellow), and red light at the rear. It is also mandatory to have a flag at the rear.	The trailer cannot overpass 255 cm wide and 1200 cm long.	The regulation establishes that the trailer cannot overpass 50% the weight of the_front vehicle unless the trailer has its own brakes.
Spain	No. The National Regulation Framework (Directorate General of Traffic) does not contemplate so far the usage of trailers for cycle-logistics. The municipal ordinance has the legal authority to modify and adapt			The regulation established is the general one (the same as for motor vehicles) and establishes that trailers, similarly to France, cannot overpass 50% of the bike's weight (Article 12 of BOE Regulation 1428/2003).

	municipal legislation and permit the usage of trailers with the conditions and regulations established in the municipal ordinance.			
Denmark	Yes. Trailer should only have a maximum of 2 wheels, and only 1 trailer per bike.		100 cm max width (while scooters are limited to 125 cm) and 350 cm long (bike trailer together).	Limited to 60 kg without brakes, 100 kg with brakes.
Finland	Yes.	There are existing regulations regarding lightning and reflectors but the documentation available online is only in Finnish and Swedish.	The width of the trailer must not exceed 125 cm	No more than 50 kilograms (the trailer itself, to which the weight of the load can be added).
Italy	Trailers under 3m long are allowed		Max length for bike + trailer is 300 cm.	
Netherlands	New legislation in progress (Dutch national policy framework for Light Electric Vehicles (LEVs)) with 4 categories of vehicles (1a.1b.2a.2b).	Need front and back lights, as well as reflective stickers.	Cargo-bikes will be limited to 300x100x200 cm and will require a driver's license and a minimum age of 18 years. On public roads: Max width for trailers carried by three wheeled bikes: 150cm; Max width for trailers carried by two wheeled bikes: 100cm. On cycle paths: width limited to 100 cm.	
Norway	Yes		There are no restrictions concerning the dimensions or the weight of a bike trailer. There are some requirements for all products, see information about the general product safety directive which also is valid in Norway.	
Sweden	Vehicles towed by another vehicle must be coupled in a satisfactory manner from a road safety point of view. A bicycle with a coupled bicycle trailer must be driven on the roadway even if the bicycle lane is available if it is more appropriate with regard to the width of the vehicle.	Bicycle trailers that do not have a reflex device at the back and will travel in the dark must have a lamp that can show red light backwards.	There are no restrictions for maximum width of a bicycle trailer.	
Switzerland	Yes		Max width is 100 cm.	Max weight is 60 kg.

			Testing phase in St Gallen: 113 cm.	Testing phase in St Gallen: load 140 kg.
United Kingdom	No clear legislation concerning the use of bike trailers. From what we know they are legal and we have customers using them there.			

2.2.7 Conclusions and Recommendations

From the surveys and benchmark analysis, it came out that there is currently no common base in terms of regulation frameworks for the urban distribution of goods in Europe. Although most cities have existing regulations and restrictions, and bigger cities have more restrictive regulations (example of London with ULEZ and congestion charge), the methodology, quantification, types of vehicles affected, loading and unloading spaces and even geographic zones are not harmonized over Europe.

Overall, we also faced a wide diversity of data collection mechanisms, use and management across cities analysed. Indeed, some of the data we aimed to collect was public, some data was private, some municipalities outsource data management to private entities, etc. It came out that there is not quantification data in cycle-logistics so far, and no active regulation on cycle-logistics last-mile delivery in most of the cities we analysed.

In addition, we encountered a lack of internal knowledge about existing regulations at municipality level. It affects not only to the information provided to the citizens but also the regulations that might be put in place in the future. We also noticed a lack of expertise on how to build new urban mobility as when asking for future regulation for urban distribution of goods and services, some municipalities couldn’t provide specific policies or projects in this field for the upcoming period. One of the big challenges identified is to work on long-term policies while being limited in time with short term government mandates.

The following recommendations can be put forward in the framework of the DECARBOMILE project:

- On local ecosystems, it is key to identify and engage economic agents, stakeholders and society when developing new policies for urban distribution and infrastructure and developing related KPIs.
- Currently, the urban logistics sector is under constant change and local governments mostly make their policies for the period of four years which is a significant challenge for all involved stakeholders.
- It’s very important to ensure financial support for making the business operations profitable, particularly in the first years after the business is being launched.
- The more regulation of motor vehicles, the more viability comes up for an alternative urban distribution of goods.
- Regulations needs to be combined with alternative management models, promotion of new ways of mobility and urban infrastructure.
- Proposal of a structured regulation toolkit for urban distribution of goods might help municipalities to better identify, unify and measure different policies that need to be carried out.

3. LITERATURE REVIEW

Logistics is becoming more and more important, especially in cities, as it keeps them liveable and attractive and supplies them with the relevant goods (Maes, Sys and Vanelslander, 2015, p. 414; Montwiłł, 2019, p. 337). Due to the rising e-commerce the expectations in terms of delivery speed and plannability have increased. With a growing urban population, the delivery traffic within a city is rising, which has negative externalities congestion, air pollution, noise pollution, GHG emissions, accidents, habitat loss, infrastructure (Figure 91) etc. (Luigi Ranieri *et al.*, 2018, p. 5; Edouard *et al.*, 2021, p. 451; Brusselaers and Mommens, 2022, p. 2095; Demir, Syntetos and Van Woensel, 2022, p. 551). The e-commerce service is characterized by high frequencies and small packages, failures in attended home deliveries and low utilization of vehicles (Guerrero and Díaz-Ramírez, 2017, p. 8; He and Haasis, 2019, p. 2). By 2030, in the 10 most populated cities worldwide, an increase by 36% in the number of delivery vehicles is expected, thus putting pressure on the two main stakeholder groups (public sector stakeholders and private sector stakeholders) of urban logistics (Anand *et al.*, 2012).

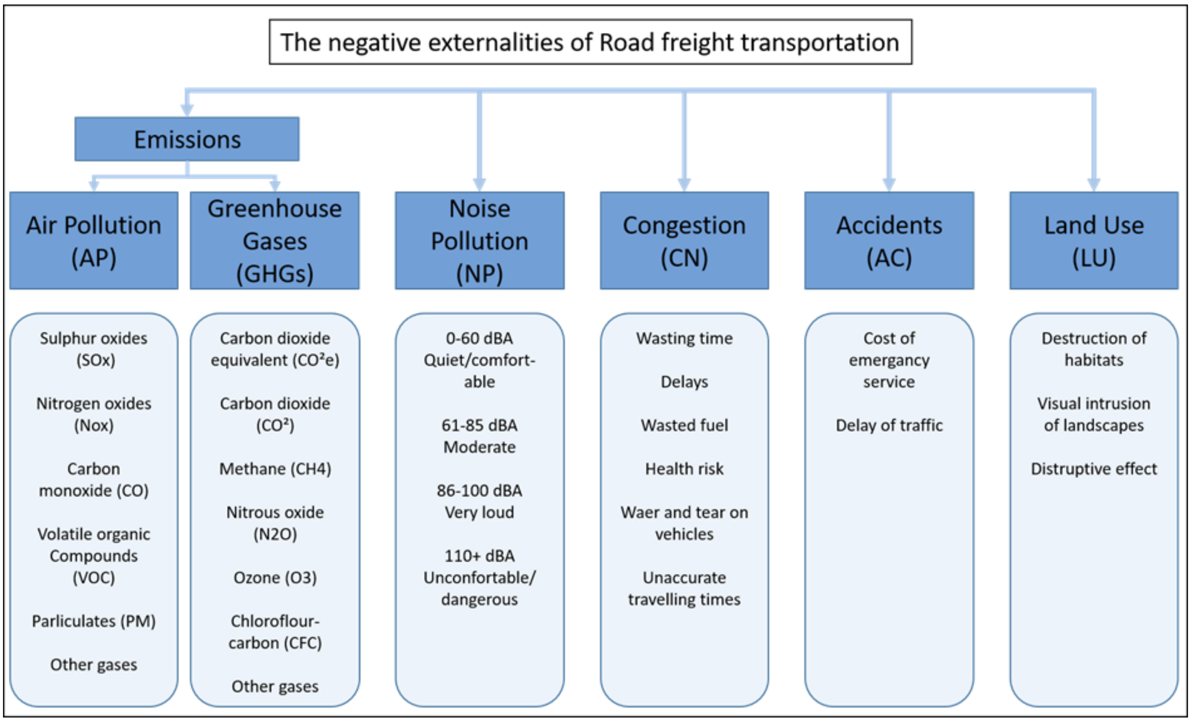


Figure 91: Negative externalities of road freight transportation (Own illustration according to Demir, Syntetos and Van Woensel, 2022, p. 552)

Urban logistics "can be defined as all movements of goods, in to, out from, through or within the urban area made by light or heavy vehicles, including also service transport and demolition traffic, shopping trips made by private households and waste" (Santinha *et al.*, 2021, p. 38). According to the European Commission, the key challenges in urban logistics are:

1. "A lack of focus and strategy on urban logistics, and only a few cities with someone in authority responsible for urban logistics.
2. A lack of coordination among actors involved in urban logistics, and in many cases insufficient dialogue between city authorities and the private actors who operate there.
3. A lack of data and information, which makes it difficult to improve operational efficiency and long-term planning." (European Commission (2013) in Fossheim and Andersen, 2017, p. 1).

Therefore, urban logistics planning should become a part of the Sustainable Urban Mobility Plan (SUMP) of the cities. Urban Logistics Systems are facing a high level of uncertainty and dynamism (Kubek and Więcek, 2019, p. 225) and are “results from the interactions and combined decisions of numerous stakeholders” (Crainic and Montreuil, 2016, p. 384).

Within the urban logistics, the term of last-mile logistics is often used. Last-mile logistics are all “logistics activities related to the distribution of shipments, e.g., parcels with goods ordered online, to private customer households in urban areas” (Boysen, Fedtke and Schwerdfeger, 2021, p. 4). This includes the “process of planning, implementing, and controlling efficient and effective transportation and storage of goods, from the order penetration point [starting point in an urban area like a depot] to the final customer” (Olsson, Hellström and Pålsson, 2019, p. 10) for Business-to-Business (B2B) and Business-to-Customers (B2C) deliveries. The last-mile logistics is generating up to 28% of the total delivery cost (L. Ranieri *et al.*, 2018, p. 1). According to Boysen et al. (2021, p. 2), the increasing volume (e.g. parcels), the sustainability (congestion and awareness of customer/regulation), the costs (especially for failed delivery), the time pressure (next day shipments, varying workload) and the aging workforce are the main developments and challenges regard last-mile delivery. To overcome the challenges, the last-mile logistics operators implemented different solutions like notifications with a planned delivery date or parcel stations and boxes (Holdorf and Haasis, 2014, p. 2). Some of those solutions will be presented in this literature review.

With the rising awareness by the public for external costs like emissions, noise, safety and congestion and the regulations regarding the climate protection, sustainability strategies and concepts are becoming more important (Maes, Sys and Vanelslander, 2015, p. 413; Kubek and Więcek, 2019, p. 222).

One of this sustainable logistics concepts of the last-mile is the city logistics concept. The aim of this concept is the reduction of the negative impacts (Taniguchi, Thompson and Yamada, 2003, 2014) by improving e.g. “the efficiency of freight movements and their environmental footprint, and reduce the number of empty vehicles getting in, through and out of the city” (Crainic and Montreuil, 2016, p. 384). For reaching this goal, new organizational and business models are proposed, that are also supporting the economic and social development of the city (Crainic and Montreuil, 2016, p. 386). For the city logistics, the satisfaction of the stakeholders and the suitability to the local conditions is important for being effective in terms of reaching its goal to improve the sustainability (W. Hu *et al.*, 2019, p. 19; Arvianto *et al.*, 2021, p. 2).

The terms last-mile logistics and city logistics should not be used as synonyms. “While last-mile logistics emphasizes the perspective of private actors in supply chain networks, city logistics research is often conducted from the perspective of public actors. Generally, much of the city logistics literature focuses on externalities, while last-mile logistics focuses on organizations” (Olsson, Hellström and Pålsson, 2019, p. 16).

There are different approaches to improve the transportation of goods like innovative vehicle solutions (e.g. cargo-bikes, electric vehicles, intermodal high-capacity transport and drones), operational optimization (routing, multimodal delivery) or transport planning (consolidation) (Olsson, Hellström and Pålsson, 2019, p. 13). To reach the goal of a more sustainable urban logistics, the different approaches need to overcome the barriers, that are either institutional (e.g. weak cooperation between stakeholders and politicians and varying priorities), data collection (e.g. lack of appropriate data, no whole picture), planning (e.g declining strategic capacity, no forecasting) or ecological and legal issues (e.g. lack of coordination in planning, not enough push and pull measures) (Tsiulin, Hilmola and Goryaev, 2017).

With this systematic Literature Review, the state of the Art in the academic literature for logistics concepts, the five pillars of DECARBOMILE and vehicle routing and location problem should be shown. The Literature Review provides an overview of important definitions for DECARBOMILE, shows the current trends in the academic literature and can be used as a base for further investigation of specific aspects of the literature. Because there is a wide range of literature, which needs to be analysed regarding the DECARBOMILE project and its planned use cases, this literature review does not claim to be exhaustive. For example, for the five pillars of DECARBOMILE, searching for last-mile, city logistic, urban logistic, urban freight transport and the name of the pillars lead to 22 000 results, from which only 470 seemed to possibly fit to the DECARBOMILE project.

The Literature Review is structured as follows: after introducing the different logistics concepts (Urban Consolidation Centres, Micro Hubs, Collecting Points, Alternative home delivery, Multimodal Last-Mile Logistics, Innovative Vehicle Solutions, Use of autonomous vehicles, Metro based logistic underground, Physical Internet, Crowdlogistics, Load Pooling) and explaining their possible advantages and disadvantages, the five pillars of DECARBOMILE (collaboration, business models and value-added services, urban integration and space management, regulation and digital infrastructure) are described in detail. For all Pillars, different barriers and challenges and possibilities to overcome those barriers are presented and the possible positive impacts are described. With this theoretical background, the optimization algorithms for last-mile logistics in the field of network design (especially location problem) and vehicle routing are presented.

3.1 Logistics concepts

For identifying literature for logistics concepts in last-mile logistics, a Systematic Literature Study with the search string (TITLE-ABS-KEY ("last mile" OR "city logistic*" OR "urban logistic*" OR "urban freight transport*") AND TITLE-ABS-KEY (logistic* AND concept OR asset)) has been conducted. The 614 findings in the Databases Scopus and Web of Science included 153 duplicates, so in total, from the remaining 461 papers, the titles and abstracts were read. In total, 93 papers seemed to fit according to the title, abstract and keywords from which 23, who fitted best in the project context of DECARBOMILE have been read. For the waterside transport, an additional systematic search was carried out with the search string (TITLE-ABS-KEY ("last mile" OR "city logistic*" OR "urban logistic*" OR "urban freight transport*") AND TITLE-ABS-KEY (water OR ship OR barge)), with 264 results. After removing the 47 duplicates, 217 results remained, from which only 13 appeared suitable according to the title, abstract and key words, with five papers, fitting best to the DECARBOMILE project. 4 other papers have been included, who appeared important for the DECARBOMILE project because of their review on Last-mile Logistics in general (Olsson, Hellström and Pålsson, 2019) or to specific logistics concepts like the Physical Internet, Urban Consolidation Centre or alternative vehicles.

The Logistics Concepts and Pillars are highly interrelated. Therefore, some of the presented logistics concepts below are also addressed in the texts of the five pillars. The presentation of the Logistics Concepts is more comprehensive and includes several points of view and highlights the connection to DECARBOMILE. Also, different advantages and disadvantages are presented. For developing new logistics concepts, a lot of different aspects need to be considered and normally, the concepts need to be adapted to the local circumstances. Therefore, the descriptions of the concepts are not claiming to be exhaustive. An allocation of the concepts to the five pillars of DECARBOMILE can be found in the Table 8. The majority of the logistics concepts fits to more than one pillar.

Table 8: Logistics Concepts and the five Pillars of DECARBOMILE

		Collaboration	Business Models and Value-added services	Urban Integration and Space Management	Regulation	Digital Infrastructure
Consolidation	Urban Consolidation Centres	x	x	x	x	x
	Micro Hubs	(x)	x	x	(x)	x
New Places of Delivery	Collecting Points	(x)	x	x	(x)	(x)
	Alternative home delivery	(x)	x			(x)
New Transportation Modes	Multimodal Last-mile Logistics	(x)	(x)	(x)		(x)
	Innovative Vehicle Solutions	(x)	(x)	x	(x)	
	Use of autonomous vehicles		(x)	x	(x)	x
	Metro based logistic underground	x		x		(x)
Digital Infrastructure	Physical Internet	x	x	x	x	x
	Crowdlogistics	x	x			x

x = fits *(x) = fits slightly*

According to Flämig et al. (2002) a transportation system consists of different elements and relations (Figure 90). Activities are driving the system, in which persons and/or goods and/or information can be transported with different movables like cars, vans, trains, planes, ships etc. on different infrastructure like water, road, rail between different facilities. For the DECARBOMILE project and its logistics concepts, especially the elements movables, infrastructure and facilities can be changed in order to improve the last-mile logistics. Those changes will be presented in more detail below.

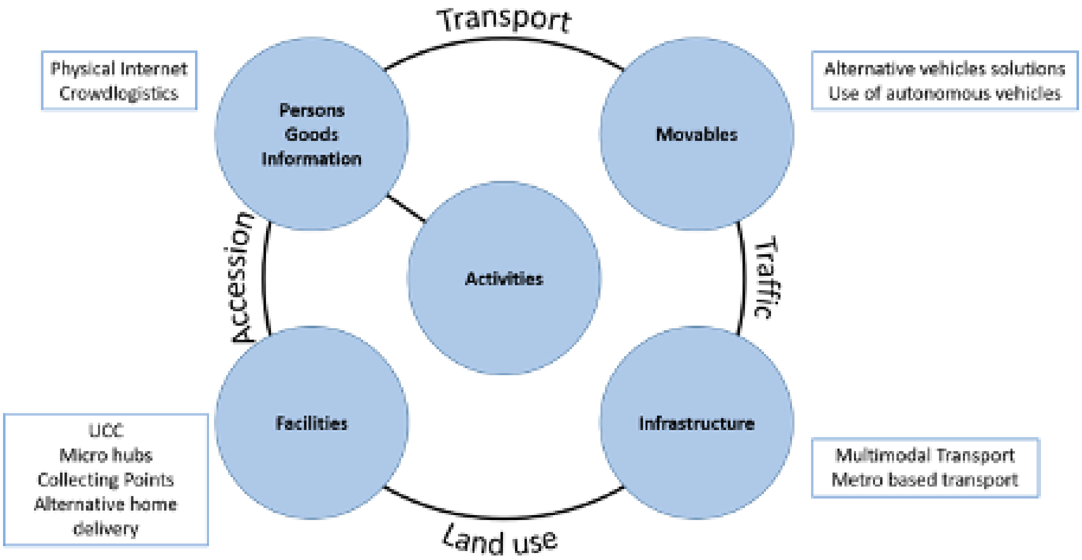


Figure 90: System model of transport and traffic (Flämig, H., Sjöstedt, L., and Hertel, C., 2002)

Normally, a last-mile logistics chain can include several of the concepts presented below. These new systems accelerate the trend toward modifying the fleets to become environment friendly by, e.g., changing the motorization of first-tier vehicles to electric or liquid gas, and relying on smaller vehicles such as electrical urban light trucks, scooters and bicycles for the second-tier operations (Crainic and Montreuil, 2016, p. 388).

Brabänder (2020, p. 22) show the different dimensions of Last-mile Delivery from a Break-Bulk Point to the point of delivery. The Last-mile consists of three steps (consolidation, transport process and handover process). For all of those steps, different approaches to optimize the steps are presented below.

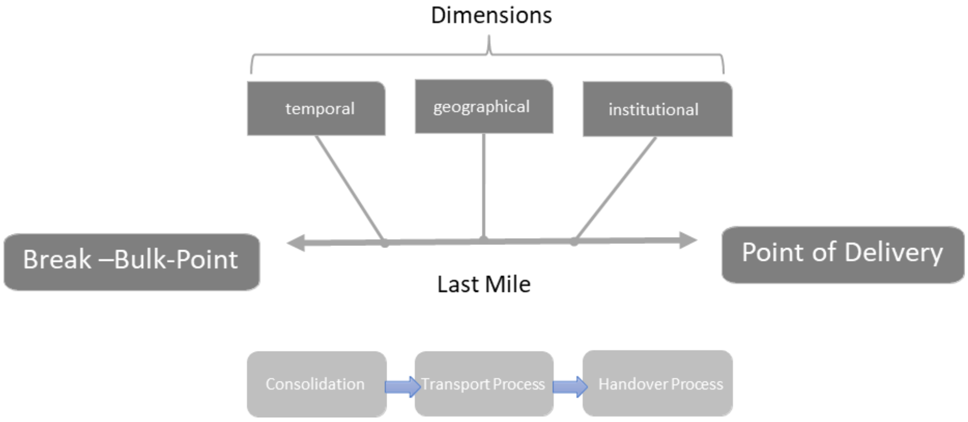


Figure 91: The three dimensions of last-mile (Own illustration according to (Brabänder, 2020, p. 22))

3.1.1 Consolidation

In order to improve the flow of goods, new facilities for consolidation are included in the last-mile logistics chain. Those new facilities are presented below.

Urban Consolidation Centres

Urban Consolidation Centres (UCC) can be used for consolidating loads in the last-mile transport and were already proposed in the 1970 (Ranieri *et al.*, 2018, p. 6). The UCCs can either be owned and/or operated by one private company or as a shared infrastructure (Elbert *et al.*, 2019, p. 267) and are located close to the city (centres). An UCC is a cross-docking terminal with multiple functions and installations and should be "located at the breakpoints in the transport chain" (Tsiulin, Hilmola and Goryaev, 2017, p. 253). They are "creating an integrated logistics system for different companies, providing storage, classification, consolidation, and deconsolidation as well as several value-added services such as accounting, legal consultancy, and brokerage" (Özbekler and Akgül, 2020, p. 336).

In the literature, UCCs are also named as urban freight centres (UFC) or freight consolidation centres (Tsiulin, Hilmola and Goryaev, 2017, p. 253).

In a last-mile logistics with an UCC, the loads arriving from the main haulage are first transported to the UCC and are consolidated and sorted there. After this process, the delivery to the final customer can be carried out with a higher utilisation (Crainic and Montreuil, 2016, p. 387; Ranieri *et al.*, 2018, p. 6; Özbekler and Akgül, 2020, p. 336). In such a two-echelon logistics system, for the transport to the UCC (first echelon), typically larger vehicles are being used, while smaller vehicles (second echelon) are used for the transport from the UCC to the customer (Huang, Savelsbergh and Zhao, 2018, p. 96; Anand, van Duin and Tavasszy, 2021, p. 1). The UCC is normally situated at the cities' periphery, in order to offer an easy access for bigger trucks (Anand, van Duin and Tavasszy, 2021, p. 1).

The impact of a UCC on the delivery chain can be seen in Figure 92. Instead of transporting the goods from the factories and warehouses directly to the target delivery areas, the goods are delivered at the UCC first and are transported to the target delivery area in a second step.

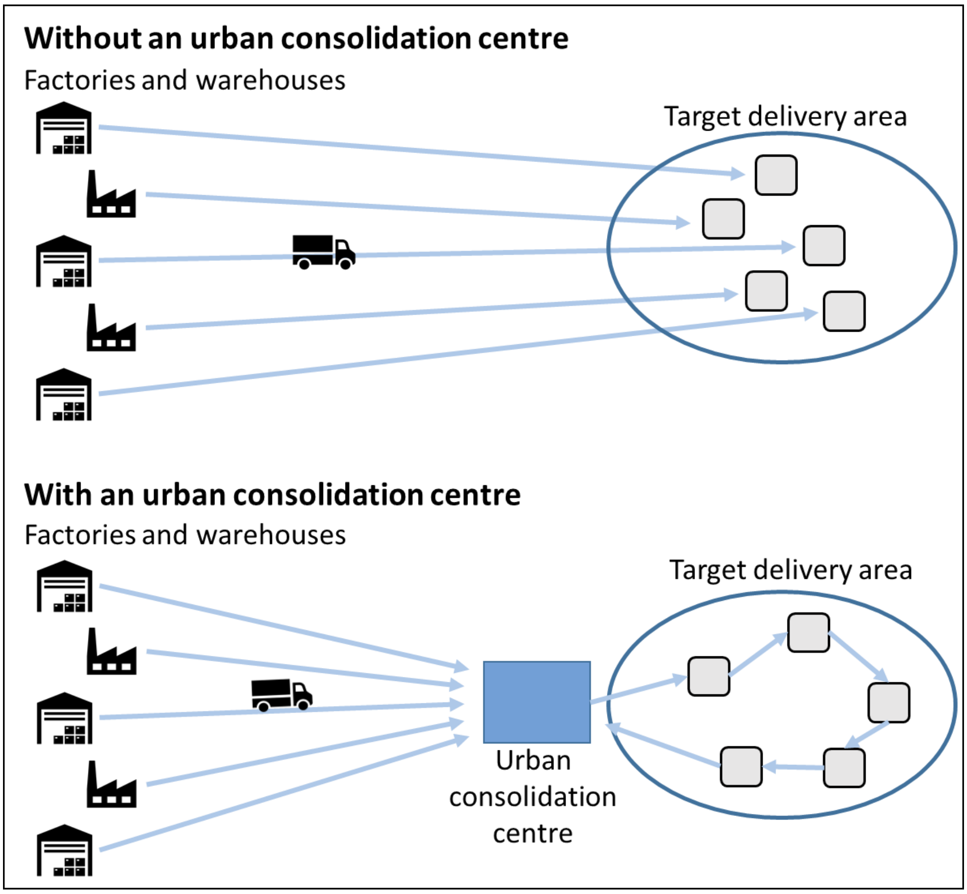


Figure 92: Distribution with and without UCC (Own illustration according to (Özbekler and Akgül, 2020, p. 336)

UCCs can be a good concept for areas with a large commercial development or bigger construction sites (Tsiulin, Hilmola and Goryaev, 2017, p. 265). With an UCC and the bundling of goods, the distance travelled per shipment, the environmental issues as well as the externalities like traffic congestion or emissions can be reduced (Ranieri *et al.*, 2018, p. 6; Özbekler and Akgül, 2020, p. 336). Also, the resources used by private stakeholder can be lowered (Anand, van Duin and Tavasszy, 2021, p. 9).

However, operating an UCC makes extra resources for handling goods (e.g. trucks, drivers) necessary and can lead to extra costs (Anand, van Duin and Tavasszy, 2021, p. 9). For stakeholders, it is important that the UCC is operated permanently, as they are otherwise less willing to participate in research demonstrations. It needs to be taken into account, "that the estimated number of participating actors prior to the establishment of an UCC is higher than the number actually participating, resulting in lower-scale economies than anticipated" (Tsiulin, Hilmola and Goryaev, 2017, pp. 264–265).

In lots of cases, the UCC had a full subsidy from the government. After the end of the subsidy, the UCCs are often shut down again (Anand, van Duin and Tavasszy, 2021, p. 1). To find a long-lasting business model, the different stakeholders and their individual perspectives need to be understood and considered (Anand, van Duin and Tavasszy, 2021, p. 2). At the beginning of implementing an UCC, it was expected that the potential reduction of negative effects like congestion or pollution in combination with the free use of the UCC is enough for the Logistics Service Provider (LSP) to use the UCC. But it could be shown in the literature that those reductions of the negative effects weren't enough, because arguments of the rise of operational costs for using the UCC as well as questions regarding the liability (UCC or carrier) if the goods are damaged are more important in the decision-making process. For costumers, goods that are delivered via an UCC might take longer and might be more expensive (Anand, van Duin and Tavasszy, 2021, p. 1).

According to Tsiulin et al. (2017), the current challenges of UCC are lack of scientific data, urban sprawl, stakeholder acceptability and financial concerns. UCCs are facing practical, legal and ecological barriers. In order to solve those problems, establishing new business models and an improved and more detailed planning is needed. Barriers of UCC implementation are according to Tsiulin et al. (2017, p. 264):

- Location selection (minimize distance between depot and customer)
- Policy benefits
- Institutional issues ("lack of cooperation among all actors: business representatives, carriers, stakeholders and local authorities in case of implementing the UCC. The reason that it happens, is the high diversity of interests in freight distribution systems, related to time and local delivery issues and unwillingness to collaborate with each other, assuming their own costs and handling problems independently")
- Practical barriers.

In order to overcome the barriers presented above, studies showed, that value-added services like the handling of goods in stores or of return goods or mail services are important for a successful implementation of an UCC. Those services need to be beneficial for the users/end-receivers and the users need to be willing to pay for that (Tsiulin, Hilmola and Goryaev, 2017, p. 267). Another important influencing factor is the involvement of all potential actors already at an early stage of the planning process.

An overview of possible algorithms regarding the two-echelon freight transport is given later in the review.

Micro Hubs

Another option to consolidate loads and to improve the last-mile logistics are the use of micro hubs, which can be either stationary or mobile. Micro hubs or micro consolidation centres are a smaller scale of an UCC. Same as UCC, micro hubs can be shared across LSP (Elbert *et al.*, 2019, p. 267; Katsela *et al.*, 2022). Micro hubs can be operated in combination with an UCC, where the consolidated loads are then transported to the micro hubs and are transported with smaller vehicles like cargo-bikes to the final customer (Crainic and Montreuil, 2016, p. 387; Özbekler and Akgül, 2020, p. 336).

Micro hubs are in the centre of the city and close to the reception points and are therefore very suitable for the last leg of the transport of normally light freight like parcels. The use of smaller vehicles like cargo-bikes can reduce the negative aspects of urban planning and makes it easier to carry out the loading and unloading activities. Micro hubs can be for example a loading dock of a shop, a garage in a car park or a trailer (Özbekler and Akgül, 2020, p. 336; Boysen, Fedtke and Schwerdfeger, 2021, p. 14). For the mobile version of a micro hub, normally trailers "fitted with a loading dock, warehousing facilities, and an office" (Özbekler and Akgül, 2020, p. 336) are used. By using mobile depots, empty travels for cargo-bikes for the replenishment of their shipment can be reduced (Boysen, Fedtke and Schwerdfeger, 2021, p. 17).

It might be difficult to choose a location for the micro-hub. For solving the location problem, onetime fixed costs like rent and/or possible daily usage costs (parking fee for a mobile micro hub) need to be included in the decision-making process (Boysen, Fedtke and Schwerdfeger, 2021, p. 15). An overview of the network design and location problem can be found in **Error! Reference source not found.**.The m icro hub can be combined with other innovative business models like the click and collect model (Özbekler and Akgül, 2020, p. 336).

Özbekler and Akgül (2020, p. 337) are evaluating the city logistics schemes in terms of environmental, social and economic sustainability, mobility and liveability of the city (Table 9). It can be seen that all kind of consolidating flows in UCC, Micro Hubs or Mobile depots are better for the mobility, as well as the environmental and social sustainability in comparison to the conventional distribution. For Micro hubs and Mobile depots, also the liveability and economic sustainability is rated as good.

Table 9: Evaluation of City Logistics Schemes (Own illustration according to (Özbekler and Akgül, 2020, p. 337))

		Conventional Distribution	Urban Consodiation Centre	Micro Consodiation Centre	Mobile Depot
Mobility		Poor	Good	Good	Good
Sustainability	Enviroment	Poor	Good	Good	Good
	Social	Poor	Good	Good	Good
	Economic	Fair	Fair	Good	Good
Livebility		Poor	Fair	Good	Good

In the DECARBOMILE project, in some of the living labs, UCC and micro hubs should be implemented for consolidating the flows. The UCC and micro hubs are addressing the pillars of collaboration, business model, urban integration, regulation and digital infrastructure. In the UCC and in shared micro hubs, normally different stakeholders are working together. For implementing a long-lasting solution, the developed business models need to be sustainable, while finding a suitable location for UCCs and micro hubs is a challenge in all cities. Normally, both options can be supported by regulations and are operated with the use of digital infrastructure.

3.1.2 New places of delivery

As the home delivery is often failing for the first attempt, new places of delivery are offered to the customers. Those new places can either be collecting points at another location, where the customer can pick up his parcel or an alternative home delivery approach like front door boxes (Holdorf and Haasis, 2014, p. 2; Asdecker, 2021).

Collecting Points

For collecting points (or pick-up points at micro hubs), the goods are delivered to decentralized facilities points and need to be picked up by the customers there. The collecting points can be self-collecting points/automated storage systems like smart lockers, who can be either stationary or mobile or can be attended collecting points like parcel shops. Another option can be the employer delivery, where the parcels are sent to the workplace of the customer (Holdorf and Haasis, 2014, p. 2; Asdecker, 2021; Boysen, Fedtke and Schwerdfeger, 2021, p. 18).

The unattended, self-service parcel lockers are located at well-frequented areas and are opened 24/7. Customers need to identify themselves at a central control panel or with an app and can pick up and often send parcels there. The recipient gets a validation code via Mail, SMS or with a notification card for opening the smart locker. For some smart lockers, a membership card is necessary. Smart Lockers can be selected as favourite place of delivery or parcels, who couldn't be delivered at the first attempt, are redirected to the smart locker (Ranieri et al., 2018, p. 8; Behnke, 2019, p. 145; Asdecker, 2021, p. 3; Boysen, Fedtke and Schwerdfeger, 2021, p. 19). Possible locations are normally near workplaces, railway stations, apartment blocks or parking areas (Behnke, 2019, p. 144).

Mobile parcel lockers can change their location during the day by either being equipped with an autonomous drive or by being transported by another vehicle. They can have a higher reach towards the potential customers, as they are also moving during the day (Boysen, Fedtke and Schwerdfeger, 2021, p. 40).

Smart Lockers have several environmental and economic advantages like a reduced handling effort, no need to drive to each home address, no failed delivery and second delivery attempt or reduced costs and amount of work. Moreover, environmental benefits, like less delivery vehicles on the streets and a reduction of congestion and emissions are possible. The parcel lockers can be handled faster than home deliveries and the pick-up of the shipment is possible at any time (Behnke, 2019, p. 145). By delivering the parcels directly to the smart locker, the load factor can be risen, and the delivery time can be lower, if the lockers are filled during low traffic times at night (Ranieri et al., 2018, p. 8). Disadvantages can be if a membership card is needed, it can be a hurdle for customer. Also, the recipients need to decide over their delivery preference and it will not be beneficial for the customers to order their delivery to a parcel locker if they anticipate that they will be at home during the estimated home delivery time (Behnke, 2019, p. 145).

Attended collect and delivery points are locations, who are functioning as decentral collection units, "where shipments for multiple customers are taken over and handled by a human service person" (Boysen, Fedtke and Schwerdfeger, 2021, p. 18). Examples for pickup stores can be small convenience stores, post offices, tobacco shops, petrol stations or reception desks of fitness centres or office buildings, who can have additional revenues by operating such a point (Behnke, 2019, p. 144; Boysen, Fedtke and Schwerdfeger, 2021, pp. 18–20; Demir, Syntetos and Van Woensel, 2022, p. 557). For the LSP it is advantageous that he doesn't need to establish an extra network if they are using existing shops and that the customers might like the human interaction (Boysen, Fedtke and Schwerdfeger, 2021, p. 20).

By delivering the parcels to a decentralized location, the LSP can save efforts and it makes the handling of the increasing parcel volume easier, lowers cost and can help in terms of the (aging) workforce (Boysen, Fedtke and Schwerdfeger, 2021, p. 18). The locations are mostly used for the return of online orders (Demir, Syntetos and Van Woensel, 2022, p. 557).

The decentralized locations are lowering the convenience for the customers, as they need to travel to the pick-up place and may cause delays of the receipt of the parcel while at the same time, incentives for picking up the parcels might be necessary. The saving of travel distances for the LSP needs to be evaluated against the background of the additional travels by the customers to get the environmental impacts. The CO2 emissions for picking up the parcel can vary a lot, depending on the mode of transport used for picking up the parcel (bike, car, foot, bus, train) (Behnke, 2019, p. 146; Boysen, Fedtke and Schwerdfeger, 2021, p. 18).

Alternative Home Delivery

For alternative home delivery concepts, the delivery still takes place at the front door, but the customer does not need to be present at the time of delivery. For this reason, drop-off-systems for an unattended delivery are installed at the customers house like front door boxes or the commitment logistics (Holdorf and Haasis, 2014, p. 2; Boysen, Fedtke and Schwerdfeger, 2021, p. 36). Other options are controlled access systems for the trunk delivery or home access systems (Behnke, 2019; Asdecker, 2021).

A reception box is like a bigger version of the letterbox and is permanently fixed for example at the garage or the home yard or mounted safely without an installation. Reception boxes can be different in terms of the size, costs and refrigeration capabilities. The boxes can also differ regarding the accessibility for LSP. While some boxes can be opened only by one LSP or have a maximum capacity of one parcel, other boxes can be opened by more LSP. They are normally privately owned or rented. For apartment buildings, also sharing the reception boxes might be an option. The parcels can be delivered into the reception box, which can be opened by the delivery company with an electronic code or key and the customer can pick up the shipment after he or she arrived back at his or her place (Behnke, 2019, pp. 144–146; Asdecker, 2021, p. 4). Another option are delivery boxes, which "are filled with goods at the depot of the logistics service provider and attached temporarily to the home with some locking device" (Behnke, 2019, p. 144). The customer can open the delivery box with a key or code and the empty boxes are picked up by the LSP at the next delivery tour (Behnke, 2019, p. 147).

Advantages of the reception boxes are that it is easy to order goods at home and there is no need to redirect the parcel nor to collect the parcel from another delivery place. For the delivery boxes, only minor additional costs occur while the "costs, time, effort, and the resulting environmental impacts decrease" (Behnke, 2019, p. 147). A disadvantage is the cost for the reception box, which can be around 100€ to 900€ or a monthly payment and that in some places like urban rental apartments, installing reception can be impossible or very difficult (Behnke, 2019, p. 147; Asdecker, 2021, p. 14).

Controlled access systems authorize the LSP to access the house, garage or trunk key-less and to store the delivery there. For this reason, the deposit location needs to have a smart locking system (Behnke, 2019, p. 148). For the trunk delivery, the LSP locates the car by using GPS, opens the trunk with a temporary key and delivers or dispatches the shipment there (Asdecker, 2021, p. 4). Home access systems are granting LSP access to the home or garage of the recipient with smart locks and are normally also recording the delivery. The customer gets a notification of the successful delivery and the video link (Behnke, 2019, p. 144; Asdecker, 2021, p. 4).

For the controlled access systems, there are no additional costs, no need to install extra boxes and the customer does not need to collect the parcels at another place and can save time. Therefore, the flexibility for the pick-up and delivery times increases, the delivery is more reliable and the customers are independent from their neighbours. A disadvantage can be the necessity to have a modern infrastructure and that for the trunk delivery, the Vehicle Routing Problem might be more difficult for the LSP, as the car can be moved during the day (Behnke, 2019, p. 148; Asdecker, 2021, p. 10).

By using alternative places of delivery, logistics costs and time pressure but also air pollution, traffic congestion, noise and GHG emission can be reduced and the sustainability increases (Asdecker, 2021, p. 15; Boysen, Fedtke and Schwerdfeger, 2021, p. 37).

The use of those new places of delivery is mainly dependent on the acceptance level of the customer, which varies a lot between the different options. The most important factors influencing the acceptance are safety, security and liability and the spatial impediments, "followed by 'data protection/privacy' and 'car access/ownership'" (Asdecker, 2021, p. 11). For the customers, the sustainability of their logistics practice is not an important factor for changing the place of delivery. While parcel lockers and reception boxes are accepted, controlled access systems have a high level of rejection, because it implies, that the LSP has access to private space (Asdecker, 2021, pp. 9–11; Boysen, Fedtke and Schwerdfeger, 2021, p. 37).

Behnke (2019, p. 149) is evaluating the different delivery locations in terms of the recipient's unique effort and handling effort, the LSP's unique effort and handling effort and the potential CO2e reduction (Table 10). It can be seen, that for the CO2e reduction, only the parcel locker station is rated as high. For the LSPs unique effort, the parcel locker station is rated as high, while the other options have none to only small ratings. The handling efforts of the LSP are different. The parcel locker stations are decreasing the handling effort for LSP a lot, while all other options (except car trunk) only make a small handling effort necessary. With regard to the recipient's unique effort, only the parcel box needs a high effort, while the rest is either minor (parcel locker, delivery box) or dependent on the exact design (front door or garage and car trunk). The handling effort for the recipient is medium for the parcel locker station, for all other options are very small.

Table 10: Evaluation of new places (Own illustration according to (Behnke, 2019, p. 149))

	Parcel locker station	Parcel Box	Delivery Box	Front door or garage	Car trunk
R´s unique effort	Minor	High	Minor	Depend	Depend
R´s handling effort	Medium	Negligible	Minor	Negligible	Negligible
LSP´s unique effort	High	None	Small	Minor	Minor
LSP´s handling effort	High decrease	Small decrease	Small	Small	Medium
CO2e reduction	High	Small	Small	Small	Small

R = recipient LSP = Logistics Service Provider

Holdorf and Haasis (2014, p.3) are summing up different solutions and their positive and negative aspects (Figure 93). For parcel shop concepts from different LSP and pick points, the simple implementation is a positive aspect, while the limited opening hours are a negative aspect. For boxing systems like parcel lockers, there are no opening hours, but they might be capital intensive. Expanding the delivery time is rising the convenience, but at a higher price. Nearly 70% of the persons surveyed would be willing to pick up their parcels at collecting stations in case they still have to pay no or just low delivery costs. This is especially reflected by the fact that the willingness to pay for the express delivery is 5.54 Euro on average.

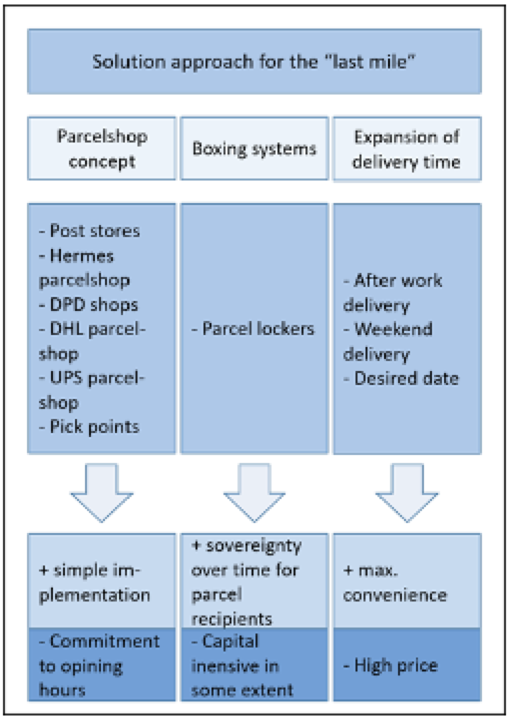


Figure 93: New Solution approaches for last-mile logistics (Own illustration according to (Holdorf and Haasis, 2014, p. 3))

For DECARBOMILE, especially the implementation of collecting points is important. In several Living Labs, Smart Lockers should be installed to improve the handover of the parcels. Regarding the Pillars of DECARBOMILE, collaboration can be an issue, if the collection points and alternative home delivery options can be used by several LSP. Also, the Business Model or Value-added services at the smart lockers are in the focus of DECARBOMILE. As the Smart Lockers are located on the infrastructure outside, the question of urban integration is important. Both options require digital infrastructure for opening and closing the places of delivery.

3.1.3 New transport process

Other concepts are changing the transportation mode from transporting the goods with vans to transporting them with rail, inland waterways or air and only delivering the last leg with a cargo-bike or van. This co-modality leads to an efficient combination and use of the transport modes either by including rail or water or transporting passenger and freights in the same vehicle (Elbert *et al.*, 2019, p. 270). Another option is the change of the vehicle used for transportation.

Micro Hubs

In a multimodal last-mile logistics, the last-mile logistics is done with at least two different modes of transport. If the goods are moved with several modes of transport in the same loading unit or vehicle, it is called intermodal transport.

This chapter focuses on the combination of water transport and road transport, as this combination will be tested during the DECARBOMILE project.

For the transport with water, goods can for example be transported to the city border by truck and are transhipped to small vessels, who are transporting the goods into the city centre. If the final destination is not directly at the water, the short last-mile by road might be necessary by vans or trucks or alternatively by cargo-bikes, foot or carts (Maes, Sys and Vanelslander, 2015, pp. 415–416; Alewijnse and Hübl, 2021, p. 605). Because of the broken transport chain and the two-echelon transport network, a small depot might be needed to provide a temporary storage space and the goods need to be handled for example with a hydraulic crane or hand trucks (van Duin, Kortmann and van den Boogaard, 2014, p. 189; Maes, Sys and Vanelslander, 2015, p. 428). If the goods are palletized, it is normally easier to transport them and the speed and efficiency of the transport operations increases. Consolidating the goods is decreasing the transport costs per unit (Maes, Sys and Vanelslander, 2015, p. 416). In order to use the inland waterways, infrastructure measures like ship fixing points, quay walls or increasing the water depth might be necessary (Maes, Sys and Vanelslander, 2015, p. 428).

For example in Utrecht, drinks and catering in rolling containers are transported on a ship with a hydraulic crane. The hydraulic crane is preventing the historic quays from damage and no extra infrastructure is needed. The boot is electric and has enough power for one day, even though there are charging points in the city. Besides the drinks and catering, also conditioned containers and building material can be transported. The transport is independent from time windows, traffic congestion, one-way streets and length or weight limitations and increases the reliability of the deliveries while being more environment-friendly. Also, the capacity and flexibility increase and the city can get a more positive image. A disadvantage is the necessity of organizational changes and a shift in costs from less transport costs per load unit to higher inventory costs. As two staff members and storage space and equipment are necessary, the operational expenses are increasing (Maes, Sys and Vanelslander, 2015, pp. 418–422).

Inland ports can function as integrated logistics centres for the urban and metropolitan areas and are normally multifunctional and multimodal. They offer transport, loading and unloading, logistics and distribution and intermodal services, production and office centres and are included in different flows. Those flows can be for example “transport of goods from storage and distribution centres located in inland ports to the sales network (stores) or direct deliveries to recipients (courier parcels), distribution of goods produced in the area of an inland port into the city / metropolitan area, transport of goods produced in the city or metropolis to storage and distribution centres located in inland ports, delivery of supplies and service maintenance of enterprises located in the areas of logistics hub or the collection of sanitary waste generated by enterprises located in the areas of the logistics hub” (Montwiłł, 2019, p. 339).

Transporting construction material on the waterway might have a huge impact, because in the EU construction is responsible for 20 to 35 % of all urban freight traffic (Brusselaers and Mommens, 2022, p. 2093). Using the water and implementing a Construction Consolidation Centre (CCC) can be beneficial to reduce negative externalities of the supply chain of constructions. A CCC “is a distribution hub for the construction industry, thanks to which material deliveries are sent just-in-time, consolidated and bundled to construction sites” (Brusselaers and Mommens, 2022, p. 2093) and has already been piloted in Valencia, Luxembourg, Paris or Verona. Furthermore, the CCC can offer different logistics services like “storage, quality check, work pack creation, pre-assembly, just-in-time, grouped or last-minute delivery, just-in-place unloading, reverse logistics and massification” (Brusselaers and Mommens, 2022, p. 2094). A CCC can increase the productivity and the on-time delivery of the trucks while lowering the costs and congestions for the construction companies. Cities can benefit from lower emissions, air pollution and accidents, fewer obstructing vehicles and a better use of the transport infrastructure. For the LSP, the flexibility and punctuality increase and the travel times and costs are decreasing. Also, the cooperation and coordination between the players increases (Brusselaers and Mommens, 2022, p. 2094).

Some pilot project for multimodal transport stopped because of problems with loading or unloading equipment and because there was no critical mass reached for the transport. Also, the existing infrastructure (height of bridges and locks, sailing width and draught) can limit the operational capacity. The waterway capacity can be expanded, but only until its physical limitations and with regard to potential environmental and safety impacts. The ship capacity can be expanded easier, especially the length and width, to reach a critical mass (Maes, Sys and Vanelslander, 2015, p. 434).

Innovative Vehicle Solutions

Another option to make the last-mile delivery more environment-friendly is the use of innovative vehicle solutions like cargo-bikes, electric cars or vans.

Using alternative and environmentally friendly vehicle solutions like cargo-bikes and porters (walkers) in combination with small storage spaces can be cost effective, if the demand density is high enough and the shipments are quite small (Bayliss *et al.*, 2022). Also, a high population density and a high traffic volume are reasons for using alternative delivery modes. Cargo-bikes can be either manually or electric powered and are already successfully implemented in daily operations in several cities like Antwerp, Vienna or Hamburg. They are independent from congested roads or access restrictions, can reach areas like pedestrian zones and can operate well in areas with limited parking space. Cargo-bikes are driving locally emission free and can decrease the external costs (emission, congestion, noise) by 40% per delivery (Boysen, Fedtke and Schwerdfeger, 2021, p. 14). The capacity of cargo-bikes is smaller than the capacity of a delivery van, therefore cargo-bikes need to be filled up during the day. In order not to lose too much time for returning to the depot and replenish shipments, cargo-bikes are normally implemented with a “network of decentralized micro- (also denoted as satellite)” hubs (Boysen, Fedtke and Schwerdfeger, 2021, p. 14). This network of cargo-bikes with mountable cargo boxes increases the complexity of the vehicle routing problem, because trailer location(s), sorting of the deliveries into cargo boxes, the routes for the cargo-bikes and the cyclists need to be managed (see also chapter **Error! Reference source not found.**). According to Boysen, Fedtke and Schwerdfeger (2021, p.15) it is q uestionable, if cargo-bikes can be “scalable for mass markets”. The potential to lower costs and to deliver the parcels on time is dependent from their velocity. Besides the price of the cargo-bikes, also the charging infrastructure for e cargo-bikes can be a disadvantage. For the aging workforce it might be difficult to deliver goods with cargo-bikes, as they demand a higher level of physical fitness than a delivery van, but on the other hand, the work can be less stressful because they don’t use congested roads (Ninnemann, 2017; Arnold *et al.*, 2018; Behnke, 2019, pp. 152–153; Boysen, Fedtke and Schwerdfeger, 2021, pp. 14–15).

Other options for innovative vehicle solutions are electric l-category vehicles (EL-Vs) like mopeds, motorbikes, quads, tricycles or other small vehicles. Because of their size, those vehicles are suitable for the deliveries of small parcels in urban areas, as they are agile, have low impacts and need limited space for parking. By using EL-Vs, delivery times can be reduced as there is no time loss for searching for parking spaces, the fuel consumption is lower or zero (electric vehicles) and the air and noise emissions are decreasing (Ranieri *et al.*, 2018, p. 7).

If the EL-Vs are not big enough, also electric delivery vans like the Mercedes Electric Sprinter or DHL StreetScooter can be used. Normally, they can operate with a 80 km to 250 km range and have a load capacity of 500 kg to 1 000 kg, while keeping into account the geography and the delivery area and zone (Behnke, 2019, p. 150; Huschebeck and Leonardi, 2020, p. 64). Electric vans work best “in the context of recurring volumes in known areas and follows the classical depot to home concept.”

(Huschebeck and Leonardi, 2020, p. 64). By using the electric vehicles, local emissions can be reduced and urban access restrictions and often road tolls can be avoided. Moreover, costs for maintenance and wear of the vehicles can be reduced up to 80%. But as those vehicles have high initial costs and need charging infrastructure and have a limited driving range, the use of electric vehicles might be more difficult (Behnke, 2019, p. 150; Elbert *et al.*, 2019, pp. 267, 273).

Metro based logistics underground

Due to the ongoing traffic problems and difficulties in street freight activities, there is always the idea of shipping goods underground from an outskirt central depot to a micro hub in the city centre. The last leg can be carried out by cargo-bikes. This concept can reduce the congestion and emissions. (Boysen, Fedtke and Schwerdfeger, 2021, p. 40). Despite being relatively competitive, the investment costs are keeping the concept from an implementation (Boysen, Fedtke and Schwerdfeger, 2021, p. 40; Hu *et al.*, 2021). To reduce these costs, a shared use of existing public transport underground lines is proposed by several authors (Hu *et al.*, 2021; Johnson and Chaniotakis, 2021; Demir, Syntetos and Van Woensel, 2022, p. 558) for which Hu et al. list an overview of existing projects in various cities in their paper (Hu *et al.*, 2021, p. 3). For implementing such a system, a network of metro system, urban distribution centres/depots with metro stops for storage and redistribution and delivery servicemen are necessary. Building up such a system is a complex task, and the public scheduled lines need to be coordinated with the vans while on the same time, the acceptance of the public needs to get reached (Johnson and Chaniotakis, 2021, p. 2; Demir, Syntetos and Van Woensel, 2022, p. 558). Also, in the crowdshipping concept (see chapter 3.1.4), the public transport can be used for the transport of goods (Boysen, Fedtke and Schwerdfeger, 2021, p. 34). The approach of using the underground for logistics operations has positive aspects for the sustainability, while it is unsure what impacts it has to handle the increased volume, time pressure and aging workforce. If the transport takes place during off-peak times, the noise pollution in those time windows might increase. Regarding the development of the costs, the authors have different opinions. While some authors say it is unclear, how the costs are developing, other say that the transportation costs are reduced because the driving time of the van is reduced (Boysen, Fedtke and Schwerdfeger, 2021, p. 35; Johnson and Chaniotakis, 2021, p. 2; Demir, Syntetos and Van Woensel, 2022, p. 558). Hu et al (2021, p.2) are missing “operation mechanism and facility functions”, which leaves a research gap in this area.

Use of autonomous vehicles

Small autonomous vehicles (AV), like delivery robots that are driving on the sidewalk or aerial drones, are seen as promising alternatives for the last-mile delivery as they are expected to improve the ecological footprint, reduce the delivery costs and improve the efficiency of operations and traffic safety (Elbert et al., 2019, p. 268; Balaska et al., 2022, p. 2).

Drones are unmanned aerial vehicles (UAV) that can be fully or partially autonomous. They typically transport only one not too heavy shipment and have a limited flight range, resulting in the necessity of providing a big fleet of drones. Therefore, it is questionable, if they can handle large amounts of shipments and are reducing costs (Boysen, Fedtke and Schwerdfeger, 2021, p. 21; Demir, Syntetos and Van Woensel, 2022, p. 556). For operating a drone fleet, a network of decentralized micro depots, where the drones can be loaded and recharged, without further handling equipment is necessary. The drone stations are delivered by vans. As in urban areas, suitable landing spaces for delivery are missing, another concept could be the delivery of lockers by drones. Another concept could be the delivery of urgent but belayed shipments to the delivery van, that has already started his tour (Boysen, Fedtke and Schwerdfeger, 2021, p. 27). Since the airspace is less crowded, autonomous flying is further along in its evolution. But Benarbia and Kyamakya (2022, p. 13) show in their study that many areas (e.g. deployment of recharging stations, vehicle routing, battery swapping, optimal amount of drones) need real field data to prove their practicability. Furthermore, the public acceptance and legal challenges need to be addressed as well (Demir, Syntetos and Van Woensel, 2022, p. 556). Advantages can be seen in the fast travel time and the electric power (Boysen, Fedtke and Schwerdfeger, 2021, p. 21).

In the last years, there has been many review papers on drones. An overview can be found in Boysen, Fedtke and Schwerdfeger, 2021, p. 22.

Unmanned ground vehicles (UGV) are operated on the ground with no human presence on board (Demir, Syntetos and Van Woensel, 2022, p. 557) and have been tested successfully in the last years (Huschebeck and Leonardi, 2020, p. 63; Gertz *et al.*, 2022). Delivery robots are traveling on the sidewalks in pedestrian speed. They are slower than drones but can carry slightly heavier shipments and have a longer range than UAVs (Boysen, Fedtke and Schwerdfeger, 2021, p. 28; Demir, Syntetos and Van Woensel, 2022, p. 557). They can be used for example to deliver to parcel post-boxes. The loading of the robot is done manually, while the unloading is autonomous (Huschebeck and Leonardi, 2020, p. 63). Another concept is the attended home delivery, were the customer needs to remove his shipment after receiving a message of the arrival of the robot (Boysen, Fedtke and Schwerdfeger, 2021, p. 28). The UGV are locally emission free, as they are electric and due to their autonomous operation, the manpower can be used for managing and organizational tasks (Behnke, 2019, p. 153; Demir, Syntetos and Van Woensel, 2022, p. 557). But as they have quite a slow delivery speed, the pressure of last-mile logistics might make the use of UGV not working (Boysen, Fedtke and Schwerdfeger, 2021, p. 28). Also in some countries, the laws for driving permissions on the roads or sidewalks are missing. Including autonomous vehicles in existing fleets might cost a lot and there are not many options (Behnke, 2019, p. 153). For delivery robots, Balaska et al. (2022, p. 4) detect two areas (perception & cognition of vehicles), which are the most challenging for autonomous driving. In terms of last-mile delivery, perception of the environment by the AV can be difficult, as deliveries can also be made in unstructured areas, i.e. not in regular traffic areas. Furthermore, the cognition for AV must be advanced, so that a safe navigation and operation in urban area can be ensured, even in unexpected situations (Balaska *et al.*, 2022, p. 5).

Both types of vehicles mentioned have the advantage of contactless delivery and are considered to be most efficient in a shared use case (Balaska *et al.*, 2022, p. 3; Benarbia and Kyamakya, 2022, p. 2). As Benarbia and Kyamakya (2022, p. 2) point out “the use of drone-based delivery is potentially very interesting for city suburbs, small villages and the countryside, all areas/contexts where the amount of parcels to be delivered is low and the delivery destinations are spatially dispersed”. But despite their promising solutions, both areas are facing a lot of challenges before reaching a market maturity.

3.1.4 Physical internet

The logistics concept of the Physical Internet (PI) aims to improve the environmental, economic and societal sustainability and efficiency of the logistics system by creating a hyperconnected logistics network and an effective interoperability by standardizing and modularizing the physical and information flows (Crainic and Montreuil, 2016, p. 388; Kubek and Więcek, 2019, p. 223; Edouard *et al.*, 2021, p. 455) (Crainic and Montreuil, 2016, p. 388; Buldeo Rai *et al.*, 2017b, p. 2; Kubek and Więcek, 2019, p. 223; Edouard *et al.*, 2021, p. 455). The PI can be seen as "as an open, global and multimodal logistics system founded on universal physical, digital, operational, business and legal interconnectivity enabled through world standard encapsulation, protocols and interfaces" (Crainic and Montreuil, 2016, p. 388). With this data-driven approach it is possible to conduct a "comprehensive and multi-dimensional data analysis" (Kubek and Więcek, 2019, p. 225) for improving the efficiency of the decision-making process. For the PI, computer technologies like Internet of Things, Big Data Analysis, Business Intelligence or Data Mining are necessary (Kubek and Więcek, 2019, p. 225). A further description of some of those technologies and the PI can also be found in the chapter 4.2.5 (Elbert *et al.*, 2019, p. 267).

The current transport and logistics process is independent from the freight movement in the PI network. The movements are consolidated with the interconnection and open cooperation between the different logistics stakeholders (e.g. shippers, carriers, logistics service providers), the logistics resources (hubs, assets, information systems, distribution centres) as well as the handling systems (carriers, vehicles) are standardised and interconnected. The trips of the goods are divided into several segments. For each segment, the most suitable means, mode and business is used. The use of open warehouses and distribution centres can shorten the delivery distance to the customers (Crainic and Montreuil, 2016, pp. 384; 389; Kubek and Więcek, 2019, p. 223).

For the transport, the standardized containers should fulfil several key characteristics which can be seen in the Figure 9496 below.

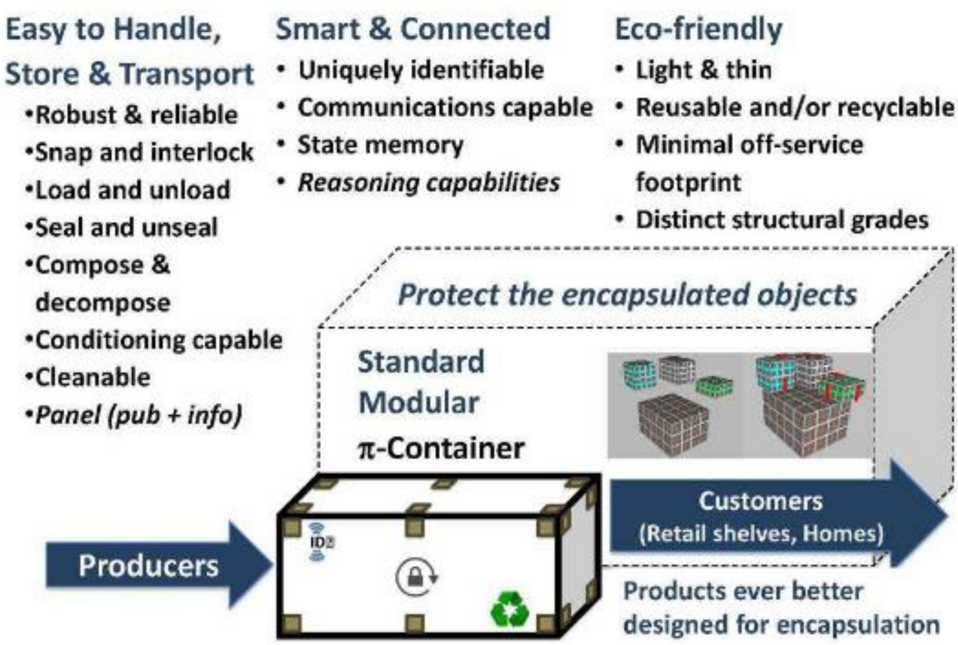


Figure 94: PI containers (Crainic and Montreuil, 2016, p. 389) after Montreuil et al., 2015)

Changing the logistics systems and its daily operations is a challenge and different stakeholders need to be involved and work together to make it happen (Demir, Syntetos and Van Woensel, 2022, p. 559).

An overview of the seven Open Logistics Interconnection (OLI)- layers (Physical, Link, Network, Routing, Shipping, Encapsulation and Logistics Web) as well as the strategic managing and planning layer, the tactical network and coordination layer and the operational layer influencing the PI can be found in Kubek and Więcek (2019, p. 227).

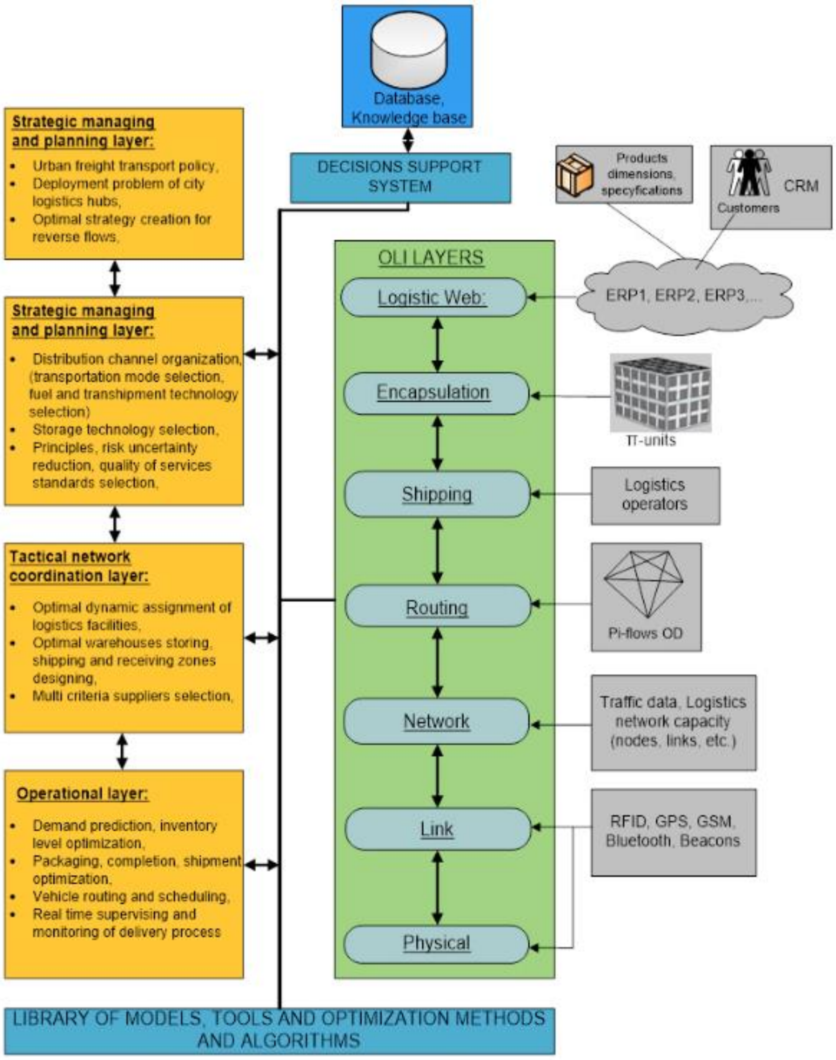


Figure 95: Open Logistics Interconnection Layers (Kubek and Więcek, 2019, p. 227)

The core components consolidation, cooperation and separation of the commercial transactions and the transport and storage of the freight can also be found in the city logistics concepts. The concepts of city logistics and the concept of the PI are therefore complementary, as the "City Logistics provides the final and last segments of the Physical Internet-enabled hyperconnected logistics and transportation networks." (Crainic and Montreuil, 2016, p. 384) With the help of the PI, the LSP can use for example real-time information from Intelligent Transport Systems (ITS) to optimize their routing by including the current travel conditions. With the PI, the efficiency, reliability and the sustainability of the urban logistic could be increased. For this reason, it is important that the city administration is offering accurate data to support the logistics service providers (Elbert *et al.*, 2019, pp. 268, 271).

According to Crainic and Montreuil (2016, p. 390), the use of a hyperconnected transportation system can reduce the induced travel by 19% and the fuel used by 29% and the average delivery time can increase by 15%. If not only the transportation is hyperconnected but also the distribution (no dedicated distribution centres), the average and maximum delivery time can be reduced by 79% and 71% and also the induced travel and fuel consumption can be reduced by 42% and 44%.

For the PI concept it is important, that not every city sets his own standards on a digital, operational, physical nor on a business model level (Crainic and Montreuil, 2016, p. 392).

The PI concept includes all pillars of DECARBOMILE. PI is a horizontal collaborative transport solutions and a new business model, which aims to optimize the space management through collaboration. It can be supported by regulations and is using several different digital infrastructures.

Crowd logistics

Crowd logistics is "an information connectivity enabled marketplace concept that matches supply and demand for logistics services with an undefined and external crowd that has free capacity with regards to time and/or space, participates on a voluntary basis and is compensated accordingly" " (Buldeo Rai *et al.*, 2017). In the concept of crowd logistics, underutilised capacity in passenger transportation can be used for the transport and delivery of goods, increasing the synchronization and consolidation of existing resources. There are four main stakeholders: the suppliers of the goods, the crowd, the customer and the digital hub, coordinating the operation. The delivery is carried out by the "crowd", meaning that persons, who are registered on the hub, are offering their free capacity, delivering the goods to the final destination and receive a compensation for this work (fixed) or from a bidding system (Buldeo Rai *et al.*, 2017; L. Ranieri *et al.*, 2018; Boysen, Fedtke and Schwerdfeger, 2021, p. 29; Johnson and Chaniotakis, 2021) (Ranieri *et al.*, 2018; Boysen, Fedtke and Schwerdfeger, 2021, p. 29; Johnson and Chaniotakis, 2021). Responding to growing customer demands and resource constraints, the concept of crowd logistics increases the capacity utilization, while also reducing the costs (Elbert *et al.*, 2019, p. 267). The concept can be either a support for the traditional van delivery or the only delivery concept. Examples for crowd logistics are UberRUSH, Cargomatic, Grabr or Amazon Flex (Boysen, Fedtke and Schwerdfeger, 2021, p. 29).

Besides the name crowd logistics, also the names crowdshipping, crowdsharing, freight-sharing, cargo-hitching, crowdsourced delivery or collaborative logistics can be found in the literature (Buldeo Rai *et al.*, 2017, p. 2; Johnson and Chaniotakis, 2021, p. 1) (Johnson and Chaniotakis, 2021, p. 1).

The concept of crowd logistics is related to the concepts of the Physical Internet (PI) and the sharing economy trend. The technology of the PI is necessary for an efficient share of the spare capacity of the vehicles and the matching between the supply and demand of the logistics services on a hub (Buldeo Rai *et al.*, 2017, pp. 1–2; Boysen, Fedtke and Schwerdfeger, 2021, p. 29; Johnson and Chaniotakis, 2021, p. 2). Also, the on-demand economy relies on the logistics structures of the PI (Huschebeck and Leonardi, 2020, p. 64).

If the delivery operations are executed with movables, who are driving anyway, the concept of crowd logistics can have environmental, social and economic benefits. Sharing the unused excess capacity improves the use of resources and reduces the number of trips, alleviates congestion and air pollution. Furthermore, it can make on-demand transport options more flexible, reliable and economical in terms of cost savings in investments and management for the businesses, carriers/crowd as well as the consumers (Buldeo Rai *et al.*, 2017; L. Ranieri *et al.*, 2018, p. 9; Johnson and Chaniotakis, 2021; Demir, Syntetos and Van Woensel, 2022, p. 558). The environmental impact is dependent on the mode of transport used. If the delivery is carried out with the public transport, by bicycle or walking, it can reduce the environmental impact significantly. If the trips are carried out by private cars or motorcycles, it may have a rebound effect, if the trip would not have been executed without the delivery request. On the other hand, deliveries with crowd logistics are more likely to be successful at the first attempt and are improving the performance of deliveries (Ranieri *et al.*, 2018, p. 9; Johnson and Chaniotakis, 2021). The main challenges for the crowd logistics are the crowd. The crowd is not employed permanently, therefore it might be difficult to scale up the concept and to be reliable in terms of the availability of drivers, so a backup solution needs to be provided (Boysen, Fedtke and Schwerdfeger, 2021, p. 29).

Table 11: Crowdlogistics and sustainability (Own illustration according to (Buldeo Rai *et al.*, 2017b, p. 8))

Stakeholder	Criterion	Sustainability		
		Economic	Social	Envirometal
Receiver	B or C			
Commissioner	B or C			
LSP	Third Party Involvement			
Platform provider	Revenue model			
	Role			
	Strategy			
	Logistics task management			
	Location dependence			
	Transparency			
	Trust generating mechanism			
	Cooperation			
	Marketing			
	Geographical scale			
Crowd	Character			
	Transport			
	Incentive			
	Motivation			
	Modal choice			
Light blue =	NO IMPACT		Dark blue =	IMPACT

The sustainability implications of the five stakeholders Receiver, Commissioner, LSP, Platform Provider and Crowd can be found in Table 1111.

The concept of crowd logistics might be helpful in terms of cost reduction. It is not sure, how it can help with the increasing volume and time pressure. The impact on the sustainability depends on the design of the crowdlogistics concept.

3.1.5 Load pooling

Load pooling is a concept based on the adaptation of “ride sharing /pooling” approach in “passenger mobility” to logistics operations. Its workflow relies on the use of an online system that matches commercial vehicles with spare capacity with customers who need delivery space. The algorithm receives information from the couriers about the available space, the route, the limitations to the receivable goods and the route of the courier, and from the customer the characteristics of the asset to be shipped, the delivery windows, the destination and the place of arrival of the package to be shipped. After receiving the information, it provides both with an optimized route and dynamic pricing based on the alternatives chosen. The goal is to maximize vehicle load utilization and reduce the number of vehicles that need to be on the roads. It can be thought of as a virtual (cyber) urban consolidation centre (Marcucci et al. 2021).

The load pooling concept is already being applied widely (almost globally) in the field within long distance (inter-city) freight operations under the name of "LTL (Less-Than-truckLoad)" and it has been also spreading in inner-city urban logistics (last-mile) operations day by day with the increasing number of actual field applications particularly in the USA and with some other examples in Europe as well.

For instance, the parcel delivery company UPS (in the USA) announced in July 2022 that they started their first pilot program (with "CommerceHub") for the load pooling concept. According to the announcement made by the company, a new delivery process is developed in order to hold an order virtually on an order management system until it can match another shipment to the same address. Once the system matches the orders, it applies a certain level of discount to the relevant UPS client (e-commerce merchant/sender) for the additional order in return for the close distance between the delivery locations of the orders. Through that pilot program, the parcel delivery company aims to increase the average load ratio of its vehicles while decreasing the number of stops during delivery travels.

In Europe, there are some grocery chains (such as Ocado, Sainsbury's, etc.) applying the load pooling concept as "green delivery options". Through this approach, which is quite similar to that of UPS mentioned above, the merchant informs its customer on the delivery booking stage (page) for the time (delivery) slots already scheduled to deliver to the customer's nearby with financial (pricing) incentives on delivery fees, with an aim to increase delivery productivity through the involvement of customers (Yang *et al.*, 2016)) (Figure 97).

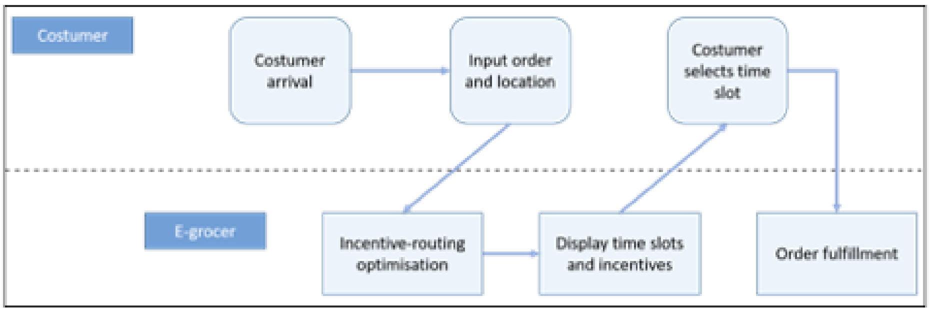


Figure 96: E-commerce ordering process in general with dynamic pricing incentives (Own illustration according to (Vinsensius et al. 2020))

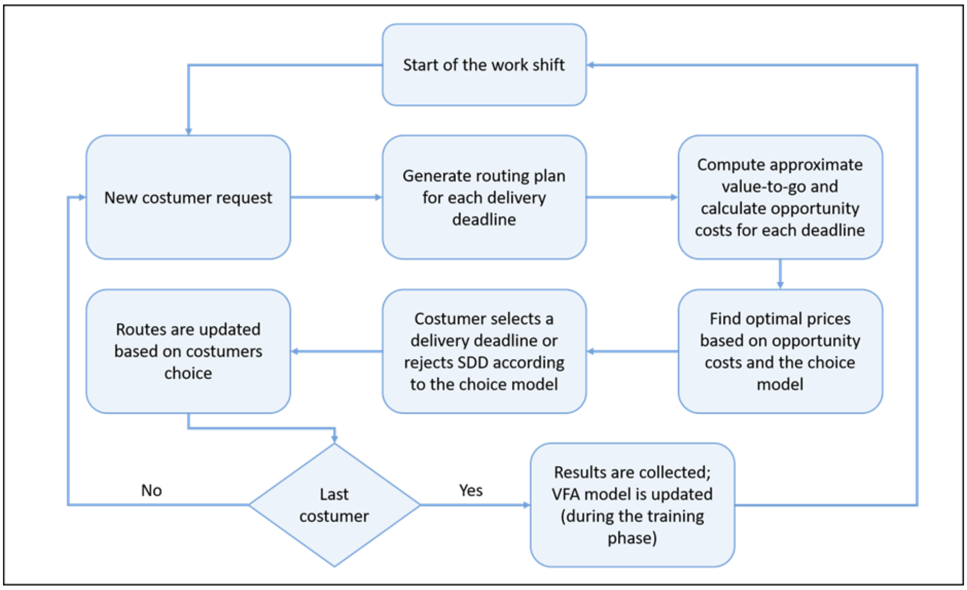
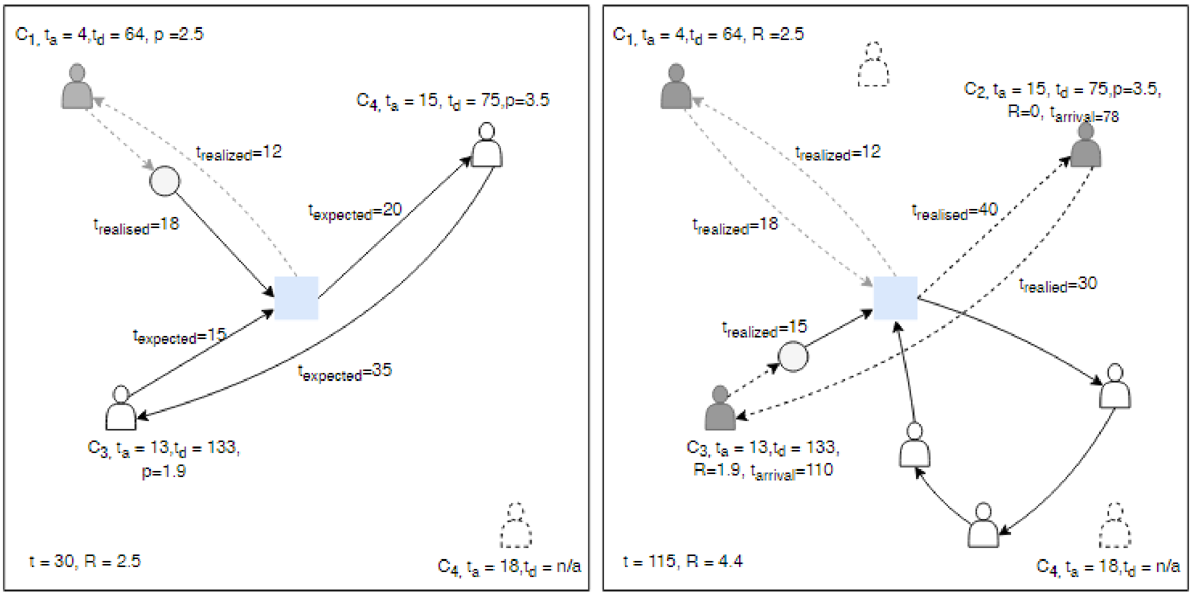


Figure 97: E-commerce ordering process in detail with dynamic pricing incentives (Own illustration according to (Prokhorchuk, Dauwels and Jaillet, 2019))



Square = depot, finished routes = dotted arrows, planned routes = solid arrows, served customers = shaded, customers who choose next-day delivery = dotted

Figure 98: Illustration of "Dynamic Pricing for Same-Day Delivery Routing" at two-time instances (Prokhorchuk, Dauwels and Jaillet, 2019)

Despite the increasing trend that the load pooling recently gained in the real world, quite a few academic studies have been made to date in order to display its benefits in urban logistics. It was first introduced (proposed) in the vehicle routing literature as "Vehicle Routing Problem in a Competitive Environment (VRPCE)" (Figliozzi, Mahmassani and Jaillet, 2007) and later classified as "dynamic/differentiated pricing/slotting" approaches in demand (and also revenue) management (Table 12). Table 12The majority of the existing studies regarding load pooling gather around local retail (grocery) delivery operations (the case in which the merchant delivers its own selling items through its own fleet with multiple stops routes – also known as "Vehicle Routing Problem With Time

Windows / VRP-TW") by almost ignoring (neglecting) all the other types of delivery flows in urban logistics such as express parcel (package) delivery, on-site services, instant/quick (on demand) delivery and B2B operations etc.

Table 12: Classification of Demand Management (Klein et al. 2019)

	Time slot allocation	Time slot pricing
Static (offline, forecast-based)	Differntiated slotting (a)	Differentiated pricing (d)
Dynamic (real-time, order-based)	Dynamic slotting (b)	Dynamic pricing (c)

The results obtained by those abovementioned studies varies from one to another rising from the diversity of problem definition, mathematical models and decision factors applied (used) and/or considered. The studies report that deliverers (merchants, distributors) may get additional gains ranging from 5% to 70% in profits, customers and they can also decrease their delivery costs in the same range. Through the list below is a summary of existing studies (Table 13).

Table 13: Summary of existing studies

	Study	Industry	Mathematical Model	Decision Factors / Scenarios	Results And Benefits
1	(Klein and Steinhardt, 2023)	Attended Home Delivery (within VRP-TW)	An Approximate Dynamic Programming (ADP) model (based on Bellman equation) introduced/proposed/presented by the study itself for estimation / approximation/ anticipation of fulfilment / delivery/ transportation/ opportunity cost.	• Fleet capacity levels / fleet size (number of vehicles) • Order density (number of customers served) • Customer segments	10–50% increase in revenue depending on fleet sizes.
2	(Akkerman, Mes and Lalla-Ruiz, 2022)	Grocery Delivery	A regression model (instead of heuristic methods) introduced/proposed/presented by the study itself (called “RFR: Random Forests Regression”) for estimation/ approximation/ anticipation of fulfilment / delivery / transportation / opportunity cost		• 1-6% more customers • 6-11% decrease in travel costs depending on sensitiveness of customers on prices
3	(Vinsensius *et al.*, 2020)	Grocery Delivery	An Approximate Dynamic Programming (ADP) approach introduced/proposed/presented by the study itself for estimation / approximation / anticipation of the marginal fulfilment / delivery / opportunity cost	• Fleet capacity levels (number of vehicles) • Order density • Arrival probability of customers to the online store	Between 30% - 70% decrease in total delivery costs depending on the incentive scenarios offered and applied in the study.

4	(Ulmer, 2020)	Grocery delivery	An Approximate Dynamic Programming (ADP) approach introduced / proposed / presented by (Ulmer, 2017) (called "VFA: Value Function Approximation") for estimation / approximation / anticipation of the marginal fulfilment / delivery / transportation / opportunity cost	• Fleet capacity levels (number of vehicles) • Order density	When compared to fixed (static, constant) pricing delivery scenarios: • 13.2% increase in revenue • 3.9% increase in the numbers of customers served
5	(Koch and Klein, 2020)	Grocery Delivery	An Approximate Dynamic Programming (ADP) approach introduced / proposed / presented by (Ulmer, 2017)(called "VFA: Value Function Approximation") for estimation / approximation / anticipation of the marginal fulfilment/delivery / transportation / opportunity cost	Fleet capacity levels / fleet size (number of vehicles)	Between 2% and 5% increase in profit (depending on fleet capacity levels) compared to fixed (static, constant) pricing delivery scenarios
6	(Lebedev, Margellos and Goulart, 2020)	Grocery Delivery	Three different approximate dynamic programming algorithms (both from a control-theoretical perspective and in a parametric numerical case study) for opportunity (delivery) cost estimation/approximation/anticipation	• Fleet capacity levels / fleet size (number of vehicles) • Order density (number of customers served)	From 10% to 15% increase in profit compared to fixed (static, constant) pricing delivery scenarios

7	(Mackert, 2019)	Grocery Delivery	• Two Mixed-Integer Linear Programs (MILP) introduced (proposed, presented) by the study itself (namely called "OCS-R" and "OCS-AR") for opportunity (delivery) cost estimation/approximation/anticipation. • For time slot offer decisions; this study linearizes a previously introduced (proposed) non-linear binary program (which uses "choice-based conjoint analysis"). That non-linear binary program is introduced (proposed) at (Chen and Hausman, 2000)	• Fleet capacity levels (number of vehicles) • Number and width (size) of delivery areas • Number of time slots (or average time length per a single time slot)	5% profit increase compared to fixed (static, constant) pricing delivery scenarios
8	(Prokhorchuk, Dauwels and Jaillet, 2019)	Grocery Delivery	An Approximate Dynamic Programming (ADP) approach introduced / proposed / presented by (Ulmer, 2017)(called "VFA: Value Function Approximation") for estimation / approximation / anticipation of the marginal fulfilment / delivery / transportation / opportunity cost		• More than 5% increase in revenue • Up to 40% decrease in missing customers
9	(Klein *et al.*, 2018)	Grocery Delivery	An opportunity (delivery) cost estimation / approximation / anticipation approach introduced (proposed, presented) by the study itself	Fleet capacity levels	5.5% profit increase compared to fixed (static, constant) pricing delivery scenarios

10	(Yang and Strauss, 2017)	Grocery Delivery	An opportunity (delivery) cost estimation / approximation / anticipation approach (called “OC-CR”) introduced (proposed, presented) by the study itself	Order density/size (number of totes) in total	2% profit increase compared to fixed (static, constant) pricing delivery scenarios
11	(Ulmer, 2017)	Grocery Delivery	An Approximate Dynamic Programming (ADP) approach introduced/proposed/presented by the study itself (called “VFA: Value Function Approximation”) for estimation / approximation / anticipation of the marginal fulfilment / delivery / transportation / opportunity cost.	• Fleet capacity levels (number of vehicles) • Order density	• 13.2% increase in revenue • 3.9% increase in customers served
12	(Yang *et al.*, 2016)	Grocery Delivery	• An opportunity (delivery) cost estimation/approximation/anticipation approach (called “Choice-Based Foresight Policy”) introduced (proposed, presented) by the study itself. • Multinomial Logit (MNL) Model for customer choice behaviours	Fleet capacity levels	From 2.6% to 6% profit increase compared to fixed (static, constant) pricing delivery scenarios
13	(Figliozzi, Mahmassani and Jaillet, 2007)	Long Distance Freight Transportation (with trucks)	• This is the first study introducing (proposing) the load pooling concept to the vehicle routing literature with its first mathematical definition as “Vehicle Routing Problem in a Competitive Environment (VRP-CE)”. • An approximate solution approach with a finite look-ahead horizon	• Length (number) of time windows • Order density (arrival rate of customers to the online ordering system)	From 0.1% to 79.8% profit increase (depending on the order density and length of time windows applied) when compared to fixed (static, constant) pricing delivery scenarios

The study below investigates the "differentiated pricing" instead of "dynamic pricing".					
14	(Klein *et al.*, 2019)	Grocery Delivery	• Three mixed-integer linear programming formulations (namely called "DTSPP", "DTSPP-G" and "DTSPP-TB") introduced/proposed/presented by the study itself for opportunity (delivery, fulfilment, transportation) cost estimation (approximation, anticipation • A general nonparametric rank-based choice model introduced (proposed, presented) by the study itself for modelling customer choice behaviours	• Fleet capacity levels (number of vehicles) • Number and width (size) of delivery areas • Customer segments	Minimum 5.6% better performance compared to fixed (static, constant) pricing delivery scenarios
The study below just investigates the use of "green delivery labels" instead of "financial / pricing incentives".					
15	(Agatz, Fan and Stam, 2021)	Grocery Delivery	A multinomial (MNL) regression analysis to estimate the utilities for the different slots featured with various labels and price incentives.	• Fleet capacity levels (number of vehicles) • Order density (number of customers served)	• From 8.9% to 12.6% decrease in delivery costs. • Green labels intrinsically motivate to work in fundamentally different ways than commonly studied in extrinsic motivators (price promotions). • Green labels and price promotions/price incentives do not work well together. •

This study below just investigates the management of slot offering processes from only the retailer side (customers are not involved). There are no financial (pricing) incentives in this study.					
16	(Randall, Kheiri and Letchford, 2022)	Attended Home Delivery (within VRP-TW)	The main goal in this paper is to gain insight into how certain parameter choices affect key performance measures in slot offering processes, such as the number of customers served and the total travel time without implementing any complex mathematical model.	• Length (number) of time windows • Order density (number of customers served)	10% additional contribution to "travel times" and "number of orders delivered by per vehicle"
The two studies below (no 17 and 18) investigate contributions of pricing incentives for "flexible time slots" a process that customers may let the merchant choose the delivery slot itself in order to select the most productive route. In this process, the customer agrees to be informed only shortly prior to the dispatching of the delivery vehicle in which regular time window the goods will arrive (known as "no rush delivery" applications in the industry).					
17	(Strauss, Gülpınar and Zheng, 2021)	Grocery Delivery	A Linear Programming (LP) model introduced / proposed / presented by the study itself for estimation / approximation / anticipation of a) the marginal fulfilment/ delivery/ transportation/ opportunity cost b) the marginal revenue expected from that delivery	Number of flexible slots	Up to 13% increase in profit compared to fixed (static, constant) pricing delivery scenarios
18	(Yildiz and Savelsbergh, 2020)	Attended Home Delivery (within VRP-TW)	A dynamic programming algorithm proposed by the study itself to compute optimal discount offers.	Order density (number of customers served)	Up to 30% decrease in total delivery cost compared to fixed (static, constant) pricing delivery scenarios

The studies below investigate the results of distance (route) based pricing incentives in different last-mile delivery industries.					
19	(Zhou, Mandania and Liu, 2022)	On-site services (Traveling Repairman Problem)	• A green time-dependent vehicle scheduling and routing model built with "Parallel variable neighbourhood search" and "Dynamic programming to optimise departure times". • A pricing model built with non-linear programming	Demand (order) density (number of customers served)	Increase in revenue between 8% and 13.25% depending on order density
20	(Gevaers, Van de Voorde and Vanelslander, 2014)	Parcel Delivery	This study investigates if and how financial incentives can be applied for the parcels (packages) to be delivered in dense urban areas (such as central regions of cities with dense working places) from the deliverer's profit/revenue/cost perspective by proposing (introducing) a B2C last-mile cost calculation model per package.		Up to 45 % decrease in delivery costs depending on density (closeness) of delivery points (locations) and amount of financial incentives

From the existing studies indexed above, it is emphasized that improvements in the reported range (i.e., over 1%) might appear small but might have a large impact on a company's success and are usually perceived as large in revenue management. This is because the improvements can be achieved without additional fixed costs and therefore directly contribute to the operating profit (Koch and Klein, 2020).

Although the literature on these problems is substantial, most of the existing papers consider highly specific problems, which makes it hard to know whether the conclusions are likely to remain valid for other problems (Randall, Kheiri and Letchford, 2022) .

Another additional point that might be expressed here is that all the studies regarding "dynamic pricing and slotting" approaches for VRP-TW problems were carried out through a Euclidean plane mindset without using actual distance data (matrices) from geographical information systems or mapping hubs.

Research gaps for load pooling include:

- Future research may focus on extensions of the problem and the methodology. The models proposed to date may be extended to a multi-depot setting where vehicles may pick up goods on several warehouses in the service area (Ulmer, 2020).
- Future research may also focus on what load pooling might bring in terms of the public good while the existing studies mainly prioritize the deliverer's (distributor's) gains.

3.1.6 Conclusion

The above presented concepts showed a wide variety of possible changes in the "traditional" logistics concepts. All concepts have different advantageous and disadvantageous and normally, a combination of different concepts is necessary in order to fit bests to the local circumstances.

The literature review of He (2020) is analysing research gaps to promote the urban logistics systems sustainability by analysing innovative schemes of freight network design. The authors identified 11 distribution innovations (electric vehicles, modular E-vehicles, public transit logistics (passenger and freight together), urban waterway logistics and taxi logistics (taxis used for transporting goods), cargo-bikes, robotic vehicles, delivery drones, parcel lockers, mobile depots, units consolidation (without UCC) and ICT solutions), while the papers are mostly using mathematical modelling and case/scenario studies. But many studies lack a systematic consideration of integrating all distribution innovations into urban freight network design and are also missing a feasibility analysis and risk evaluation.

In the chapter 4.3, the literature on network design will be presented.

3.2 The five pillars of DECARBOMILE

In the following section, the findings from the literature for the five pillars of DECARBOMILE (collaboration, business models and value-added-services, urban integration and space management, regulation and digital infrastructure) are described. For the pillars, a systematic literature review has been conducted, leading to around 2 200 results. After checking the titles and abstracts, around 470 seemed be suitable at the first view. After going through those abstracts again and regarding the

DECARBOMILE project and the use cases, more papers have been sorted out. The texts about the pillars are based on the remaining 80 papers.

For every pillar, a short description and the findings of the literature are presented. Moreover, the barriers and challenges for the pillars and potentials ways to overcome those barriers are presented. The presented pillars are highly interrelated with the logistics concept, making an exact delimitation difficult.

3.2.1 Collaboration

This section analyses selected literature in the research field of collaboration in urban and last-mile logistics. The following text is structured first by a look into existing literature reviews and their focus. Second different types of collaboration mentioned in literature are presented, followed by third the potentials and barriers of collaboration discussed in literature as well as possible sustainable effects. For all sources also the used method is mentioned as it shows, which qualitative or quantitative methods are relevant in the existing literature about collaboration.

For the collaboration pillar, a systematic literature review with the search string (TITLE-ABS-KEY ("last mile" OR "city logistic*" OR "urban logistic*" OR "urban freight transport*") AND TITLE-ABS-KEY (collaboration OR cooperation OR shared OR crowd)) was conducted in Scopus and Web of Science. The 1 348 results included 294 duplicates, leading to 1 054 findings. From those findings, the titles and abstract were read. Out of that analysis, 95 papers seemed suitable. From those papers, 16 have been studied in detail, because they seemed to fit best in the DECARBOMILE context.

There are already existing literature reviews in the field of collaboration. Carvalho et al. (2020) provided a brief overview of different types of collaboration in last-mile delivery and involved stakeholders, like “generators of transport demand, transport operators, and interface roles”, based on literature to develop a research agenda for collaboration in logistics. Saglietto (2020) got more detailed and reviewed 85 articles from 2007 to 2019 to identify the main structure and trends in the literature on sharing economy logistics and crowd logistics. Identified trends are “optimization of urban logistics problems”, “mobilization of crowd logistic for efficient business crowdsourcing” and “shared mobility for last-mile delivery”. The author also stated that future research on crowd cyber systems and crowd intelligence would help on the development to Logistics 4.0 (explanation see chapter 3.1.4). By reviewing state-to-practice and state-to-research literature Pourrahmani and Jaller (2021) identified the challenges and opportunities of crowd shipping in last-mile deliveries connected to cost reduction, working conditions and preferences, trust, security, reliability and level of service, environment, equity and society, infrastructure as well as pricing and payments. The authors showed "that there is a mismatch between the practical challenges and the scientific solutions". In comparison to the more general approaches Cleophas et al. (2018) presented a literature review for operations research approaches for collaboration in urban transportation with a focus on vertical and horizontal collaboration.

“For vertical collaboration, transport is often organized along modes and service operators. For instance, the first leg within the city may be carried out by conventional trucks, whereas the last-mile to the recipient may be operated by environment-friendly city freighters or freight bikes.” (Cleophas *et al.*, 2019, p. 3).

Horizontal collaboration is, according to Cleophas et al. (2018), the cooperation of multiple providers "in the same section of the transport chain, potentially sharing orders and infrastructure." (p. 3) The authors analysed real-world collaboration based on existing projects, like CarGoTram, Monoprix, Border Courier Service, and others.

The already existing literature reviews showed that there are different types of collaboration. To get a better overview of these potential types, further literature was analysed. Especially horizontal collaboration and the use of urban logistics hubs or urban consolidation centres (UCC) is a highly discussed topic within the last years. Nataraj et al. (2019) used a metaheuristic algorithm to analyse the location of UCC for horizontal collaboration and to analyse different levels of collaboration of the actors in the UCC . De Souza et al. (2019) analysed horizontal collaboration by integrating the concept of 4th party milk run (4PMR) and used an optimization model and two scenario calculations based on the cities Jakarta and Surabaya in Indonesia. The authors showed that 4PMR can reduce last-mile logistics costs with a small number of deliveries up to 4.16 % and with a large number of deliveries by 24.84 %. Allen et al. (2017) examines the challenges on the parcel last-mile delivery and creating the concept of "Freight Traffic Controller" by using a combinatorial optimisation approach of literature, a survey and practical insight of two carriers for the UK market. Freight Traffic Controller are "a trusted third-party, assigned to equitably manage the work allocation between collaborating carriers and the passage of vehicles over the last-mile" (p. 2). Hribernik et al. (2020) created a blockchain decision framework for CEP carriers to promote a collaboration in logistics and last-mile distribution.

Potentials And Challenges Of Collaboration

The analysis of the different collaboration types showed that there are multiple potentials when it comes to collaboration in urban and last-mile logistics. But barriers can also arise with the concepts and can hinder the implementation of collaboration. With the help of a qualitative approach, with focus groups, semi-structured interviews and a survey, Lindwati et al. (2014) identified potential motivations, like reduction of costs or improved reliability, and barriers, such as no competent staff or insufficient IT capacity, for collaboration in urban logistics by the example of Singapore. The authors showed that two factors matter when it comes to collaboration: on the one hand "the perceived benefits of collaboration" and on the other hand "the risk of losing competitive intelligence". With a comparable approach, based on two surveys in Bristol, UK, and Cagliari, Italy, Paddeu et al. (2018) also identified potential drivers and barriers for collaboration but in UCC. On the one hand the collaboration in UCC can reduce emissions and there is a high willingness in large companies for shared logistics, while on the other hand the financial sustainability is insecure and a collaboration is highly dependent on the type of good to be delivered. Especially perishable goods can be difficult to manage through UCC because of higher quantities or special storage and transport conditions like cooling. Moreover, Raicu et al. (2020) provided solutions for using horizontal collaboration at urban distribution centres located at the boundaries of urban congested areas to consolidate flows of goods. Based on three scenarios results, it showed the possibilities of consolidating from the perspective of the involved actors with a focus of the road infrastructure used. Furthermore, Russo et al. (2021) analysed the cooperative use of an urban logistics hub by different courier, express and parcel providers (CEPs) to offer guidance for designing a more sustainable last-mile logistics using the example of Vienna. The authors identified that involved stakeholder groups like CEPs, citizens and city administration have conflicting as well as common goals. A common goal is for example the importance of reducing regional and global emissions, while societal awareness-raising is of less importance to all three stakeholder groups. There is also a wide range in perceptions of opening hours and customer service, with these being less important to the city administration and CEPs than to citizens.

Effect On Sustainability

In addition to the potentials and barriers from the perspective of the stakeholders, the different types of collaboration can lead to effects on the sustainability of the supply chain from an ecological and an economical perspective. Do et al. (2019) showed that logistics collaboration can lead to a reduction of environmental impacts with the example of pharmaceutical suppliers in Seoul, Korea using a microscopic trucking routing model. Also, Yao et al. (2019) calculated, next to the growth of profit, the CO2-emissions of two collaborating carriers based on a lane-covering-problem by a computational study. The study showed that collaboration has a positive effect on the emissions. Muñoz-Villamizar et al. (2019) evaluated the use of a mix vehicle fleet in horizontal collaboration and showed that the use of gasoline vehicles is more profitable on the short-term while electric vehicles are more advantageous in the mid-term. However, the authors stated that all in all the ecological benefits of electric vehicles are in relation higher than the economic benefits of gasoline vehicles, as ecological reductions were in best case up to 22% "with economic overruns of only 2% in operational costs" (2019, p. 27).

From an economic perspective, Serrano-Hernandez et al. (2016) identified, with the help of an agent-based model, that horizontal cooperation in last-mile distribution might result in an increase of service quality by a reduction of lead times. In a further study Serrano-Hernandez et al. (2018) assesses these impacts in a business-to-business relationship also by using an agent-based simulation and showed that lead times can be reduced through wholesaler collaboration, though trust-issues can be a barrier for more improvement in the service quality. The findings were based on a case study of Vienna, Austria. Rabe et al. (2018) examines the use of horizontal collaboration with UCC in Athens, Greece, and its outskirts by using a discrete event simulation and showed that the use of UCC in city logistics can lower the number of tours, decrease distances and shorter the length of tours.

The different effects were often analysed based on simulation models with routing problems. El Ftouh et al. (2020) had a deeper look into the used methods and presented "a classification of carriers' collaborative routing problems according to type of planning [...] and a review of the most popular routing problems related to city logistics". Wang et al. (2020) formulated and solved a two-echelon collaborative multi-depot and multi-period vehicle routing problem to analyse collaboration across multiple time periods by using an empirical study of the city Chongqing, China.

To sum it up, the existing literature reviews collected relevant publications were the different types of collaboration involved in urban and last-mile logistics is described. This literature provides a further insight and shows that there is already a wide range of topics discussed, like potential and barriers or ecologic and economic effects. Furthermore, qualitative methods like interviews or surveys as well as quantitative methods like agent-based or discrete-event simulations which are used to analyse these possible effects, were identified in this review. From the mentioned finding in the literature, it can be derived, that collaboration can have positive effects from an ecological and economical perspective, but barriers are still a high burden to implement collaboration into urban and last-mile logistics.

Currently, several collaboration hubs are being tested in different project on urban logistics. Some of those hubs are presented below.

Existing Digital Collaboration Hubs AND Projects For Urban Logistics

For some recent years, several initiatives have been observed in order to enable digital collaboration within urban logistics operations through the partnership of public and private sector. The continent Europe is considerably stepping forward according to the number of current active (and also past completed) projects when compared to the other regions of the world. When the urban logistics literature is scanned, the following below projects come to the forefront however there is a lack of publicly available information in the literature describing the actual benefits they bring to real-world operations with measured (actual) metrics (numbers).

The SENATOR project, as an Horizon 2020 project, aims to produce governance schemes on user-demand planning, transport planning, freight and logistics planning, and city infrastructure (Giuffrida *et al.*, 2022).

The LEAD project, as another Horizon 2020 project, allows testing innovative solutions to generate a sustainable inner-city logistic service for parcels. Important approaches for sustainable parcel logistics in that project include crowd-shipping solutions, hub-based approaches and public consolidation places like mobility hubs (Tapia, Kourounioti and Tavasszy, 2021).

The ULaaDS project, as the third Horizon 2020 project, supports the deployment of novel, feasible, shared, and zero-emission solutions by offering a new approach to system innovation in urban logistics. Through the re-localisation of logistics activities and the re-configuration of freight flows at different scales, the project aims to develop sustainable and liveable cities, allowing people and local businesses to easily use alternative modes of shopping and delivery by translating its findings into open decision support tools and guidelines that urban areas can adopt to identify, explore and assess different sets of intervention measures to deal with the requirements of urban logistics (Kanak *et al.*, 2022).

The workflow of the CUDO hub (in Singapore) is outlined as follows. During the day, the customers (i.e., tenants in shopping malls) place delivery orders to their contracted LSPs. An order indicates the location, the amount of goods to be delivered on the next day, and the time window within which the delivery should be made. Each LSP submits its orders to the CUDO hub by a certain cut-off time. The CUDO hub will then generate the routes of all the delivery orders and schedule the (dock) time slots at the shopping malls, all to be done within one hour. Specifically, this means that the hub will decide which order is assigned to which vehicle and to what time slot (the usage of a dock) at a shopping mall, along with the vehicle routes. The scheduled time slots are then reserved via the interface with the various external Dock Scheduling and Queuing (DSQ) systems. On the next day, a vehicle will serve the orders according to the plan, and a shopping mall will manage the vehicles' entrances based on the time slot reservations (Song *et al.*, 2022).

A recently completed research project KOMBINOM (in Frankfurt, Germany) analysed the potential regarding the handling, generation and processing of specialized data from the field of passenger transport and logistics in rural areas with regard to a fully comprehensive simulation of combined transport concepts through the use of autonomous vehicles (Schocke, Becker and Henninger, 2021).

Another project being carried out under the name of "RIDE-PARCEL POOLING" (in Munich, Germany) examines the integration of freight delivery into the passenger transport of an on-demand ride-pooling service with the goal to use existing passenger trips for logistics services and thus reduce additional vehicle kilometres for freight delivery and the total number of vehicles on the road network. (Fehn *et al.*, 2023).

Through the "Sii-MOBILITY" project (in Italy), as a national smart city project on mobility and transportation, a flexible hub has been designed in order to enable setting up heterogeneous and complex scenarios that integrate sensors/actuators as IoT/IoE in an overall Big Data, Machine Learning and Data Analytics scenario (Badii *et al.*, 2018). There are also some other countries following the approach in Italy with similar national MaaS hubs such as DŌCŌ in Spain, TROTA in Turkey, UMAJI in Taiwan etc.

In addition to those existing projects above it is also recommended in the urban logistics literature that "an effective partnership between the public and private sector should be established in the North and South America as well for digital collaboration of freight transportation operations" (Goldsmith, Gardner and Jamieson, 2021) .

3.2.2 Business models and value-added services

The second pillar of DECARBOMILE are the business models. Business models in last-mile logistics (LML) are diverse and encompass both traditional and more recent models. These include well-established concepts such as parcel delivery service providers, like DHL or UPS, as well as newer approaches that are based on principles of the sharing economy. In this chapter, firstly the well-known logistic principle of urban consolidation centres (UCC) is going to be presented. Subsequently the concept of the sharing economy in the context of last-mile logistics will be introduced. It will examine two specific business models that are based on the sharing economy principle (shared warehousing and crowd logistics), providing an overview of their structure, key challenges, resource requirements, and potential points of implementation within the supply chain. The objective of this chapter is not to provide a comprehensive examination of one business model, but rather to offer a general understanding of the various elements that comprise a business model in the field of last-mile logistics.

For the Pillar Business Model, a systematic literature review (SLR) was conducted in Scopus and Web of Science with 753 results, including 123 duplicates. After removing the duplicates, from the 630 results the title and abstracts have been analysed, from which 206 appeared suitable for the topic. Of those papers, 12 were most suitable for DECARBOMILE and have been analysed in depth.

To start with, a general definition for business models is given: "A business model is a conceptual tool containing a set of objects, concepts and their relationships with the objective to express the business logic of a specific firm. Therefore, we must consider which concepts and relationships allow a simplified description and representation of what value is provided to customers, how this is done and with which financial consequences" (Osterwalder, Pigneur and Tucci, 2005).

A table with more definitions can be found in Wirtz (2019, pp. 9–11)

Urban consolidation centre

UCCs are logistics facilities situated in suburban or inner-city regions, where goods from multiple suppliers are brought together before being dispatched to a specific location, like an entire city, its downtown area, or a specific shopping centre (see Figure 99). UCCs are used to combine loads from various carriers, which can lead to more efficient delivery plans, better utilized trucks, and higher service levels. They play a key role in the supply chain by constituting the nodal points where cargo assembled is transhipped from large and polluting heavy good vehicles (HGVs) to smaller, cleaner, and more flexible vehicles that perform the last-mile distribution in urban areas. Another objective is to decrease the overall distance travelled when delivering goods to urban areas and to reduce the negative environmental impact by boosting the load factor of vehicles that enter the city. They also aim to make urban freight transport more sustainable by decreasing the number of vehicles entering a city, which would alleviate issues related to urban freight transport such as congestion, pollution, and reduced safety. Theoretically, a UCC is expected to make the transition to zero-emission vehicles easier, reduce route lengths, decrease pollution, and lower costs. However, consolidation can also be achieved through various means such as using existing local distribution centres, modifying the behaviour of actors, and collaborating horizontally or vertically with various players in the supply chain (Nordtømme et al., 2015; Gogas und Nathanail, 2017; Hezarkhani et al., 2019; Dreischerf und Buijs, 2022).

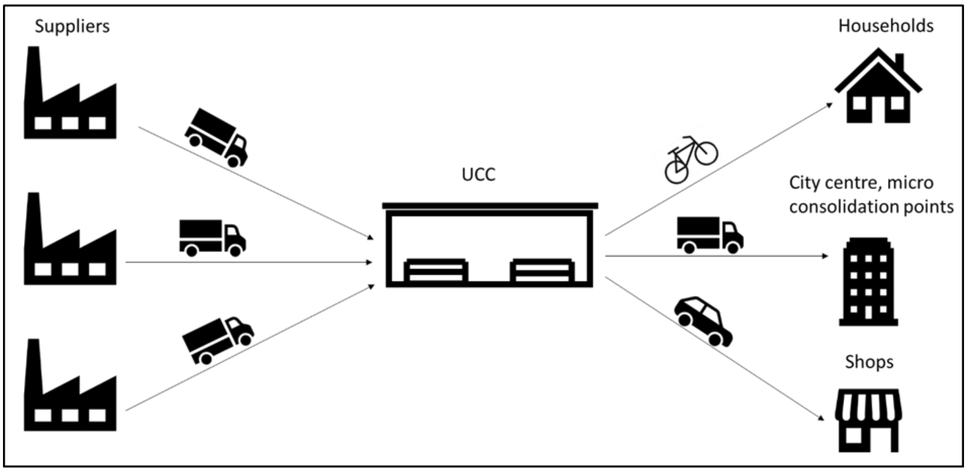


Figure 99: Urban Consolidation Centres (Own illustration according to (Hezarkhani, Slikker and Van Woensel, 2019; Dreischerf and Buijs, 2022))

Implementing UCCs can be challenging and may come with financial challenges. UCCs require the collaboration of multiple parties, including local authorities, companies, and scholars, which might be difficult. Additionally, UCCs are often not economically viable, and the benefits they provide may not outweigh the costs of their implementation (Dreischerf and Buijs, 2022). The main financial challenge is to determine how to share the savings and costs, and make sure that these mechanisms are equitable and transparent. Research suggests that the majority of initiatives in urban logistics collaborations fail during implementation. One of the main barriers to the success of UCCs is the deficiency of the mechanisms used to share the savings among, or cover the costs from, the participants. Carriers may hesitate to collaborate if they do not have a clear understanding of the mechanisms employed and whether or not they will receive a fair share of the collaborative operations (Hezarkhani, Slikker and Van Woensel, 2019).

Sharing economy

The sharing economy is a business model that focuses on temporary access to goods and services over ownership. It is also known as peer economy, collaborative economy, on-demand economy, or collaborative consumption. Members of sharing communities can temporarily rent items or buy services from one another (peer-to-peer). In this scenario, provider and contractor are independent private persons (peers). However, it is also possible that services are sold from business-to-business (B2B), for example shared warehousing or business-to-Customer (B2C) (e.g. conventional last-mile delivery). The use of information technology (IT) is an essential part of the sharing economy, as it enables various types of transactions between businesses, consumers and peers. The sharing economy is particularly developed in cities and has a significant impact on the lives of its users, as it allows them to temporarily access goods and services, they may not be able to afford to own. In the context of last-mile logistics, the sharing economy refers to the sharing of delivery vehicles, warehouses, logistic data, staff or other logistics resources among multiple businesses. This can help retailers meet the changing expectations of consumers for fast, cost-effective delivery and ease of returns by providing more distribution choices and maintaining high-level service while reducing costs. Additionally, the sharing economy model can also provide significant environmental benefits such as increased efficiency of use of resources, reduced waste, reduced number of vehicles thus reducing traffic congestion and emissions and allowing small businesses to have access to delivery resources they would not have been able to afford otherwise. It addresses the three constituents of sustainability – economic, social and environmental. However, the sharing economy is still in its early stages of development and considered as an umbrella term for a variety of organizational models that are transforming marketplaces and cityscapes (Behrend and Meisel, 2018; Rogers *et al.*, 2020; Y. Li *et al.*, 2020; Strulak-Wójcikiewicz and Wagner, 2021).

Figure 100 shows examples of where sharing economy business models can be implemented in the field of last-mile logistics.

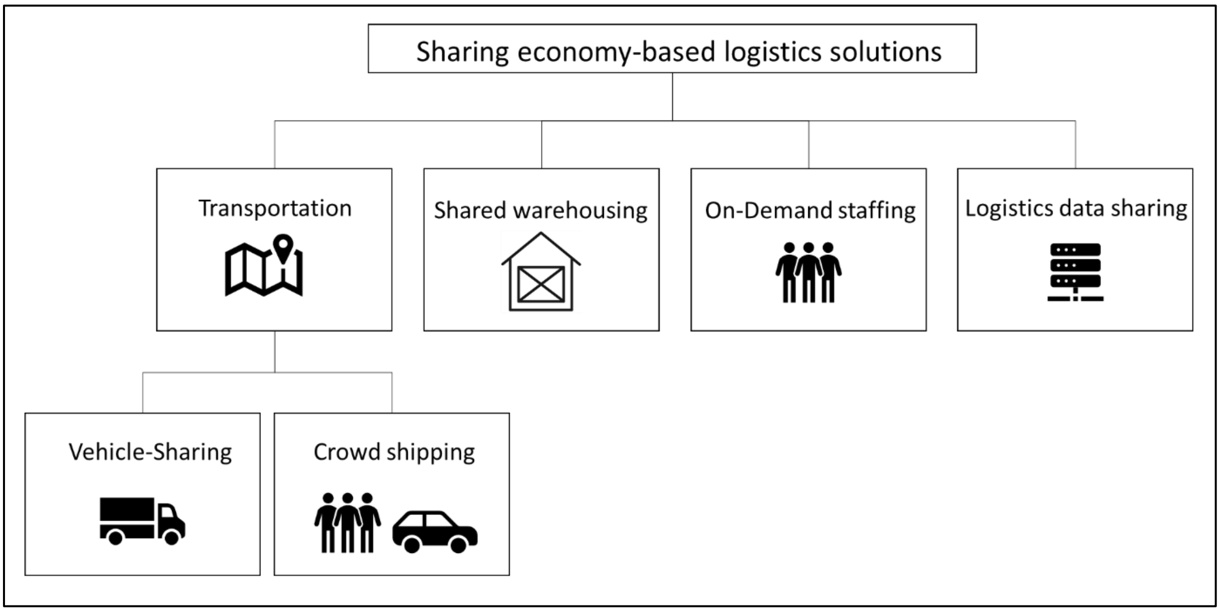


Figure 100: Sharing Economy (Own illustration according to (Strulak-Wójcikiewicz and Wagner, 2021))

To give two examples how shared economy business models look like, shared warehousing and crowd shipping is explained in the following.

Shared warehousing is a model that allows companies to make use of the excess distribution capacity of other companies or warehouse providers. It allows firms to utilize excess distribution capacity of other companies to provide storage, handling, and fulfilment services at a large scale through a single software hub, and on a variable cost basis. Shared warehousing produces a scalable, highly flexible spot market companion to the existing model of owning or leasing warehouses. It is most commonly used to solve problems related to peak-season inventory overflow, supply chain disruptions, expanding e-commerce or retail fulfilment operations in the field of last-mile logistics. This allows companies to augment their fulfilment networks quickly to meet customer delivery expectations, without the need for risky long-term commitments. This is especially useful for retailers that are trying to sell through multiple channels, as it allows them to have a network of various types of distribution centres that can handle different types of operations. With the emergence of the sharing economy and warehouse sharing hubs, having a diverse portfolio of warehouses has become more accessible for a wider range of firms (Rogers *et al.*, 2020).

Another logistic solution which can be used as a business model based on the sharing economy is crowd shipping. Crowd shipping, also known as crowdsourced delivery, crowd logistics, cargo hitching or collaborative logistics is a concept based on the sharing economy that aims to improve the efficiency and sustainability of logistics by utilizing the excess capacity of individuals' vehicles. Central to crowd logistics is the shared use of excess capacity in vehicles to deliver goods. This is achieved by drivers using their own vehicles to provide logistics services as independent contractors, and shippers outsourcing logistics tasks to a large number of drivers through technology hubs such as mobile apps or websites. (Buldeo Rai *et al.*, 2017; Behrend and Meisel, 2018; Strulak-Wójcikiewicz and Wagner, 2021).

Crowd shipping can be defined "as an information connectivity enabled marketplace concept that matches supply and demand for logistics services with an undefined and external crowd that has free capacity with regards to time and/or space, participates on a voluntary basis and is compensated accordingly." (Buldeo Rai *et al.*, 2017, pp. 10–11).

It has the potential to offer several benefits, including faster and more flexible delivery, more convenient and personalized service, real-time traceability, and better pricing than conventional business models. Businesses also stand to benefit from the reduced investment in vehicle fleet, employees, and maintenance costs. For consumers, crowd logistics can provide access to a more extensive range of products, while the local character of the service can empower communities. Environmental benefits include reduced traffic and congestion, efficient vehicle loads and routes, and lower emissions (Buldeo Rai *et al.*, 2017; Strulak-Wójcikiewicz and Wagner, 2021).

However, there are also several challenges associated with crowd logistics. One of the main challenges is ensuring the quality and reliability of service. This can be difficult to achieve with a large and dispersed network of independent contractors. Another challenge is ensuring compliance with regulations, particularly regarding safety, insurance, and tax. Additionally, there is a risk of over-reliance on the crowd, which could lead to a shortage of drivers during periods of high demand. Finally, there is also the risk of under-utilization of resources and capacity, which could lead to inefficiency and increased costs. As mentioned above, for sharing economy business models as crowd shipping or shared warehousing the IT-infrastructure is essential and a crucial factor. Crowd shipping, shared warehousing and the field of sharing economy business models in general is a recent phenomenon (concerning last-mile delivery) and research on the topic is limited and dispersed. Due to the recent emergence of the concept, it is an ongoing challenge for researchers to fully understand and evaluate the potential benefits and drawbacks of crowd logistics, shared warehouses and sharing economy in the field of last-mile logistics (Buldeo Rai *et al.*, 2017; Strulak-Wójcikiewicz and Wagner, 2021).

Related to the sharing economy, but one step further, there is the concept of Logistic-as-a-Service (LaaS) or Delivery-as-a-Service (DaaS). This idea follows the concept of the sharing economy and conventional logistic concepts with the difference that LaaS and DaaS want to unite all the different business models, resources and providers to maximize efficiency and sustainability in one hub (whereby the individual companies continue to operate independently without profit sharing). For example, orders are collected in one hub for a district or a whole city and are visible for all logistic service providers. The same applies for information about empty transport vehicles or free capacity to reduce the amount of transport vehicles operating with unused loading space. Besides a well-functioning IT infrastructure and highly digitalised businesses this idea requires an open and neutral service-point which could be set up by local authorities (Huschebeck and Leonardi, 2020).

3.2.3 Urban integration and space management

The third pillar of DECARBOMILE is urban integration and space management. In the last century there has been a growing urbanization worldwide, with more than half (55%) of the world's population living in urban areas in 2021 and a projected increase to 68% in 2050 (WHO, 2021). As these areas appear to have local differences and specialties, the solutions for solving the problems of last-mile logistics (e.g. congestion, lack of space, failed delivery) in cities need to differ as well. In their paper, Hu et al. (2019) summarize the research on urban logistics and arrive at the classification of sustainable urban freight logistics as shown in Fig. 1. The authors differ three categories (land use, environmental impact, sustainability) within the researched articles and name the overlapping areas with examples of topics in the scientific research. Land use is closely linked to urban integration because any logistic activity depends on available built infrastructure. It is necessary to find feasible solutions in terms of economic, social and environmental (sustainable) aspects in a last-mile delivery. For DECARBOMILE, especially self-service container, UCC terminal and emission control are relevant. Nearly all described research identified by Hu et al. (2019, p. 16) can be found in this literature review mostly in the chapter 4.1, night-time delivery can be found in chapter **Error! Reference source not found.** and the intelligent t ransport systems in chapter **Error! Reference source not found.**.

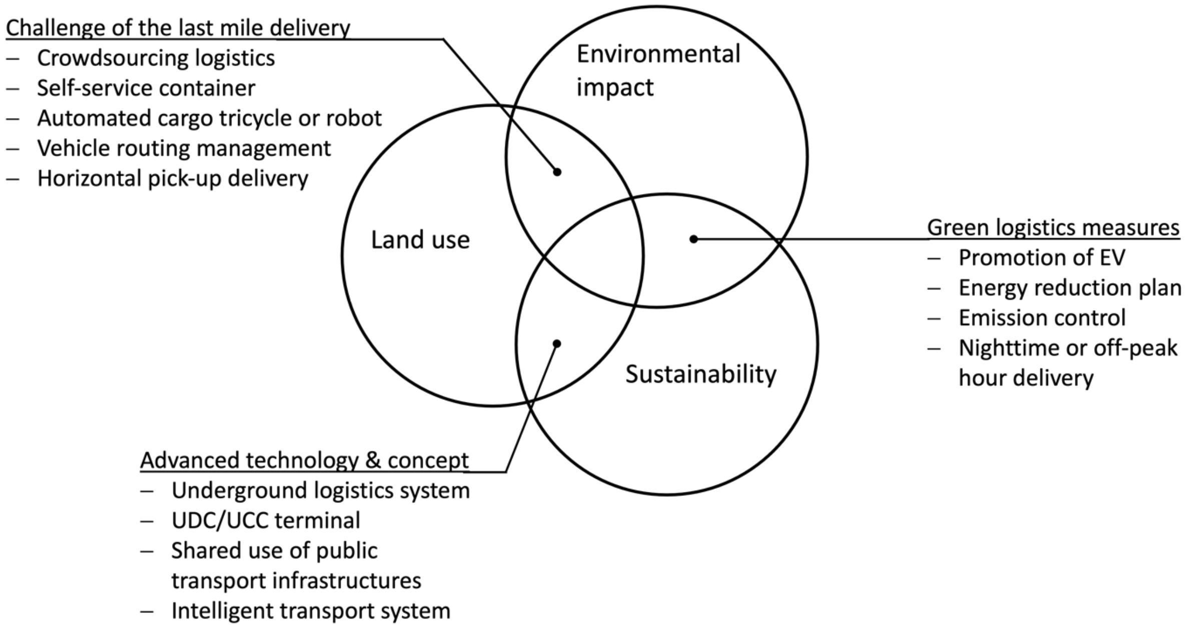


Figure 101: Clustering of scientific research regarding sustainable freight transport from Hu et al. 2019, p. 16

Methodology

For this literature review, the following search string was considered based on previously read articles.

((TITLE-ABS-KEY ("last mile" OR "city logistic*" OR "urban logistic*" OR "urban freight transport*") AND TITLE-ABS-KEY ("urban integration" OR "space management*" OR "land consumption*" OR "facility location*" OR "land use*"))

For finding relevant papers, the online databases for scientific papers Scopus and Web of Science were used.

The combined 365 articles found under the search string were merged, sorted and 118 duplicates were removed. From the remaining 247 articles, the title, abstract and keywords have been read and 119 papers that did not match were sorted out. After several rounds of going through the title, abstracts and keywords, 11 very suitable articles finally remained. This literature review is based on those 11 papers.

Findings

Urban logistics can be defined as "the process for totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, the traffic congestion and [the] energy consumption within the framework of a market economy" (Taniguchi *et al.*, 2001, p. 2). Urban areas are particularly significant in the last-mile logistics context, as numerous stakeholders, e.g. local authorities, residents, customers or logistic companies, are involved in the decision-making process. Cui, Dodson and Hall (2015, p. 9) added, that the relationship between the different participating public and private actors "has received only modest attention in the literature". In this context the authors highlighted as well, that "the provision of dedicated freight infrastructure (ports, railroads, storage, etc.) has periodically shifted between the public and private sectors, with the private provision more typical since the current global privatization wave that began in the 1980[s]" (Cui, Dodson and Hall (2015, p. 9).

Some cities tend to have a negative image of the transport and logistics sector although it"[…] is often a major source of employment" (Cui, Dodson and Hall, 2015), but according to Buldeo Rai et al. (2022, p. 5), many of these jobs are low-paid and temporary. Raimbault (2021, p. 21) is pointing out, that in urban areas the land consumption compared with the jobs created doesn't satisfy local authorities, because space is rare in dense urban areas and larger logistic halls are highly automated where not a lot of people can work. The opposite is true in suburban areas where there tends to be more space for logistics facilities (Raimbault, 2021, p. 21).

Due to a growing density in urban areas many cities face a tension between the need for economic development and the allocation of space for different purposes. As a result of this tension many logistic companies have built their facilities in the suburban regions of the cities because of less spatial constraints and better market conditions (e.g. "cheap land availability, transportation system reliability or land use regulations" (Sakai, Kawamura and Hyodo, 2018, p. 576)). This is called 'logistics sprawl' (Boltze *et al.*, 2020, p. 16; Sakai, Beziat and Heitz, 2020, p. 2). According to Alonso Montolio, Serra Coch and Isalgue Buxeda (2021, p. 5) the factors influencing the choice of location for logistic land can be divided into five groups:

1. Labour costs and access to diversified skilled workforce
2. Transportation accessibility
3. Availability and cost of land
4. Access to necessary supporting infrastructures
5. Presence of anchor tenants or large logistic firms

In this context, Sakai, Beziat and Heitz (2020, p. 3) clarify that "the features of a location that attract storage activities should be different from those that are important for cross-docking facilities".

Many negative impacts of traffic such as congestion, air pollution, noise and crashes are transferable to the freight transport sector. However, while research regarding the reduction of these impacts in the area of passenger mobility is widely known, the research in the area of freight transport is underdeveloped, "particularly regarding the intersection between transport planning, land-use and wider urban planning" (Cui, Dodson and Hall, 2015, p. 4). Although there are many similarities between passenger transport and freight transport, a major difference exists regarding the costs for transportation as Wygonik et al. (2015, p. 9) stated, that "the demand for freight transport is more inelastic with respect to price than for passenger journeys (and therefore less likely to alter or stop than passenger journeys when prices change)". Recently, the (last-mile) logistics sector is facing a change in the market due to a […] "growing e-commerce sector, […], an accelerating urban logistics start-up scene, and a maturing hub-based 'gig economy'. A second force of change is represented by policies and planning, characterized by increased attention and sensitivity to urban transport and its externalities" (Buldeo Rai *et al.*, 2022, p. 1) "[al]though freight is a relatively minor component of the overall urban transport task, [accounting for 10 to 15%][…] of metropolitan road traffic volumes" (Cui, Dodson and Hall, 2015, p. 6).

When looking at possible urban freight solutions which can be implemented by the local administration, Munuzuri et al. (2005, p. 3) presented a classification of the existing solutions which can be seen in table 1. The different options are separated into four different categories, depending on their scope. The in this literature review presented solutions are highlighted.

Table 14: Classification of urban freight solutions for application by the local administration (own illustration based on Munuzuri et al. 2005 p. 3)

Possible solutions for local administrations		
Public infrastructure	Transfer points	City terminals **[Urban consolidation centre]** **[Micro-hubs]** Outskirts logistic centres Logistic improvement of terminals **Use of rail or ship terminals** Use of public parking lots
	Modal shift	**Use of the train or underground system** Shuttle train **[Use of cargo-bikes]**
Land use management	Parking	Load zone provision Parking space planning Hub areas Use of other reserved spaces
	Building regulations	Load/unload interfaces Use of private parking lots **Mini warehouse [smart locker]**
Access conditions	Spatial restrictions	Access according to weight and volume Access to pedestrian zones

		Street blocking allowance Closing the centre to private traffic Road pricing
	Time restrictions	Adequate rotation in load zones Night deliveries Double-parking short time restrictions Access time windows
Traffic management	Scope of regulations	Carrier classification Freight zone classification Harmonization of regulations Street classification
	Information	On-line load zone reservations

PUBLIC INFRASTRUCTURE

The first part of the solutions is about building new or adapting existing public infrastructure for logistic purpose. Transfer points are terminals or centres where goods can be transferred between different vehicles. This can either be built infrastructure which is especially for logistics services like a city terminal or an urban consolidation centre (UCC), or a use of existing infrastructure like rail/ship terminals. In addition to the above-mentioned challenges of UCC (see chapter 3.1.1) in terms of financial design and stakeholder management, the difficult availability of land in dense urban areas is a major factor as well. Another example for transfer points are Micro-hubs. Both have in common that they are used for storage, fulfilment and customer delivery, using environmentally friendly transport modes (Katsela *et al.*, 2022, p. 2).

Micro-hubs are “logistics facilities where commercial transport providers (or ‘carriers') consolidate goods near the final delivery point and serve a limited spatial delivery area in a dense urban setting” (Katsela et al. 2022, p.6). In distinction to UCC, micro-hubs are smaller and closer to the actual delivery area and the final delivery point (see also chapter **Error! Reference source not found.**).

For a defined delivery area micro hubs “aim to reduce total vehicle trips” (Janjevic and Ndiaye, 2014, p. 3). However, Katsela et al. 2022 point out that micro hubs differ in their operational typology to reach this goal. In a last-mile collaboration, a regional transport provider is completing delivery tasks for multiple clients using a micro hub for combination and a high utilization for the last-mile delivery (Katsela et al. 2022, p. 7-8). From an urban perspective it may be worthwhile to support a shared micro hub for multiple carriers with enough space to consolidate and sort the deliveries. But a transport company can implement an own mobile or stationary micro hub into their delivery strategy as well. In addition to high utilization and use of environmentally friendly vehicles, “the activities of micro hubs include logistical setups and parcel handling in the city centre “ (Janjevic and Ndiaye, 2014, p. 3).

LAND USE MANAGEMENT

Pick up Points are used in delivery strategies to address the problem of home delivery failures. They can be either attended (collection-and-delivery point (CDP)) or unattended (smart locker) (Song *et al.*, 2022, p. 3). After a failed home delivery, a carrier brings the parcel to a pick-up point where the customer must pick it up by himself. Whereas with a CDP the customer is dependent on opening hours, as these are usually normal stores, with a smart locker he gets an opening code so the pick-up can be at any time (Katsela *et al.*, 2022, p. 6). Their goal is to increase efficiency in the system by taking the package to a pick-up point after a failed delivery attempt. For further improvement, the delivery option can also be selected already for primary delivery (Song *et al.*, 2013, p. 2).

In Figure 102 Katsela et al. 2022 provide an overview of the consolidation practices in an urban delivery chain, differentiating in their size and their level of spatial extent. For an urban integration, it is important, that the demanded space is smaller for a micro-hub than for an UCC, but several micro-hubs are needed citywide as their delivery radius is at neighbourhood-level. The authors differentiate four types regarding their level of spatial extension and land use, with a larger footprint for suburban warehouses but a regional-level structure and a smaller footprint for pick-up points. For the choice of location, Katsela et al. (2022, p. 9) point out the conflict between locational parameters (demand, infrastructure or land use restrictions) and logistic conditions (e.g. costs or fleet composition).

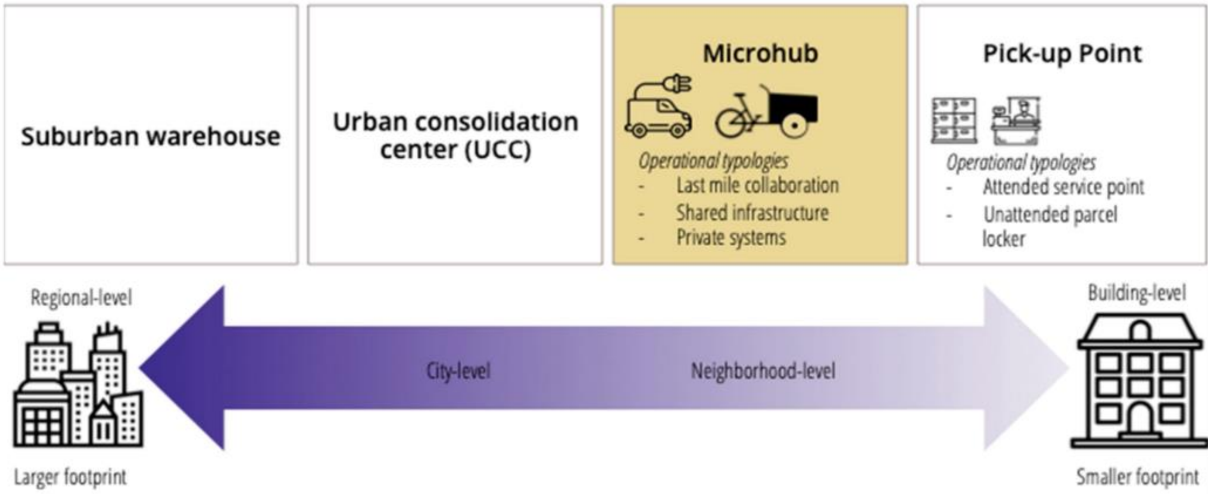


Figure 102: Consolidation practices in urban deliveries (Katsela et al. 2022 p. 7)

"Use of public parking lots" as transfer points in the public infrastructure means that regular parking lots can be used as a mobile transfer point where a shift between a van and a cargo-bike can be done. Where possible, a modal shift from mostly car transport to the use of public train services can be considered. Shuttle trains are a special form of use of the public train system, as they are running between a big logistic centre in the suburban region of a city and a city terminal in the city centre. The capacity of this train would be significant, but it would probably require a special infrastructure adaption and more than one carrier as a partner to make it a business model. For the project, the use of modal shift can mean not only the use of railroads as a replacement for motorized vehicles but also waterborne transport or the use of cargo-bikes.

As already mentioned, land use management is a big field of conflicts in urban areas, especially the question where the delivery vehicle is parking for their last-mile delivery task. While today most cities are providing load zones for this problem where parking is only allowed for freight transport, the authors mention an urban parking space planning to reduce curb side parking spaces (Muñuzuri *et al.*, 2005, p. 5). To ensure the right amount and size of load zones, a smart parking enforcement is necessary (Alho *et al.*, 2018, p. 2). The main challenge for local authorities is an adequate vehicle rotation for the load zones with a sufficient booking system (Muñuzuri and Alho, 2019, p. 15). This must be surrounded with suitable alternatives. A similar solution are hub areas, where multiple delivery vehicle can park and perform the last-mile by foot or something similar. Another area of solution is the "use of other reserved spaces" under which Munuzuri et al. (2005, p. 5) group the use of bus lanes in off-peak times for public transport, taxi zones [or] motorcycle parking spaces [...]. Along with the parking problem comes the regulation of commercial buildings. A provision of load/unload interfaces on the ground floor or at a different entrance can decouple the traffic of goods from visitor traffic. With the use of private parking lots in this section the authors suggest that freight delivery vehicles can use parking spaces in buildings which have their own parking lots because they are usually less frequented during the day. Mini warehouses are more known as smart lockers today, where the delivery does not depend on the customer to be present and to reduce the number of stops for one delivery task. As Zhang and Lee (2016, p. 1) point out, the use of smart lockers "can release the time constraint for both customers and couriers […]". Another argument of the authors is a higher privacy for the customer because the delivery is not made to the private address (Zhang and Lee, 2016, p. 1). Depending on their integration in the delivery chain smart lockers can be used in a horizontal or vertical structure. In the case of a horizontal collaboration, multiple carrier use the same smart locker to increase the utilization while a vertical structure leads to a more integrated supply chain (Cruijssen, Dullaert and Fleuren, 2007, p. 3). Munuzuri et al. (2005, p. 6) also see a potential for overnight deliveries here because there is less traffic.

Spatial and time restrictions

A big lever for local administrations are spatial and time restrictions for certain areas within their city. This can mean paying a general price when entering the city (road pricing), a more differentiated price depending on weight and volume or a limited access for freight vehicles (access time windows, night deliveries). A city can even take a step further and close the centre for private traffic, either totally or temporary, or can design new pedestrian zones. To allow last-mile logistics within a pedestrian zone a city can give access during the night or during certain time windows, or determine the use of specific vehicles, as well as allowing vehicles for certain goods to enter the pedestrian area. In addition to the above restrictions, Munuzuri et al. propose legalising two practices that are already the norm today. Street blocking allowance means to allow the practice that a delivery van is blocking a narrow street with only one lane for a short amount of time. Likewise, on streets with more than one lane, the authors suggest that a delivery car can quickly double park if there is no possible load zone nearby. With street blocking allowance is meant to legalize the practice in narrow streets with only one lane to block the traffic for a short time, which is performed illegally nowadays. Likewise, the authors suggest legalizing the practice of double parking on streets with more than just one lane and no possible load zone nearby for a certain amount of time (Muñuzuri *et al.*, 2005, pp. 21–22).

Traffic management tools

The fourth part of solutions for cities are traffic management tools. Regarding the year of publication by Munuzuri et al. (2005) the area of information system tools can be continued and filled up with more recent IT systems. A carrier classification can be helpful to differentiate depending on the load factor, their delivery type and item weight. The other three solutions can be summarized under the premise, that a harmonization of regulations within a city and between different cities is a main objective to reduce uncertainties.

Newer solutions in the last-mile logistics sector in urban areas "include constructing new facilities on abandoned or underused areas and reconstructing existing facilities by renovating or refurbishing" (Buldeo Rai *et al.*, 2022, p. 5). Furthermore, the authors are adding that facilities which serve multiple uses (e.g. housing, retail, work spaces) "are an emerging type" (Buldeo Rai *et al.*, 2022, p. 28). One example for this emerging building type is the Hôtel logistique Chapelle International (Sogaris, 2020) in Paris, where a rail-road container handling terminal is in the basement and several other functions (restaurant, biogas plant, data centre, business school, CEP logistics area, fitness centre, urban agriculture, and sports grounds) are built above. Another area was already mentioned in the business models paragraph in chapter **Error! Reference source not found.**, as there are several different u pcoming solutions, which are based on a sharing economy logistics. These often have different requirements for logistics facilities as many of them are trying an immediate fulfilment of the customer demand. Buldeo Rai et al. (2022, p. 16) name dark stores as an example, which emerged in the sector of fast food delivery and have small warehouses with high space utilization near to their customers. The authors mention "warestores", a mixture of a store and a warehouse, and urban satellites, a small warehouse in a city to serve multiple stores of one company, as two other examples of this fast delivery hubs (Buldeo Rai *et al.*, 2022, p. 6).

Barriers and challenges

Regarding the potential barriers and challenges for the presented solutions, May et al. (2006, p. 5) point out the importance that a solution is accepted by both the local politics and the residents. Cui, Dodson and Hall (2015, p. 13) have observed, that "oversight of trade-related activities is fragmented, both spatially and institutionally" which can lead to decisions without taking into account the local specifics, or in contrast, to very specific logistic solution which are not very suitable in a global supply chain. In this context, May, Kelly and Shepherd (2006, p. 5) point out the possibility that there are legal and institutional barriers that limit the city's ability to implement a solution. Furthermore, the authors describe that there are financial barriers on the side of local authorities, as road construction and public transport infrastructure are two very cost-intensive areas (May, Kelly and Shepherd, 2006, p. 5). Another point is that "cities […] vary in terms of their internal composition, whether it be economic mix, socio-economic distribution, spatial structure and infrastructure mix, and the presence of sensitive environmental features. They also have their own developmental history and position in relation to other cities and regions" (Cui, Dodson and Hall, 2015, p. 11). It is important to consider these differences in the structure of the cities when a solution from another city should be replicated. Especially European city centres were often established long before there was motorized transport, therefore their infrastructure and building design is not very suitable for large vehicle transports (Wygonik *et al.*, 2015, p. 3; Alonso Montolio, Serra Coch and Isalgué Buxeda, 2021, p. 2). It can be added that also on the side of the logistics industry, the cost of implementing a new solution is a major barrier, especially in the field of technology and real estate. Munuzuri et al. (2005, p. 12) make clear that the solutions presented must always keep the various stakeholders in mind. The transition process from the status quo to a desired solution must also be considered, as the situation can be significantly worsened here (Muñuzuri *et al.*, 2005, p. 13). As Wygonik et al. (2015, p. 13) is mentioning, „the demand for goods movement changes on a daily basis, which makes owning and operating a larger fleet of smaller trucks more expensive than a smaller fleet of large trucks, especially if a company may not need all of the small trucks (and drivers) every day". The authors are also showing existing research gaps in the areas of access, parking and loading zones regarding an appropriate number of parking spots, loading zones and allowed vehicles (Wygonik *et al.*, 2015, p. 6).

3.2.4 Regulation

Due to climate change, sustainability and environmentally friendly strategies are becoming increasingly important. At the same time, e-commercial consumption has risen sharply in the last years, especially during pandemic lockdown (Correia et al. 2021 in (Ferrari *et al.*, 2022, p. 2)). In Germany alone, the share of parcel shipments grew by 11.2% year-on-year in 2021 to 4.5 billion shipments (BIEK, 2022, p. 11). This has led to increasing delivery traffic and the associated rise in emissions ((Fan et al., 2018) in (Ku Donggyun *et al.*, 2020, p. 241); (Letnik *et al.*, 2018, p. 245)).

According to the European Commission, there are several key challenges of urban logistics:

1. "A lack of focus and strategy on urban logistics, and only a few cities with someone in authority responsible for urban logistics.
2. A lack of coordination among actors involved in urban logistics, and in many cases insufficient dialogue between city authorities and the private actors who operate there.
3. A lack of data and information, which makes it difficult to improve operational efficiency and long-term planning." (European Commission (2013) in Fossheim and Andersen, 2017, p. 1)

However, many of these factors have been neglected in recent years. Now these are to be processed and made up for.

In order to improve urban logistics, the European Commission has decided that urban logistics planning should become part of the Sustainable Urban Logistics Plans (SUMPs). In this way, high quality and sustainable solutions in mobility and urban transport in city centres are expected (Fossheim and Andersen, 2017, p. 2 after (European Commission (2013)).

Nevertheless, numerous problems have a logistical origin, which are pointed out by Letnik et al. (2018). Therefore, cities face many problems in this regard. First, they need to deal with environmental problems, such as increasing emissions from delivery vehicles. Second, the infrastructure is also poor. The road infrastructure is in a bad constitution, as traffic jam is increasing, especially in urban areas. But also, the infrastructure of logistics centres is poor, in some cases not even available. Finally, the high cost of delivery is also a challenge for cities resulting from logistics operations (Letnik et al., 2018, p. 255).

Therefore, a Sustainable Urban Logistics Plan (SULP) has been introduced by the EU to cover the logistics concept of a SUMP and to go into more detail regarding urban freight (Fossheim and Andersen, 2017, p. 2). The SULPs, in combination with the SUMPs, should find sustainable solutions to the ecological and economic challenges of urban logistics, such as greenhouse gas emissions and efficiency. In order to be able to implement those solutions, different regulations are introduced, which will be explained in the following.

Methodology

For this literature review, a search string was considered based on previously read articles. For finding relevant papers, the online databases for scientific papers Scopus and Web of Science were used.

((TITLE-ABS-KEY("last mile" OR "city logistic*" OR "urban logistic*" OR "urban freight transport*") AND TITLE-ABS-KEY("regulation*" OR "SULP" OR "emission zone" OR "freight plan")))

The combined 338 articles found under the search string were merged, sorted and 96 duplicates were removed, so 242 articles remained. The decision for the articles selected in the end was based on the titles and abstracts. The 242 articles were read and papers that did not match were sorted out. In this way, 42 suitable articles remained, from which 8 particularly suitable papers were selected. These were mainly related to the explanation and application examples of regulations. The 8 selected papers were supplemented by 2 previously read papers to complete the content.

VEHICLE RESTRICTIONS

Vehicle restrictions are measures to regulate and shrink the urban traffic load. Therefore, the access to specific areas can be blocked for vehicles falling under the regulations (Quak, 2014, p. 187). The restrictions can be "based on transparent characteristics" (Lopez, 2018, p. 143), e.g. size, weight and emission class.

The regulation of size causes larger vehicles to be replaced by smaller ones, resulting in more traffic and harm to the environment (Quak, 2014, p. 187). Nevertheless, there are places where such regulations make sense and can be implemented well, like regulations for the height under bridges (Quak, 2014, p. 187). The implementation of such restrictions can be clarified by signage. Due to the partly poor characteristics of the vehicle restrictions, it is necessary to weigh the benefits of the regulations against the negative environmental impacts and the deteriorated logistics performance (Lopez, 2018, p. 143).

If vehicle restrictions for vans are applied, using cargo-bikes can be an option.

Cargo-bikes are mostly electrified bicycles that can be used for light deliveries over short distances (Letnik *et al.*, 2018, p. 252) and are a great alternative to conventional delivery trucks. Especially in inner-city areas, cargo-bikes can get into areas that are inaccessible for classic cargo vehicles due to regulations (Letnik *et al.*, 2018, p. 252). Cargo-bikes can reduce congestion (Lopez, 2018, p. 157) and bypass it themselves, which has positive effects on the environment (Letnik *et al.*, 2018, p. 252).

However, cargo-bikes need a good cycling and logistics infrastructure to be implemented (Letnik *et al.*, 2018, p. 252), which must be created through suitable framework conditions. A good example is Paris, where "over the past 10 years, 700 km of bicycle lanes have been constructed" (Lopez, 2018, p. 157) and "have now been officially opened to electrically assisted tricycles and cargo-bikes" (Lopez, 2018, p. 157).

The practice from Hamburg, Germany shows that there is still great potential in the legislation for cargo-bikes, as in recent years, cargo-bikes have proven to be a real alternative to conventional delivery vehicles. One of the reasons for this is that they can be used for a wide range of commercial purposes (Ninnemann, 2017, p. 34). They can be used not only for the delivery and collection of goods, but also for the arrival of passenger transport to services. Cargo-bikes are a functional alternative, because they can be parked flexibly and destinations can be reached easily for example (Gruber and Rudolph, 2021, p. 29).

Nevertheless, cargo-bikes are not considered separately in the German Road Traffic Act (StVO), but are regarded as normal bicycles. As a result, they must follow the same regulations as non-commercial bicycles. Among other things, this means that the use of cycle paths is mandatory. However, in addition to the regulations that apply there for normal bicycles, the same conditions apply for the delivery of stores in pedestrian zones as for conventional delivery traffic with vans (Ninnemann, 2017, p. 34). An exception would apply if the pedestrian zone is open for bicycle traffic. In this case, delivery by cargo-bike is possible all day, as this is legally equivalent to a conventional bicycle (Ninnemann, 2017, p. 46).

Congesting Charge

Congestion charging is a less common means of restricting urban traffic. A reason for this is the "especially low acceptance of road pricing" among drivers (Lopez, 2018, p. 149). Congestion charging is a road use fee in which vehicles pay for using the road during specified time windows (Quak, 2014, p. 191) . The most common approach is a daily fee for each vehicle entering the city. In addition to this, individual vehicles can also be taxed differently according to their emission class, so electric vehicles may be exempt from payment (Lopez, 2018, p. 149). This toll affects delivery vehicles and private ones, although prices may vary between classes (Quak, 2014, p. 191).

There are already many application examples for this regularity, which differ slightly in their concepts. In Milan, the Area-C concept was introduced in 2012, where vehicles are allowed to enter the area between 7:30 a.m. and 7:30 p.m. if they have paid the daily toll. This daily toll varies depending on the type of drive of the vehicle (Ku Donggyun *et al.*, 2020, p. 242 f.). Rome also has a 6:30 a.m. to 6:00 p.m. window during which all vehicles entering the inner area must pay a fee. There are exceptions for the disabled, driving in with their own cars, residents and cabs (Ku Donggyun *et al.*, 2020, p. 242). Here the fee is the same for freight and private vehicles (Lopez, 2018, p. 150).

The results of this regulation indicate that the incentives created to use more environmentally friendly vehicles have been perceived by operators and have been well implemented (Lopez, 2018, p. 150). In London, up to 39% of emissions were saved within four years from 2003 to 2007 and in Milan, up to 28.6% of emissions were saved from 2011 to 2015 (Navarro and Vanelslander (2015) in Lopez, 2018, p. 150).

To enforce congestion charges e.g. an "automatic number plate recognition (ANPR)" (Quak, 2014, p. 191) can be implemented, as in London or Stockholm. This system reads the license plate and compares them with the data of vehicles that have already paid the fee (Quak, 2014, p. 192).

Load Factor

The load factor is a regulation that affects freight vehicles. It is intended to ensure that only vehicles that at least meet a certain load level in case of weight or volume are allowed to enter a dedicated area (Quak, 2014, p. 189). The goal is to reduce the number of light- and heavy-duty vehicles on the road, with poor capacity utilization (Lopez, 2018, p. 143). Therefore, when the load factor increases, the number of vehicles decreases (Quak, 2014, p. 190).

Loading factors are difficult to verify, making enforcement of this measure complex. In Gothenburg, the regulation was abolished after one year because enforcement failed (Lopez, 2018, p. 144). This was due to the difficulty of proving a payload capacity level (Lopez, 2018, p. 144). In Copenhagen, on the other hand, it was introduced that suppliers must credibly demonstrate that their vehicles usually have an average load factor of 60% combined all tours (Quak, 2014, p. 191).

Night / Off-Hours Delivery

Night/off-peak hour deliveries are deliveries where rush hours are deliberately avoided, e.g., in work traffic, but also in customer traffic for deliveries to pedestrian areas. The delivery takes place during nigh hours or before or after the peak hours. Delivering at night or off-peak hours has advantages. For example, there is significantly less traffic congestion on the roads, which leads to a faster delivery. This has both economic and environmental advantages (Lopez, 2018, p. 159). Nevertheless, the strict laws regarding noise protection must be observed, which makes it difficult to make deliveries during night and rest periods (Morfoulaki *et al.*, 2016, p. 672). Indeed, according to studies, many deliveries cannot take place at night because the noise limits of 60 to 65 dB are exceeded by loading and unloading processes (Morfoulaki et al., 2016, p. 672).

Nevertheless, such delivery would mean less traffic on the roads and therefore less conflict between modes. This would make expansion from non-motorized transportation more attractive. Furthermore, this type of delivery would reduce costs for suppliers and customers and improve air quality (Wygonik *et al.*, 2015, p. 13).

Time Access Restriction

In time restricted access zones, the access to areas is only allowed during specific time windows (Lopez, 2018, p. 142). This allows to keep delivery (and private) vehicles away from pedestrian areas during peak shopping hours. This regulation ensures that no street is blocked by parked delivery traffic (Quak, 2014, p. 184) and that deliveries are timed separately from shopping (Quak and de Koster, 2009, p. 212). Therefore, with fewer vehicles and emissions, like noise and pollution, the reputation and safety of the city centre increases (Quak and de Koster, 2009, p. 212).

Nevertheless, in addition to increasing liveability, time access restrictions also have negative effects on the environment, due to deteriorated logistics performance (Quak and de Koster, 2009, p. 225). Because of the time access restrictions, in addition to the generally shorter time windows for delivery, more delivery targets can be successfully made within one time window (Quak and de Koster (2007) in Quak, 2014, p. 184). Similarly, increased traffic volumes may occur when time slots and peak hours coincide (Quak, 2014, p. 184).

Nevertheless, this scheme is considered to be quick and inexpensive to implement and also very effective. That is why this measure is frequently used. In an assessment by Morfoulaki et al. (2016), 12 selected experts rated the features implementation time, cost and effectiveness of time access restrictions with 9 out of 10 possible points (Morfoulaki *et al.*, 2016, p. 676) what speaks for a high suitability of this measure. For example, in 2002, in 53% of Dutch municipalities, such time restrictions are being used (Quak and de Koster, 2009, p. 212).

Low Emission Zone

Low emission zones (LEZ) are a widely used regulation. Sweden is said to be the first country which have introduced the first LEZ in 1996 (Ku Donggyun *et al.*, 2020, p. 241). LEZ are based on the regulation of vehicles by their pollutant class (Lopez, 2018, p. 144), which is called EURO standard (Quak, 2014, p. 188). This EURO standard was adopted by the European Commission and classifies vehicles according to their emission levels and fuel types (Ku Donggyun et al., 2020, p. 242). LEZs prohibit the entry of high-emission class vehicles into certain areas. In this way, they ensure a more sustainable environment by preventing pollutants (Quak, 2014, p. 188). This regulatory applies to both freight and passenger vehicles (Slávik, 2020, p. 186).

LEZs are used in London, among other places. Here, vehicles with a gross weight of over 3.5 tons must meet the EURO 3 standard (Lopez, 2018, p. 144). In 2020, the regulations were tightened even further under the name “Ultra Low Emission Zone” (Lopez, 2018, p. 145). All diesel-powered vehicles that did not meet the EURO 6 standard were banned from the city centre. This regulation applies not only to freight vehicles but also to private vehicles (Lopez, 2018, p. 145). To control compliance to the regulation, "Automatic Number Plate Recognition (ANPR) cameras" (Lopez, 2018, p. 145) are used.

Another method of recognizing pollutant classes that is frequently used in Europe are stickers in the windshield of vehicles, as it is the case in France in Paris and in several cities in Germany (Lopez, 2018, p. 147).

Another strict example for LEZ is Athens. The LEZs there are valid annually between September and July. "Vehicles over 2.2 tonnes, and first registered before January 1991, were banned in 2013" (Lopez, 2018, p. 146) and this restriction is extended every year. Thus, the year of first registration is raised annually. Therefore, in 2014, only vehicles registered as of January 1992 were allowed to drive in the LEZs (Lopez, 2018, p. 146). In this way, the high-emission vehicles are creepingly outsourced.

Strict regulations of vehicles, especially those that release large amounts of pollutants, are intended to limit locally emitted pollution and thus improve air quality (Quak, 2014, p. 188). LEZs can provide an incentive for carriers to acquire new and more sustainable vehicles, thus replacing the fleet to continue delivering in areas with access restrictions (Quak, 2014, p. 189).

Implementing Regulation

In Letnik et al.'s (2018) analysis of 129 European cities of their sustainability concepts in relation to logistics, five types of planning documents emerged: SUMPs without city logistics measures; Mobility plan documents with city logistics measures; SUMPs with city logistics measures; Logistics plans; SULPs.

Of the 129 cities, "four have logistics plans and nine have SULPs" (Letnik et al., 2018, p. 250). It can be observed that all nine cities with a SULP are part of the European project ENCLOSE (Energy efficiency in City Logistics Services for small and mid-sized European Historic Towns). In total, 45 of the cities surveyed would have had a SUMP (Letnik *et al.*, 2018, p. 250). This number is expected to rise to over 424 cities by 2025 under the European Commission's new Trans-European Transport Network (TEN-T) regulation, which is to establish a SUMP by that year and collect relevant data (European Commission, 2021). One effective measure that appears in the plans of nearly half of the cities analysed are urban consolidation centres (see chapter 3.1.1) (Letnik *et al.*, 2018, p. 255). Nevertheless, other regulations are also frequently applied, such as time-access restrictions or LEZs. These are comparatively inexpensive to implement and yet effective.

The cooperation with the government but also with other private stakeholders is of high importance to reach goals and to apply meaningful, target-oriented methods. Therefore, "collaboration is also highlighted as a key element in the Sustainable Urban Transport Plan (SUTP), SUMP and SULP methodology fundamental to improvement of the planning procedures" (Fossheim and Andersen, 2017, p. 10). The complexity here is that with many stakeholders, it is a challenge to adopt common goals. This is especially true for public-private decisions, which have shown to be difficult to take because of the very different interests involved (Quak, 2014, p. 197).

When implementing a regulation, it is important to ensure that they are neither too complex nor too expensive. In Gothenburg for example, the load factor was abolished after one year because it was difficult to control. But also, the implementation of other regulations can cause difficulties. For example, time-access restrictions are criticized for causing a loss of logistics performance. For example, "Time-windows force carriers to make a large number of all their urban deliveries during the morning, and as a result the carriers cannot make optimal roundtrips because many deliveries have to be made at the same time" (Quak, 2014, p. 193). For this reason, more vehicles would have to be used leading to inefficient tours (Quak, 2014, p. 194). Similarly, vehicle restrictions in terms of size are also criticized because they would cause a change from one large vehicle to several small ones, which would lead to more traffic (Quak, 2014, p. 187). In conclusion, it can be said that "all restrictions increase the costs for carriers" (Quak, 2014, p. 197). It is important to make regulations that are based on the acceptance of citizens in order to achieve legitimacy (Fossheim and Andersen, 2017, p. 2). For these reasons, the government's intervention should start with low-cost and effective methods like defining freight routes and delivery and servicing plans to achieve reductions in pollutants quickly. This is because the possibility of a successful implementation increases as the cost decreases. However, this is not only true when costs are low, but when the potential for savings (e.g. UCC) is very high. Therefore, measures that save large amounts of pollution in a short period of time are preferred to be implemented (Letnik *et al.*, 2018, p. 254).

Implication For DECARBOMILE

"It is important to keep in mind that […] restrictions are often meant to do something other than just restrict urban freight transport operations in the city" (Quak, 2014, p. 183).

This quote can be seen as a basis for alignment with DECARBOMILE. After all, this project is not born out of prohibitions, but is intended to create incentives for new, ecological solutions in freight transport.

Thus, in the case of already established regulations, advantages can be expected for emission-free delivery with a cargo bicycle, for example.

Cargo-bikes, have the advantage that they are significantly quieter than conventional vehicles. For this reason, off-hour delivery would be feasible at any time of day in terms of noise levels. This type of delivery also has considerable advantages in low- and zero-emission zones. Due to the zero-emission delivery, there are no limits for the delivery bikes in low emission zones. They are always allowed to enter, so in most cases deliveries can continue 24/7. In most cases, this could also apply to pedestrian zones.

Moreover, a very good load factor can also be expected here. Although cargo-bikes can transport fewer packages than large vans, if these vans have a low utilization rate, it could make sense to replace them with cargo-bikes.

Probably the biggest advantage, however, besides the positive effect that there would be less traffic on the roads, is that there would be no more direct emissions. This would consistently reduce air pollution, especially locally.

In addition to cargo-bikes, other CO2-neutral delivery options, such as the combination of cargo-bikes with smart-lockers, also have advantages over conventional delivery trucks. However, these are not necessarily based on regulations adopted by governments and cities, which is why they are not mentioned.

Furthermore, it is important not only to look at individual regulations in isolation, but to see connections between them and to create combinations that achieve the goals even more consistently. For example, UCCs in inner cities would make sense especially if they were also used in conjunction with handcarts and cargo-bikes (Ninnemann, 2017, p. 102).

3.2.5 Digital infrastructure

The topic of digital infrastructure is so extensive that this text will only give a short overview of possible digital infrastructure in last-mile logistics and cannot claim to be exhaustive.

Definition

An initial classification on Digital Infrastructure (DI) by Ferrari et al. (2022, p. 1) emphasizes that DI is intended to serve the automation of operational tasks as well as the exchange of real-time information in urban logistics processes. In this way, participating actors are better connected. DI could also be seen as a way to advance both logistics as a whole and supply chain management (Edouard *et al.*, 2021, p. 453). Bad environmental conditions such as air pollution and congestion are expected to be improved by DI technologies, not least, due to improved flows of goods and traffic, which should promise a better quality of life. In any case, the digitization of logistics is inevitable, especially nowadays, as we are in the age of digitization (Purchase 2019 in (Ferrari et al., 2022, p. 2)) and the demand for instant deliveries is becoming more important due to the rise of e-commerce (Marcucci *et al.*, 2020, p. 1).

General

The Industry 4.0 concept, which is largely synonymous with DI, has been around since 2011, when it was first introduced at an industrial automation fair in Hannover, Germany (Hofmann et al. 2019 in (Ferrari *et al.*, 2022, p. 2). The goal of Industry 4.0 is to strengthen the man-machine relationship by means of IT technologies such as Internet of Things (IoT), Intelligent Transportation System (ITS) and Big Data analytics (Ferrari *et al.*, 2022, p. 2). This concept could contribute with these IT technologies to solutions of supply chain management challenges such as reducing cost and increasing speed and flexibility (Edouard *et al.*, 2021, pp. 453–454). Thus, Industry 4.0 enhances logistics processes.

In the following, DI and Industry 4.0 are used synonymously due to the large overlap.

Martins et al. (2019, p. 26) refer to DI models that work on the basis of Information and Communication Technology (ICT), blockchain, and gamification tools (will be explained in more detail later) as a kind of "logistics-as-uber." Analogous to the ride service Uber, the sharing of resources is ostensible, in this case the sharing of ICT systems. Therefore, the aim of the DI models is to promote cooperation between companies and to share resources in logistics processes.

Through the innovative technologies of Industry 4.0, logistics has evolved from its image as an unpopular cost driver that causes pollution and congests the roads to a real competitive advantage in the market (Florence and Shyamala Kumari 2019; Yavas and Ozkan-Ozen 2020; Tang and Veelenturf 2019 in (Ferrari *et al.*, 2022, p. 4)). In order to improve logistics services, the application of Industry 4.0/DI could be profitable as its introduction is expected to provide more dynamic and better integrated solutions to urban problems (Ferrari *et al.*, 2022, p. 2).

Therefore, Perboli et al. (2014, p. 473) determines, that the reduction of greenhouse gases is particularly important to cities, as the potential for savings is huge, especially in urban regions, which account for 80% of all greenhouse gases. Through new DI technologies, cities can plan urban areas better and change individual's behaviours, in order to reduce the city´s overall emissions output.

Closely related to the DI is the concept of the Smart Cities. Smart cities are defined as cities that integrate innovative and novel technologies, services and applications to achieve a relationship and coordination between different sectors (Perboli *et al.*, 2014, p. 470 f.). Over the last few years, there have been several Smart City Projects worldwide. Among others, the European Commission's Seventh Framework Program (FP7) has given the opportunity to take up ideas and approaches regarding smart cities in many case studies and frameworks.

The technologies that DI can provide to build smart cities and improve logistics operations and environmental impact are discussed below.

Examples for DI

As mentioned at the beginning, DI contains a large variety of concepts and technologies. Accordingly, only a few approaches to DI will be explained in more detail below.

Information and Communication Technology (ICT)

ICT is a combination of complex technologies and innovations, between a wide variety of areas, such as information systems, sensors and communications. The transmission of information is digital (Ferrari *et al.*, 2022, p. 4). For example, traffic surveillance can increase efficiency in urban areas, but above all it can improve safety on the road (Ferrari *et al.*, 2022, p. 6). With the use of ICT, it is also possible to implement new production, sales and administrative processes (Perboli *et al.*, 2014, p. 474).

According to Perboli et al. (2014, p. 477), ICTs are the most widespread DI because they enable collaboration between different sectors and areas, connecting and converging them at the highest level. In 86% of so-called Smart City Projects, ICT is represented and therefore is the most popular technical tool. (Smart Cities propose a holistic of future communities. (Perboli *et al.*, 2014, p. 470))

Internet of Things (IoT)

This technology enables the creation of information without human observation (Edouard *et al.*, 2021, p. 454). Using telecommunication networks and Internet-based communication, sensors and other autonomous devices can be connected to communicate and interact with each other (Ferrari *et al.*, 2022, p. 4).

In particular, the joint use of ICT and IoT, especially in supply chains, makes it possible to have a very broadly based information infrastructure. In addition to improving efficiency, this infrastructure can also reduce energy consumption (Garrido-Hidalgo et al. in (Ferrari *et al.*, 2022, p. 5)).

Intelligent Transportation System (ITS)

As defined by Lin et al. (2017, pp. 167–169), the Intelligent Transportation System is a system that provides innovative services for transportation management. It combines technologies such as information systems, sensors and controllers to not only avoid congestion but also increase safety and productivity at the same time. It is composed of four layers (Figure 1). The physical layer consists of the physical transport system such as infrastructure and vehicles. The communication layer contains the exchange between the technology carriers, for example between several vehicles.

The third layer, the operation layer, translates the incoming data and converts it into useful information. This layer consists of 3 components. The first one is Advanced Transportation Management System (ATMS), which represents the general system management, followed by Advanced Traveller Information System (ATIS), providing information to travellers. The third component is the Advanced Vehicle Control System (AVCS), a control system used in infrastructure and vehicles. The last layer is the service layer. This finally puts the services into operation.

By interlocking all these layers, the goals of this technology, increased security and better mobility, can be achieved.

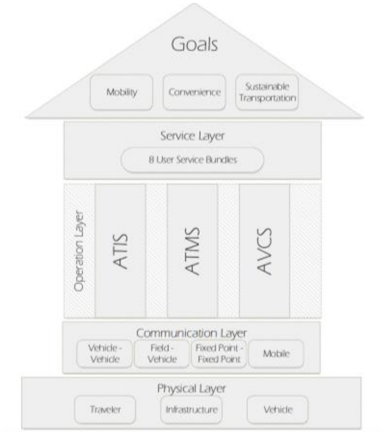


Figure 103: ITS Architecture (Lin et al., 2017, p. 168)

Digital Twins (DT)

A digital twin is a set of real-time data that represents a digital twin of reality based on the data (Edouard et al., 2021, p. 454). There is a connection between the physical and digital worlds. The three basic elements according to Marcucci et al. (2020, p. 3) are: “(1) real space, (2) virtual space and (3) the spreading of data/information flow between real and virtual space.” Through this system, data-driven analytics can be performed in addition to models based on reality (Marcucci et al., 2020, p. 3). Thus, according to Edouard et al. (2021, p. 454), this DI can be used to make tests, simulations and optimizations for the organization of warehouses, for example.

This has relevance for the DECARBOMILE project, as DTs of Hamburg, Logrono, Nantes and Istanbul will be created in further work packages. These twins should be used to monitor, evaluate and test the impact of new algorithms and innovative technologies related to routing, positioning and others.

Physical Internet

In addition to the above examples of DI, there is a concept that reaches across the digital boundary to physical objects, called the Physical Internet (PI). This scheme was first described in 2011 by Montreuil, who described it as a milestone capable of overcoming the hurdles of sustainability in logistics (Ambra, Caris and Macharis, 2021, p. 6).

PI, which was new at the time, was a concept that should make it possible to act better in terms of economic, ecological and sustainable aspects. This is to be achieved by moving, storing and supplying goods more intelligently throughout the world (Montreuil, 2011; Physical Internet Initiative, 2012 in (Crainic and Montreuil, 2016, p. 384)) to design a Global Logistics Web that uses standards, interfaces and protocols to create physical and digital connectivity (Edouard *et al.*, 2021, p. 455).

The way it works is largely analogous to that of the Digital Internet. While on the one hand digital data is transported worldwide by DI, on the other hand physical goods are transported worldwide by PI´s logistics network (Ambra, Caris and Macharis, 2021, p. 6). In order to make the best use of the logistics network, all logistics actors are connected to each other and share the resources that are available, such as distribution centres, city hubs or information systems. In this way, a network is created in which the movement of goods deviates from traditional logistics processes - with the aim of making the best possible use of the available capacity through standardization and cooperation (Kubek and Więcek, 2019, p. 223).

The essential components needed to establish PI are a broad logistics network characterized by cooperation and the latest technologies in logistics centres in the area of storage and handling, as well as modular, standardized loading units called PI containers (Edouard *et al.*, 2021, p. 455).

According to Crainic and Montreuil (2016, p. 396), any other components of the logistics process should be designed around these boxes so that the various building blocks can be interlinked. Therefore, among other things, all forms of hubs, such as urban hubs and distribution centres, should be adjusted to the PI Containers. But also transport systems as well as transport vehicles are to be adapted and adjusted, as claimed by Crainic and Montreuil. PI Containers would have the ability to communicate not only with each other, but also with the collection and distribution centres. This communication is intended to achieve the goal of optimal capacity utilization (Edouard *et al.*, 2021, p. 455). As defined by Ambra et al. (2021, p. 9) these standardized PI containers move along a network of physical corridors in which collection and distribution centres navigate the goods, various mode of transport such as road or rail move the goods, and intermodal terminals allow the goods to change mode of transport from, for example, truck to airplane.

As mentioned at the beginning, PI can be broadly related to DI. The Table 15, by Ambra et al. (2021, p. 10), shows various counterparts between PI and DI. It can be seen that basic principles and approaches are largely similar in both parts. Nevertheless, there are several differences that cannot be replaced. Crainic and Montreuil (2016, p. 388) have found that, among other things, the speed at which physical goods move is significantly slower than that of digital data. Moreover, the costs incurred by PI are higher and therefore not negligible.

From these and other differences, metrics can be worked out which must be taken into account in PI and which only appear in this form for physical goods. The categories into which these metrics can be classified are costs, time and schedule. The cost reflects variable costs that arise due to the type of transport and added value services such as unpacking and packing or unloading and loading. Time is relevant in that transition times are of great importance as they can depend on factors such as the mode of transport and the availability of labor. The schedule is also a critical issue, as it must constantly change with the current status of shipment. This can be the case when a vehicle breaks down, for example, and this causes the schedule to be delayed, which can result in additional costs. However, these categories do not stand alone, but are closely intertwined (Ambra, Caris and Macharis, 2021, pp. 11–12).

Table 15: The similarities between the Physical Internet and the Digital Internet (Ambra et al., 2021, p.10)

LSP – Logistics Service Provider; ISP – Internet Service Provider

	Physical Internet	Digital Internet
User	Private and commercial shippers	Private and commercial Internet users
Flow	Physical objects	Digital objects
Unit of the flow	Standardized packages, e.g., standard containers, the Modulushca box (European Comission, 2016)	Data packets
Routing of the flow	Ports, cross dock facilities, distribution centers, multi-modal transfer centers, etc.	Routers and switches
Carrier of the flow	Transportation modes, e.g., roads, rail, sea, air, inland waterway, pipeline	Physical medias, e.g., coaxial, fiber, air (wireless)
Protocols	Standardized sending/receiving processes	Five-layer Internet protocol model
Service providers	Logistics service providers	Internet service providers
Collaboration between operators	Transshipment and revenue sharing between different LSPs, groupage services, pallet networks	Roaming and revenue sharing between different ISPs
Collaboration between users	Shared transportation services, shared warehousing, etc.	Peer-to-peer networking, intranets, etc.
Collaboration between a user and an operator	3PL services	Dedicated access lines (e.g., T1 links)
Ownership of basic infrastructure	Partly government-owned (highways, bridges, etc.)	Primarily privately-owned (by the ISPs), but some government ownership, e.g., national telephone carriers, etc.

Therefore, PI can be seen as a complex mode of DI, sending physical goods instead of digital data.

Conclusion

According to Giuffrida et al. (2022, p. 12), it can be observed that due to DI the classic models are being replaced by new models that focus on existing real-world problems, especially urban last-mile logistics. Increasingly, joint models are being developed that combine different logistics service providers. This is not least a matter of reducing emissions in the cities, but also of meeting the high demands of customers.

Through DI, such as Artificial Intelligence, which analyses large amounts of data generated during communication between machines to draw valuable conclusions and Machine Learning technologies (Algorithms that are able to learn independently to become faster and better. An application example for such a system is the prediction of traffic situations.), the urban last-mile can be planned better. This originates from a deeper understanding of how different situations affect and the extent to which cities respond and adapt to them (Allam and Dhunny 2019 in (Ferrari *et al.*, 2022, p. 5)). Therefore, over the last several years, scientific texts researching DI in logistics would have focused in particular on optimizing the routes of logistics service providers (Giuffrida *et al.*, 2022, p. 3). It is expected that the greatest improvements are to be made in there. With respect to DECARBOMILE, it can be assumed that the optimization possibilities can eventually be extended to all vehicle classes, so that also cargo-bikes and the walking deliveries can be delivered with improved routes.

Eduardo et al. (2021, p. 458) state that new warehouses need to be established in order to meet the challenges of the last-mile in urban regions. Among other things, Industry 4.0 is to be used for this goal. Therefore, figure 2 shows that many processes of today's warehouses could be supported by various DI, as IOT, AI and DT (Edouard *et al.*, 2021, p. 456).

Table 16: New urban warehouse specification versus classical warehouse ones (Eduardo et al., 2021, p. 451)

Classical warehouse	New urban warehouse
Large space	Small areas (a few hundred of m²)
Located in the suburbs	Located in the city centre
Rapid movement of goods	Direct access to the consumer markets (last miles)
Cross docking	Delivery in a few hours
Use typical material flow devices as conveyors, forka lifts, AGVs, …	Few clients
Standardized installation for the entire logisitc facility	Challenge of optimising the enviromental impact of buildings and transport
	Personalized and costumization offers (modular spaces, trained employees, monitoring new technologies)

This approach is particularly interesting for the DECARBOMILE project because the characteristics of the new warehouses described by Eduardo et al. (2021, p. 451) match the characteristics of micro hubs/UCCs (Figure 104). The use of DI in inner-city warehouses could be correspondingly profitable.

		BD	CC	CPS	IOT	SDt	AI	Sd/R	AR	Cyb	AM		PI
Warehouse Management	Reduce human workloads and unnecessary processes			X		X	X	X					
	Optimaze stock filling	x		X	X						X		X
	Manage the use of returnable goods (reverse logistic)	x			X					X			X
	Share information with client and supplier		X		X					X			X
	Control and locate objects, goods, and containers	x	X	X	X			X	X	X			X
	Deliver on-time				X			X					
	Eliminiate errors caused by manual recording				X			X		X			
	Manage the priorities	X			X								
	Improve coordination to consolidate orders	X			X								X
	Make identification effective	X			X		X	X	X	X			
	Manage picking errors	X			X								
	Securise confidential data									X			
	Secure employees				X		x	X	X				
	Meet changing market conditions and uncertainties	X				X		X					X
	Manage the costumer experience	X			X						X		
	Test product							X	X				
	Review quality				X			X	X				

		BD	CC	CPS	IOT	SDt	AI	Sd/R	AR	Cyb	AM		PI
Warehouse Management	Reduce human workloads and unnecessary processes			X		X	X	X					
	Optimaze stock filling	x		X	X						X		X
	Manage the use of returnable goods (reverse logistic)	x			X					X			X
	Share information with client and supplier		X		X					X			X
	Control and locate objects, goods, and containers	x	X	X	X			X	X	X			X
	Deliver on-time				X			X					
	Eliminiate errors caused by manual recording				X			X		X			
	Manage the priorities	X			X								
	Improve coordination to consolidate orders	X			X								X
	Make identification effective	X			X		X	X	X	X			
	Manage picking errors	X			X								
	Securise confidential data									X			
	Secure employees				X		x	X	X				
	Meet changing market conditions and uncertainties	X				X		X					X
	Manage the costumer experience	X			X						X		
	Test product							X	X				
	Review quality				X			X	X				

Figure 104: Actions with Industry 4.0 technology groups (*Eduardo et al., 2021, p. 456*)

BD – Big Data; CC – Cloud Computing; CPS – Cyber-Physical Systems; IOT – Internet of Things; SDt – Simulation and Digital Twins; AI – Artificial Intelligence; Sd/R – Stand-alone Devices/Robots; AR – Augmented Reality; Cyb – Cybersecurity; AM – Additive Manufacturing (known as 3D-printing); PI – Physical Internet

Success factors: Blue – Optimization; Green – Traceability; Red – Reliability; Yellow – Responsiveness; Grey – Security; Purple - Flexibility

DI thus has countless areas of application that cannot all be listed here. Nevertheless, it is clear that the pillar of Digital Infrastructure is of great importance for the DECARBOMILE project due to the many transferable application areas, such as route optimization or designing and technologizing UCCs. More detailed information on DI will be found later in this project, as DI will be explored and further developed in more depth as part of the DECARBOMILE project.

In addition to the DI, another promising methodology is also being developed. The Physical Internet. As Crainic and Montreuil (2016, p. 384) explain, this aims at cooperation between stakeholders, consolidation and a separation from shops and their traditional distribution to a new way of storing and transporting goods. More specifically, PI aims to achieve sustainability in logistics and minimize environmental impact. PI provides information integration to achieve this goal, especially through improved distribution of goods within the logistics processes.

For DECARBOMILE, this approach is very exciting on the one hand, as PI can save 30% of all costs incurred and reduce greenhouse gases by 60%, while maintaining the same level of service (Sarraj et al., 2014 in (Crainic and Montreuil, 2016, p. 391)). On the other hand, PI is also exciting for the project as the framework is created once and can subsequently be used across all levels. From small institutions to a global stage from rural to metropolitan. PI can be adapted to all conditions and creates innovations from technology to infrastructure to business models (Crainic and Montreuil, 2016, p. 389)

Achieving a large impact that has a strong influence on the world's logistics processes and emissions seems feasible with this method. Therefore, Physical Internet, along with Digital Internet, is of high importance for DECARBOMILE.

It could be shown that for all of the pillars presented, multiple studies can be found, even though they mostly only address one pillar and only one aspect of the pillar. As the last-mile logistics is facing several challenges like shortage of space, congestion, access regulations or drivers' shortage, there is a high optimization potential. Algorithms to solve the optimization problems for network design and vehicle routing are presented in the next chapter.

3.3 Optimisation algorithms for last-mile delivery in cities

For more than twenty years, the subject of city logistics has been the focus of a huge amount of research in various scientific domains, including social sciences, transportation systems or computers science. Many quantitative methods have been used to solve the specific flow optimization problems arising in city logistics and many reviews of the literature have been published, focusing on one particular aspect every time.

This section focuses on operations research models and solution methods, and more particularly the two following topics: first, network design, which is highly related to the location of infrastructures such as micro hubs, consolidation centres and lockers; second, vehicle routing, which is related to optimizing the routes of truck, vans or cargo-bikes to deliver goods to the city. The main objective of a vast majority of these models is to minimize the total logistic costs associated with the transportation system, while satisfying a set of operational or quality of service constraints.

3.3.1 Network design

In this section we review the optimization algorithms that have been designed to support strategical and tactical decisions in the design of city logistics networks. We first provide a general introduction to the field of network design in operations research and classify the literature on different problems arising in city logistics.

The Facility Location And Network Design Problems

Facility location problems consist of determining the “best” location for one or several facilities or equipment in order to serve a set of demand points. The meaning of “best” depends on the nature of the problem under study, namely in terms of the constraints and of the optimality criteria considered (Laporte, Nickel and Saldanha da Gama, 2019). In most cases, the objective is to minimize logistics costs. Facility location models have been extensively applied to the case of logistics network design. In recent years, increasingly rich models have emerged, integrating a large number of realistic characteristics:

- Complex supply chains with multiple layers / tiers, for example suppliers, factories, warehouses, customers,
- Multiple commodities,
- Complex flows between the different facilities, in particular direct deliveries skipping intermediate layers, reverse flows,
- Multiple technologies or transportation modes,
- Integration of strategic and tactical decision, more particularly with regard to storage,
- Modelling of realistic costs,
- Environmental considerations.

Supply Chain Network Design (SCND) is the set of rich models that generalize the location problem to the whole supply chain. The decision variables can typically concern the number, the location and capacity of facilities, but also technological choices, transportation modes, and the flow of materials in the network (Crainic, T. G., Gendreau, M., & Gendron, B. (Eds.). (2021). *Network design with applications to transportation and logistics*. Springer Nature) .

In logistics applications, most models concern discrete locations. A preliminary step prior to optimization is the selection of candidate facilities by a panel of experts. The mathematical models contain binary location variables, i.e. their value is set to 1 if a candidate site is selected, and 0 otherwise. Melo, Nickel and Saldanha-da-Gama (2009) propose an extensive review of facility location in the context of supply chain design, but its application to city logistics is not discussed.

Locating Urban Micro Consolidation Centres

The location of micro hubs (also called UMC : Urban Micro Consolidation centres) is one of the main applications of facility location techniques to the design of a city logistics network. Kaspi, Raviv and Ulmer (2022) highlight the fact that “determining the locations of the UMCs in the city is a long-term strategic decision that should consider current and future demand volumes as well as accessibility for both heavier replenishment vehicles and lighter delivery vehicles.” A key difference indeed with classical warehouse or hub location problems is that a micro hub is mainly used as a hub between two zones with different accessibility constraints: the outskirt of the city, where the main warehouses and consolidation centres are located, and the city centre, with different regulation aspects or high congestion, which necessitates the use of smaller, greener vehicles.

Surprisingly the micro hub location problem did not receive as much attention as the vehicle routing topics in the optimization literature. For instance, the recent survey of Kaspi, Raviv and Ulmer (2022) lists only three papers dedicated to modelling and solving this problem. More can be found however when considering the whole set of approaches that has been envisioned to locate logistics/courier distribution hubs in cities or, more generally, two echelon location routing problems (Prodhon and Prins, 2014).

Most approaches consider two types of inputs:

- A set of **possible locations** for micro hubs.
- A set of **customers / demands / delivery zones,** characterized by their locations, and quantities to be delivered as well as additional constraints.

Emissions, costs, travelling time and distances are then computed based on a cartography such as open street map.

To our knowledge, Rudolph *et al.*(2022) is the only contribution which considers identifying and evaluating a set of potential locations with a multicriteria decision making approach.

A key problem is to find locations that will reduce the transportation costs or CO2 emissions knowing that transportation occur at two echelons with different vehicles. Indeed, according to (Rudolph *et al.*, 2022):

> *City authorities and CEP (courier, express and parcel) providers have supported the inclusion of UMCs in strategic urban plans for years* (Chiffi, 2015) *but the provision of areas dedicated for logistics activities is still scarce, although UMCs located close to the distribution area are prerequisites for the successful implementation of cargo-bikes* (Conway *et al.*, 2012; Rudolph, Liedtke and Gruber, 2018)*. On the one hand, the loading capacity of cargo cycles is constrained in comparison to conventional delivery vans, and on the other hand, trip length between UMC and delivery area must be reduced to a minimum to decrease travel time and strenuous pedalling for the driver.*

Among the set of optimization approaches we distinguish two main approaches: the location-routing approach and the approaches based on a continuous approximation of routing costs, also falling in the category of mixed integer programming (MIP) based approaches in (Bektaş, Crainic and Van Woensel, 2017).

Location routing approaches

The location of UMC in a two-echelon city distribution system is highly related to the Two-Echelon Location Routing Problem (2E-LRP). In this problem, first level routes are designed to supply several main facilities to be located, from which second level routes are designed to serve a given set of customers. According to the survey of Prodhon and Prins (2014), these facilities can be plants or UMCs or satellite depots. The authors also mention that this problem arises in applications such as the distribution of newspapers and city logistics. The first mention of the 2E-LRP in the literature is related to newspaper distribution (Jacobsen and Madsen, 1980; Madsen, 1983). If the number of potential locations and satellites remain small, all possible locations can be evaluated using a 2E-VRP algorithm (Crainic *et al.*, 2010, 2012). But the combinatorial aspect of the location decisions quickly implies to integrate them in the optimization algorithm. Given the complexity of the problem, most approaches are metaheuristics. Considering only the most recent surveys, the 2E-LRP has been the subject of dedicated sections in (Prodhon and Prins, 2014) on location routing problems and in (Rosario Cuda, Guastaroba and Speranza, 2015a) on two echelon routing problems (Figure 105).

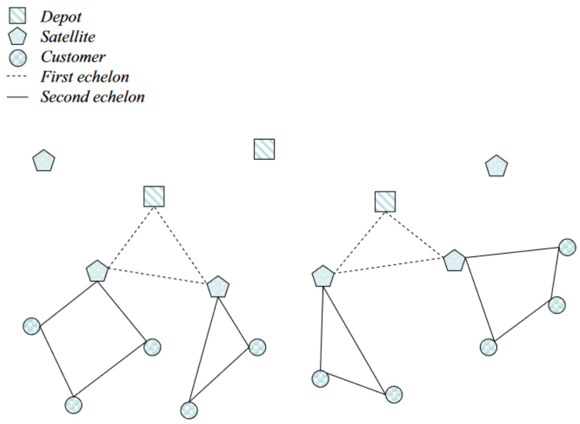


Figure 105 : Illustration of the 2E-LRP in the survey of (Rosario Cuda, Guastaroba and Speranza, 2015a).

Lin and Lei (2009) include a set of plants, a set of big customers and a set of small customers (ranked according to their demand size). They define a 2E-LRP in which customers can be served at both echelons of the two-echelon network. The authors propose a genetic algorithm to solve this problem. Prodhon and Prins (2014) mention that this method can be improved by better heuristics.

In particular, Nguyen, Prins, and Prodhon (2012a and b) propose two efficient meta-heuristics for a 2E-LRP-2E with a single central depot (already located) and a set of potential satellites with limited capacities and opening costs. The most efficient is based on A Multi Start Iterated Local Search with Path Relinking (MS-ILS + PR). They also share academic instances (24 instances with 5 or 10 satellites and 50–200 customers, available at http://prodhonc.free.fr/Instances/instancesLRP2E_us.htm) which are used as references in the literature. Their best algorithm combines multi-start with three randomized heuristics, iterative local search, path relinking together with giant tour representations and split strategies.

Boccia *et al.* (2010, 2011) study the design of a two-echelon urban freight distribution network with the location of UCCs and micro hubs and the size of two different vehicle fleets. Boccia *et al.* (2010) devise a Tabu search in which a LRP is solved for each echelon. Three sets of instances have been generated (with 2–5 UCCs, 3–20 micro hubs and 8 200 customers). (Boccia *et al.*, 2011) introduce several mixed-integer models and show that optimal solutions can be obtained with small run-time only for very small instances (3 UCCs, 5 micro hubs and 10 customers). The hypotheses of the optimization problem are listed as follows (Boccia *et al.*, 2010):

- *All freight starts from hubs. One representative freight is considered.*
- *Hubs and micro hubs are characterized by limited capacity.*
- *Customers are freight destinations. A demand is associated to each customer.*
- *Customers and micro hubs are single sourced by respectively satellites and hubs. A single demand cannot be split among different vehicles, but more demands can be loaded on the same vehicle.*
- *Direct shipping of freight from hubs to customers is not allowed, i.e. freight must be distributed first to micro hubs and then to customers.*
- *Vehicles belonging to the same echelon have the same capacity. The capacity of first echelon vehicles is much higher than capacity of second echelon vehicles and of micro hubs. The capacity of second echelon vehicles is much higher than the demand of customers.*

- *1st echelon routes start from a hub, serve one or more micro hub and ends to the same hub; 2nd echelon routes start from a micro hub, serve one or more customers and ends to the same micro hub*.

(Contardo, Hemmelmayr and Crainic, 2012; Vera C. Hemmelmayr, Cordeau and Crainic, 2012) propose an exact algorithm (branch-and-cut) as well as an Adaptive Large Neighbourhood Search (ALNS) metaheuristic to solve the 2E-LRP and the 2E-VRP. They show that the branch-and-cut algorithm can solve problems with up to 50 customers and 10 satellites to optimality. The ALNS is applied to the instances of (Boccia *et al.*, 2010; Nguyen, Prins and Prodhon, 2012) and reduces the solution costs found by MS-ILS + PR by 0.15%, 0.34% and 1.37% on average, while being twice slow (Prodhon and Prins, 2014). These results were again improved in the VNS of (Schwengerer, Pirkwieser and Raidl, 2012).

More recently, the LNS approach of (Breunig *et al.*, 2016) for the 2E VRP was applied to the 2ELRP. The authors underline the fact that their results are close to the state-of-the-art results of (Schwengerer, Pirkwieser and Raidl, 2012) with algorithms run-times of around 900s for large instances.

Following these works, a number of extensions have been provided to integrate new constraints and features. (Vidović *et al.*, 2016) study a 2E LRP in case of non-hazardous recyclables collection. (Zhao, Wang and De Souza, 2018) consider a heterogeneous fleet and *joint delivery alliances* with a case study in Chongqing, China. (Yu *et al.*, 2020) investigate outsourcing the last-mile deliveries to a third party logistics provider (3PL) and use their algorithm to design a two-echelon freight distribution system in Taipei City, Taiwan. (Huang, Huang and Guo, 2020) propose and ALNS for micro hub location and VRP with mixed delivery and pick-up for urban small-package shipping in an electronic commerce context. They evaluate their method on synthetic instances adapted from the literature and a realistic case from the city of Zhengzhou, China. (Perboli et al. 2021) consider the scheduling of in and out shipments. The number of parcels that can be delivered in a shift is determined by the number and identity of the vehicles allocated to work at it. They present a mathematical model and an effective heuristic, which are applied to the operations of micro hubs in the city of Turin, Italy. (Liu *et al.*, 2021) consider the design of a distribution network for a two-echelon E-Grocery delivery system, integrating cost and environmental aspects. (Chen *et al.*, 2023) define the concept of mixed multi-echelon urban logistics network to distribute parcel at the scale of a region in China. The algorithm locates urban distribution centres and intermediate depots to serve a large number of terminals.

A number of approaches consider locating micro hubs without integrating the first echelon routing costs (see eg (Guyon *et al.*, 2012; Gianessi *et al.*, 2016)). (Naumov, 2021) focusses especially on locating one loading hub for cargo-bikes using a simulation-based approach and integrating uncertainty.

The clear advantage of the location routing approach is that it can be embedded in a vehicle routing algorithm and provide accurate routing cost/emission estimations. The variety of implementations show that metaheuristic approaches are most appropriate to solve large scale instances, but that rather long run-times should be allocated to the algorithms to obtain satisfactory results. It can be noted that this approach requires one set of representative customers to be distributed on a single day.

Continuous approximation approaches

When the number of customers to be delivered at the second echelon is too high or many delivery days have to be integrated in the cost/impact estimations, several authors resort to Continuous Approximation models (CA models) to estimate the delivery costs or number of kilometres that are necessary to serve the customers from micro hubs. CA models have been used at the strategical level to take decisions in freight distribution networks. These were originally developed by (Beardwood, Halton and Hammersley, 1959; Daganzo, 1984b, 1984a, 2005). (Franceschetti, Jabali and Laporte, 2017) survey the use of these models in freight distribution. They note that the typical applications are districting, location, fleet composition and vehicle routing. For instance, in (Smilowitz and Daganzo, 2007), "*the goal is to find simple, yet realistic, guidelines to design and operate a network integrated both by transportation mode and service level; i.e., overnight (express) and longer (deferred) deadlines".*

The CA approach consists in defining so-called zones, segment or strips for which the distribution cost can be estimated from different locations. The challenge is both in finding the location, size and shape of the zones as well as on the approximation formulae that is used to estimate distribution costs.

Regarding the location of city hubs, the most significant work to date in the operations research literature is the redesign of the network of La poste, presented in (Winkenbach, Roset and Spinler, 2016). The objective is to redesign the network and assess the cost benefits of merging the urban mail and parcel delivery networks. They present a Large-Scale Urban Network Design and VRP. The problem consists in determining the number and type of facilities and their location; the deployment of different vehicle classes, ranging from vans to bikes. The routing costs are based on an estimate of the demand. The author states that segments of 500 × 500 meters are necessary to model the demand and geography of a city such as Nantes, which is used as a case study (illustrated on Figure 106). They consider pure single-echelon, two-echelon or a hybrid network structure. The solution approach is described in (Winkenbach, Kleindorfer and Spinler, 2016). The problem is formulated as a Two-Echelon Capacitated Location-Routing Problem (2E-CLRP) with modal choice. It is modelled as a large-scale static and deterministic Mixed-Integer Linear Program (MILP) using CA in lieu of explicit (and computationally intensive) VRP formulations. The model is called Augmented Routing Cost Estimation (ARCE). In (Winkenbach, Kleindorfer and Spinler, 2016), the author mention that *A network in a medium-sized city (e.g., more than 100 000 inhabitants) would include a number of depots, vehicles, and delivery addresses that by far exceeds typical test instances for heuristics developed in the context of location and routing problems (Nguyen et al. 2012).*

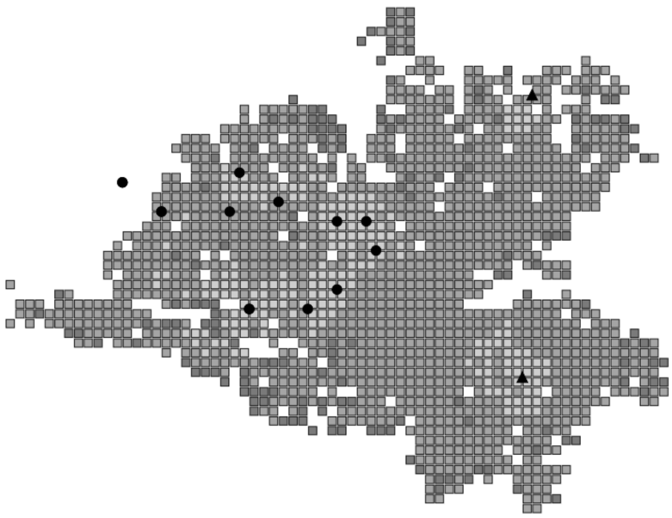


Figure 106: Illustration from (Winkenbach, Roset and Spinler, 2016) of the Nantes case study on the redesign of the La Poste mail and packages distribution network

The approach was then followed by several extensions and variants:

(Merchán and Winkenbach, 2018) study various complications to travel in real-world road networks, such as obstacles, one-way streets, and other hindrances to travel directness. (Snoeck, Winkenbach and Mascarino, 2018) apply ARCE and segmentation approach and integrate stochastic demand in order to establish a more robust network with lower expected operational cost and reduced risk of performance decline. (Janjevic, Winkenbach and Merchán, 2019) integrate collection-and-delivery points in the design of multi-echelon distribution networks. To do so, they integrate the CDP location decisions in a non-linear model and extend the ARCE model to approximate routing cost. The case study of last-mile distribution in Brazil is solved with a heuristic.

(Janjevic, Merchán and Winkenbach, 2021) consider multi-tier transportation systems with collection-and-delivery points arising in omnichannel distribution. They extend the ARCE route cost estimation formulae to model costs in a three-echelon capacitated location-routing problem.

(Snoeck and Winkenbach, 2022) study the strategical design of last-mile distribution networks with tight delivery deadlines. They propose a metamodel Simulation-based Optimization (SO) approach, which is validated on a case study on on-demand distribution from a company in Manhattan.

(Pina-Pardo *et al.*, 2022) study the design of a two-echelon last-mile delivery network under demand uncertainty. In an omnichannel context, they underline the importance of *(1) the reduced time available for order handling and delivery, and (2) the absence of a delivery cut-off time that clearly separates order collection and delivery periods*. They propose a two-stage stochastic program to model the problem. This approach decomposes the problem into strategic decisions (facility location) and operational decisions (daily distribution of goods). The model is solved by Sample Average Approximation (SAA). Routing costs are estimated by a CA model. The authors provide several managerial insights regarding the mix of transportation modes, facility location, and the impact of allowing the outsourcing of customer demand.

The pooling effects of multiple demand classes delivered by the same LSP is investigated in (Fontaine, Minner and Schiffer, 2022). They study the design of city logistics networks with multiple logistics service providers. The problem is solved with a MILP, integrating a CA model for transportation cost. On a case study on the city of Munich, Germany, they conclude that higher customer density and longer distances between depots and distribution areas promote 2-tier transportation strategies.

The clear advantage of the CA models is their relatively low sensitivity to the number of customers. However, they require a lot of data to train the cost model which rely on a lot of KPIs. These methods allow us to formulate the optimization problem as a mixed-integer program which is then solved by a commercial solver. As all papers from the literature present results that are obtained with academic version of powerful commercial solver, it remains to be found if the same models can be solved efficiently with open-source solvers such as CBC. A last notice is that the accuracy of the CA models is seldom checked in the literature on urban distribution system design because the associated 2ELRP are too large to be solved.

Related problem algorithms

In addition to the problem of locating micro-hubs many related problems have been studied in the literature.

For instance, (Voigt *et al.*, 2022) study the problem of locating the depot (e.g. UCC) of a two-echelon distribution network. The problem is solved with a meta-heuristic that hybridize LNS and a population based approach. (Bektaş, Crainic and Van Woensel, 2017) underline the fact that *strategic design models should also select the City Logistics network, e.g., the access/egress corridors and the street networks open to each vehicle type and the determination of the vehicle fleets composition and size, but very few contributions address this general case.*

Locker Or Pick Up Points Location

The location of lockers or pickup stations is an emerging research topic in the scientific literature. Most of the references are quite recent and do not yet form a unified corpus of literature. Our review of the literature found out that most of the references are not published in top journals. Moreover, the question of locating lockers and other facilities such as pickup points at micro hubs or in shops is often coupled with other optimization problems such as routing (Wang *et al.*, 2022) or scheduling (Charisis *et al.*, 2020) or is part of a complex two-echelon location-routing problem.

The methodologies used to gather data, model the location problem and solve it differ a lot from one research paper to another. The study can be presented as a cost minimization or a profit maximization perspective (Deutsch and Golany, 2018; Lin *et al.*, 2022). One central question in the modelling is the way lockers will be used. Customer’s choice can be described by simulation tools and models such as the multinomial logit choice model (Lin *et al.*, 2020). Classical uncapacitated location allocation models consider that customers will automatically choose the closest lockers. In their *close-enough* location model, (Moya-Martínez, Landete and Monge, 2021) consider that customers will move a given distance from their home to pick up their demand. (Yang *et al.*, 2020) propose a bilevel programming model where the upper-level model is to determine the optimal location by minimizing the planners’ cost, and the lower one gives an equilibrium demand distribution by minimizing the consumers’ pick-up cost.

While most models consider a single time period, (Rabe *et al.*, 2021) propose a multiperiod model that is applied to a case study in the city of Dortmund.

Vehicle Fleet Design

The problem of selecting the right fleet of vehicles to serve the set of customers is related to the Fleet-Size-and-Mix Vehicle Routing Problem (FSM-VRP) (Koç *et al.*, 2016). As this is most of the time related to having a fleet of heterogeneous vehicles in the related optimization problem, we will not review this approach for the city logistics problem in particular, but mention the presence of a heterogeneous fleet of vehicles in the other sections. It can be noted that in the 2E-VRP, this problem can be handled quite easily because city freighters, such as cargo-bikes, are operating at the second echelon, and the larger vehicles are operating at the first. Hence, both fleets can be minimized rather independently from each other.

Research Gaps And Avenues

The review on facility location for urban services by (Farahani *et al.*, 2019) studies the location of services in the city falling into the following categories: waste management systems, large-scale disasters, small-scale emergency, general services and infrastructure, non-emergency healthcare systems and transportation systems’ infrastructure. They identified many observations and research gaps, some of which are clearly relevant for urban distribution systems:

Joint decisions integrated with location: location decisions are often coupled with other strategic or non-strategic decisions, such as fleet sizing, routing, inventory management…

Realistic distance measures: the calculation of distances has a large impact on the result. When real-life application is targeted, real distances and transportation times should be used.

Sustainability: facility location in city logistics is often driven by environmental consideration. Thus, sustainability-related objectives, functions, constraints or parameters should be considered. This is indeed an important matter because the economical objective cannot alone represent the efficiency of a transportation system. This topic is more particularly covered in the survey of (Lauenstein and Schank, 2022).

Uncertainty of parameters: the majority of urban service location problems are subject to uncertain or variable parameters.

Decision makers' risk attitude is not often considered in the models. This appears as a potential research avenue in our case because logistics facilities are seldom welcome in city centres and decisions are often taken by political entities.

Dynamic models and relocations: cities are dynamic systems that can quickly evolve. Then facility location models should consider multiple periods and enable the re-location of facilities in the future.

Demand aggregation: optimization problems that deal with tens of thousands of "demand points" must be aggregated. Interested readers may refer to (Francis, McGinnis and White, 1992) to learn about the basics and concept of aggregation error for location models. The continuous approximation models are clearly trying to address this aspect but it is not yet clear how accurate they are.

Competition: In the case of services in the private sector, competitive facility location should be considered. (Eiselt, Laporte and Thisse, 1993; Drezner, 2014) to read more about basics of these models.

Location sharing: develop collaborations with some existing businesses to share locations. Indeed as urban spaces for logistics is scarce, it can be useful, even for competing carriers, to share a micro-hub in the city centre. Or different businesses can collaborate to offer more pickup-up points in their shops.

Reliability of the facilities and their services should be considered. Few studies consider disruptions and "backup coverage" in case of disruption.

Solution approaches: in recent years a special focus was set on metaheuristics or MIP based approaches based on CA models. The combination of metaheuristic with exact methods, called matheuristics is promising in addressing location problems. A research avenue could be to combine CA models and routing model in matheuristics.

Centralization versus decentralization: Keeping the balance between the number of facilities and their capacities is an example of considering economic and social impacts.

To our knowledge, the design of low emission zone has not been covered in the OR literature.

3.3.2 Vehicles routing

The vehicle routing problem consists in designing the routes of a set of vehicles in order to serve a set of customers with a minimum number of vehicles and a minimum distance travelled. This problem has been widely studied by the community with numerous exact and heuristic optimization approaches proposed in the past fifty years. Two reference books on the subject are (Toth and Vigo, 2002, 2014)

VEHICLE ROUTING IN CITY LOGISTICS

In their review on recent challenges in routing and inventory routing for e-commerce and last-mile delivery, (Archetti and Bertazzi, 2021) list several interrelated factors that influence city logistics: on-line orders, short delivery times, presence of release dates, overlap of customers' time windows, new delivery strategies and new delivery technologies. (Archetti and Bertazzi, 2021) dedicate a *section to VRP with release dates*. This topic is related with all fast delivery operations, but also to the delivery of e-commerce goods, which is not organized on a daily basis, but as on on-line system. New goods continuously arrive at distribution centres during the whole opening period and must be quickly delivered to customers. These characteristics reduce the time consolidation opportunities.

The corresponding routing problem from a distribution centre that receives shipments at any moment of the day is called *the Vehicle Routing Problem with Release Dates* (VRP-RD). The VRP-RD was introduced by (Cattaruzza, Absi and Feillet, 2016). In this paper, vehicles with limited capacity perform several trips per day. Customers ask for service within a certain time interval (time window). (W. Li *et al.*, 2020) study a similar problem, minimizing the sum of vehicle completion times while neglecting time window constraints. The VRP-RD comprises three main decisions: the allocation of orders to trips, the allocation of trips to vehicles, and the visiting sequence of customers in each trip.

Reyes et al. (2018) considers a maximum delay between the release date and the delivery date. (Yang *et al.*, 2021) developed an exact branch-price-and-cut algorithm based on the set-partitioning formulation for the VRP with release dates and due dates. The pricing problem is solved by an efficient bidirectional labelling algorithm.

In the last three years, several publications contributed to extend the first VRP-RD publication by integrating new features, including multi-depot (Zhen *et al.*, 2020), synchronization of goods delivery and service (Li *et al.*, 2021), heterogeneous fleet and lateness costs (Soman and Patil, 2020), flexible time windows (Sun, Li and Li, 2022) etc.

Another recent trend is to consider a stochastic and dynamic setting, as done by (Ulmer, Thomas and Mattfeld, 2019; van Heeswijk, Mes and Schutten, 2019; Voccia, Campbell and Thomas, 2019; Archetti *et al.*, 2020). (Klapp, Erera and Toriello, 2018a, 2018b) study a similar problem focusing on the decision about sending out the vehicles or waiting for new parcels to arrive.
According to (Archetti and Bertazzi, 2021), an interesting research direction could be the combination of the VRP-RD with time-windows assignment and crowdsourced delivery.

LAST-MILE DELIVERY WITH CARGO-BIKES

The use of cargo-bikes for last-mile delivery has known a tremendous development in recent years, enforced by multiple considerations: increase of e-commerce deliveries, high congestion and lack of parking spaces in city cores, time pressure, environmental and energy concerns. In parallel, the number of academic publications on this subject has also grown exponentially in the last five years.

(Vasiutina, Szarata and Rybicki, 2021) provide a literature review, investigating the benefits and drawbacks of integrating cargo-bikes in urban logistics schemes. The authors examine different methodologies and techniques to evaluate the impact of cargo-bikes on the environment. They present studies confirming the potential of cargo-bikes to serve as sustainable substitution for conventional delivery vehicles. Their literature review shows that cargo-bikes are best suited for last-mile delivery in cities, especially in districts with traffic restrictions and high population density. The main advantages of this transportation mode is its low impact on congestion, CO2 emissions and local pollutants. Its low sensibility to congestion which can save some cost in dense city centres. On the other hand, the low capacity and speed of cargo-bikes is pointed out as a disadvantage in other conditions and they are generally used to perform short distance trips.

A large part of the literature related to cargo-bikes is dedicated to electric bikes (see Caraccedo et al. (2022) or (Narayanan *et al.*, 2022) for a general presentation). (Gruber, Kihm and Lenz, 2014) evaluated the potential market for electric cargo-bikes, the organization of the market and the perception of electric cargo-bikes by bike and car messengers. Electric cargo-bikes are well suited for courier shipments and in urban areas facing problems like congestion and limited access areas due to environmental zones or delivery period restrictions. Their potential market is positioned between bikes and cars in terms of cost, payload and range.

(Assmann *et al.*, 2020) examine different strategies for the ***location of urban transhipment points*** and their effect on traffic, carbon footprint, and air quality. The authors conclude that the use of cargo-bikes for CEP deliveries in urban areas could reduce greenhouse gas, particulate matters, and nitrogen oxides emissions significantly. The authors point out that cargo-bike delivery networks are dominantly seen as a mean to improve liveability, e.g., by reducing traffic.

The various impacts of using cargo-bikes are discussed in many papers. (Robichet, Nierat and Combes, 2022) study the conditions for the financial sustainability of cargo-bikes compared with electric Light Commercial Vehicles (LCVs). Cargo-bike solutions can be more cost-efficient than LCVs with a few micro hubs located where the demand is densest, but they can only be relevant financially in this context. (Fontaine, 2022) study the benefits of city freighters in two-echelon delivery structures with micro-depots. They focus on the benefit of consolidation and pooling between multiple logistic service providers. The economic viability of two-tier city logistics systems varies in between service regions. They find that in their application, a pure two-tier city logistics system using only city freighters for last-mile delivery is **not economically attractive under current conditions**. The authors point out that transferring all orders at micro depot induces an extra handling cost which surpasses other savings at the first echelon. However, operating city freighters from micro-hubs to serve regions with high shares of small parcel deliveries while traditional trucks are used to deliver the micro hubs and customers in sparser regions can be economically attractive.

(Büttgen, Turan and Hemmelmayr, 2021) study a two-echelon network where the first echelon is operated by electric vans and the second echelon by cargo-bikes. The goal is to determine the best location for a city hub and the composition of the delivery fleet by minimizing the total distribution and CO2-emission cost. The study shows potential savings of 30% in distribution costs and savings of 96% in CO2-emissions by considering both indirect and direct emissions in a so-called well-to-wheel approach which integrates energy production and operation.

Due to their small coverage area, cargo-bikes are often considered within a ***two-echelon logistics network,*** where the first echelon is traditionally operated by traditional trucks or electric vans. The following two papers study alternative organizations:

- In (Boysen, Briskorn and Rupp, 2023) the first echelon is a ***cargo tunnel*** delivering a micro-hub. The critical points of such as system are the storage capacity of the micro hub, the transport capacity of cargo-bikes and the scheduling of tunnel operations.
- In (Masson *et al.*, 2017), the first echelon is operated by ***city buses*** from a depot to a set of bus stops in the city core. Cargo-bikes are in charge of the very last segment in the city centre. The problem is modelled as a variant of the pickup and delivery

problem with transfers and solved with an adaptive large neighbourhood search. This study shows the high increase in the number of required bikes as delivery time windows become tight.

Several publications study additional elements in the logistic system or features in the optimization models: In (Enthoven *et al.*, 2020), the first-echelon trucks transport goods either to covering locations, such as ***parcel lockers***, where customers can pick up goods themselves, or to satellite locations, where goods are transferred to cargo-bikes. The problem is solved with an Adaptive Large Neighbourhood search method. The use of lockers can reduce the total operational costs up to 35.4%. (Naumov and Pawluś, 2021) present the joint optimization problem of ***3D-packing*** and routing of cargo-bikes. However, their algorithm could be applied only to very small instances. (Fontaine, 2022) identifies the weight carried by cargo-bikes as a limiting factor and introduces the Vehicle Routing Problem with ***Load-dependent Travel Times*** (VRPLTT). Large instances solved with an Adaptive Large Neighbourhood Search (ALNS) method show the benefits of considering load-dependent travel times in last-mile delivery with cargo-bikes. (Caggiani *et al.*, 2021) incorporate the ***partial recharging*** policy of electric cargo-bikes in a two-echelon VRP (i.e. a battery charging operation can be interrupted before full charge to save time).

When the cargo-bikes are operated by freelancers, each vehicle is considered as an independent agent. In this context, (Fikar, Hirsch and Gronalt, 2018) propose an ***agent-based simulation*** using dynamic optimization procedures to generate and select vehicle routes and transhipment points (micro-hubs). This study is motivated by dynamic restaurant delivery services. The results highlight the importance of having a sufficient number of active cargo-bikes available. (Llorca and Moeckel, 2021) present a simulation model for the last-mile delivery of parcels both with electric vans and electrically assisted cargo-bikes. The author uses an agent-based model based on the disaggregation of commodity flows to represent trucks (for all commodities) and individual shipments (for parcel deliveries). The use of cargo-bikes allows to reduce the number of motorized vehicles and the CO2 emissions, although the presence of large parcels requires that at least half of deliveries by vans are still required. **The benefits of the two-tier system are the reduction of the noise and CO2 emissions, and the reduction of the number of motorized vehicles. The counterpart is an increase of the total distance travelled.**

Case studies based on local data:

Many papers rely on real life case studies or data provided by local stakeholders. This helps having a large spectrum of cargo-bikes applications in various contexts. A counterpart is that these studies cannot be all generalized to any other city.

- **Antwerp:** (Arnold *et al.*, 2018) compare cargo-bike systems with other delivery concepts, i.e., vans and self-service concepts, in a simulation study based on the daily distribution activities of a logistics service provider. Compared to home delivery via vans, cargo-bikes can lead to a decrease in external costs, i.e., emissions, noise, and congestion, by 40% per delivery compared to traditional home delivery via vans.
- **New York City:** (Conway *et al.*, 2017) establish that freight tricycles offer a feasible alternative to motorized vehicle operations for local and last-mile deliveries, even for transportation of temperature-sensitive goods. They can be speed competitive with motorized delivery vehicles in congested neighbourhoods. Cargo-bikes have tremendous advantages over motor vehicles in parking flexibility and space occupation. The study also points out the need of efficient transhipment between vehicles or between vehicles and storage areas. Transhipment can be supported by the use of modular containers or specialized loading equipment.

- Other papers study the use of cargo-bikes in constrained environments: (Gonzalez-Calderon *et al.*, 2022) study the development of cargo-bikes in Medellin, which is a city with many slopes. The authors argue that cargo-bikes are seen as more interesting there due to poor infrastructure and the old technology of traditional vehicle. They mention the positive impact of cargo-bikes on congestion and pollution, but they also point out the necessity to include slopes in the estimation of models since they can become an obstacle for bicycles in the urban areas with mountainous topographic conditions. (Dybdalen and Ryeng, 2022) investigate whether cargo-bikes can operate efficiently in northern climates and on winter roads, based on a case study from Trondheim, Norway. Success factors include the design of the cargo-bike and driver's equipment, but also the increase in the amount of bicycle lanes and urban consolidation centres or micro depots.
- Other local case studies include Bordeaux (France) (Sana *et al.*, 2022), Innsbruck (Austria) (Büttgen, Turan and Hemmelmayr, 2021), Krakow (Poland) (Naumov, 2021), La Rochelle (France) (Masson *et al.*, 2017), Munich (Germany) (Fontaine, 2022), Paris (France) (Robichet, Nierat and Combes, 2022), Stargard (Poland) (Nürnberg, 2019) and Stuttgart (Germany) (Rudolph *et al.*, 2022), which shows the growing interest in practice for this technology in urban delivery.

Two-Echelon Vehicle Routing Problems

The 2E-VRP is a generalisation of the VRP with a two-step distribution process. In a first echelon, the goods travel from a central depot to a set of intermediate facilities. Then, in the second echelon, the goods travel from the intermediate facilities to their final destination.

In the context of city logistics, the intermediate facilities, called *satellites* in (Crainic, Ricciardi and Storchi, 2004) are used to consolidate and transfer freight that originates from various external origins to a set of environment-friendly vehicles adapted for utilization in dense city zones, called *city-freighters*.

The 2E-VRP can be considered as two independent VRP problems (one for each echelon) that are connected through all operations that occur at satellites. Sometimes the synchronisation constraints between both echelons are quite loose. For example, (Kaspi, Raviv and Ulmer, 2022) note that the replenishment of the satellites can be performed at times when the traffic in the city is low and the last-mile distribution can then be performed at more convenient hours during the day. However, when satellites' capacity is small, one cannot ignore the tight synchronisation constraint before the two-echelons. This is why city logistic has quickly emerged as a typical field of application of the 2E-VRP.

Solving a 2E-VRP instead separated VRP at each echelon helps considering the logistics system as a whole, and integrates the existing synchronization constraints at the intermediate facilities. Interested readers are also referred to the survey of (Guastaroba, Speranza and Vigo, 2016) for a survey on intermediate facilities in freight transportation and to (Drexl, 2012) for a survey on synchronization in vehicle routing.

Two main literature reviews on the 2E-VRP have been published: (Rosario Cuda, Guastaroba and Speranza, 2015b) and (Sluijk *et al.*, 2022). (Rosario Cuda, Guastaroba and Speranza, 2015b) study two-echelon problems with a very large scope covering three main classes of problems: the two-echelon location routing problem, the two-echelon vehicle routing problem, and the truck and trailer routing problem. All usual variants of the VRP can be applied to a two-echelon system, leading to the 2E-VRPTW (time windows), 2E-CVRP (capacitated case), 2E-VRP with delivery options, stochastic 2E-VRP, etc. In 2015, (R. Cuda, Guastaroba and Speranza, 2015) mentioned that the research concentrates on the basic version of 2E-VRPs, i.e. 2E-CVRP. The recent survey by (Sluijk *et al.*, 2022) shows a rapid integration of more and more complex 2E-VRP features in the distribution schemes: multiple depots, multiple commodities, capacitated satellites, heterogeneous fleet, time-windows, split deliveries, synchronization constraints, multi-trip routes, etc. Recent models incorporate several complicating features with more and more complex material flows. For example, (Grangier *et al.*, 2016) consider multi-trip routes, time windows and synchronization constraints at satellites while (Dumez *et al.*, 2022) consider capacitated satellites, multi-trip routes and reverse flows.

Exact methods to solve the 2E-VRP include branch-and-cut algorithms (Gonzalez-Feliu *et al.*, 2008; Contardo, Hemmelmayr and Crainic, 2012; Jepsen, Spoorendonk and Ropke, 2013), decomposition-based methods (Baldacci *et al.*, 2013; Santos, Mateus and Cunha, 2015; Dellaert *et al.*, 2019; Marques, 2020). The most efficient methods are able to optimally solve instance with a few satellites and 100 customers.

Large Neighbourhood Search (LNS) (Anderluh *et al.*, 2021; Mühlbauer and Fontaine, 2021) and its adaptive version (ALNS) (Vera C Hemmelmayr, Cordeau and Crainic, 2012; Breunig *et al.*, 2016; Gu *et al.*, 2022) represents the most popular single solution-based algorithm for the 2E-VRP. Other heuristics and metaheuristic methods include many classical methods such as Variable Neighbourhood Descent (Belgin, Karaoglan and Altiparmak, 2018), Variable Neighbourhood Search (see e.g. (H. Li *et al.*, 2020) (Wang, Shao and Zhou, 2017) or (Paul *et al.*, 2021) in a multi-objective context) and Tabu Search (Zhou *et al.*, 2022).

As far as population-based algorithms are concerned, the most popular methods are the genetic algorithms (Zhou *et al.*, 2018) and well as their extensions: memetic algorithms (Bevilaqua, Bevilaqua and Yamanaka, 2019) or improved reference point-based non-dominated sorting genetic algorithm-III (Wang *et al.*, 2021) for multi-objective optimization. A few papers use GRASP (Greedy Randomized Adaptive Search Procedure) to find initial solution and then use path relinking techniques to find solutions to the 2E-VRP (Anderluh, Hemmelmayr and Nolz, 2017) (Crainic *et al.*, 2013).

There are many research avenues in the field of 2E-VRP. First, solving real-life applications involves jointly optimizing the vehicles routing and the logistic operations in all facilities, and more especially inside satellites. This requires coupling routing and scheduling algorithms and to find trade-off solution between the optimization of both components. Another important issue is the relationship between routing and packing, since the last-mile delivery with city freighter generally involves packing the goods in small dimension vehicles. Then, in two-echelon systems, any delay or unexpected event can have consequences on a large part of the network. There is still a lack of robust optimization algorithms to mitigate the impact of delays. Moreover, defining efficient recourses in case of delay is an important research topic. Additionally, routing models with accurate human resource management and fleet management in a context of variable demand are still scarce. The positive environmental impact of 2E-VRP systems for city logistics is now well established. However, finding the conditions under which of economic and social benefits can be achieved is still a challenge.

Routing With Lockers And Shared Delivery Locations

Vehicle routing problems with the use of lockers and shared delivery locations has appeared recently in the literature. (Sitek and Wikarek, 2019) defined the Capacitated VRP with Pick-up and Alternative Delivery (CVRPPAD). This paper considers multiple options for each parcel to be delivered. Lockers and post offices are modelled with limited capacities. Customer preferences are modelled with a penalty on the objective function if a non-desired option is used. No time windows are considered. Their method relies on a pre-processing phase done by constraint programming. A heuristic then groups parcels together before assigning them to a route.

(Zhou *et al.*, 2018) define the Multi-Depot Two-Echelon Vehicle Routing Problem with Delivery Options (MD-2EVRP-DO). In this paper, a parcel can either be delivered at the customer's home or to a selected pick-up facility. Shared locations are considered to have infinite capacities and customer preferences are modelled through penalties in the objective function. Time windows are not considered. This problem is solved with a multi-population genetic algorithm that embeds *ad hoc* local search.

(Orenstein, Raviv and Sadan, 2019) investigate a distribution system where customers are served at capacitated locker box stations. Home deliveries, and thus time windows for customers, are not considered in this problem. They consider different sizes for the locker boxes. However, at most one parcel can be assigned to a slot; thus, packing decisions do not have to be taken.

(Mancini and Gansterer, 2021) present the vehicle routing problem with possible delivery at home or at locker box stations. However, they do not consider different sizes for the parcels and slots. The vehicle routing problem with heterogeneous locker boxes, which is introduced by (Grabenschweiger *et al.*, 2021), includes a routing problem as well as a packing problem.

(Schwerdfeger and Boysen, 2020) deal with mobile locker box stations whose locations can change over time. They address the problem of optimally locating the mobile locker boxes such that customers are within a certain range of their assigned station at some time during the planning horizon so that the locker fleet is minimized.

(Tilk, Olkis and Irnich, 2021) solve a Vehicle Routing Problem with Delivery Options (VRPDO), which integrates lockers and several types of delivery locations, called delivery options. In this problem, customers can individually prioritize their delivery options. The routes should respect time windows, capacities at shared locations such as lockers and minimum service level requirements. They developed a branch-and-price-and-cut algorithm to solve the problem. (Dumez, Lehuédé and Péton, 2021) solve larger instances of the VRPDO with a large neighbourhood search in which a set partitioning problem is periodically used to reassemble routes. The algorithm is then improved in (Dumez *et al.*, 2021).Other recent related works concern the VRP with simultaneous pickup and delivery with parcel lockers (Yu *et al.*, 2022) and the vehicle routing problem with scheduled lines, parcel lockers, and crowd shippers (Kuo and Yu, 2022).

Integrating Regulation In Vehicle Routing

Although many problems arise from political decisions, very few papers in the literature explicitly deal with regulatory aspects. These are typically modelled by pre-assigning customers in a low-emission zone to the vehicles of each micro hub.

In 2016, (Mancini, 2016) mention that Limited Traffic Zones (LTZ) were not investigated in the VRP literature. To our knowledge, this contribution is the first to propose a model and a meta-heuristic to a variant of the VRP that integrate a regulated area in the city.

(Anderluh *et al.*, 2021) consider an interesting variant where customers in an intermediate "grey zone" can be assigned to vehicles of both echelons in a 2E-VRP.

In (Le Colleter *et al.*, 2023), the choice of parking location from which the driver can walk in a protected area is investigated.

Clearly this field could be further investigated to see if VRP algorithms could provide simulation tools to better evaluate the potential impact of LEZ or LTZ.

Research Gaps And Avenues

There are still multiple research areas identified for vehicle routing in urban logistics depending on the problem. Sustainability aspects are to be better integrated in decisions and algorithms, but still appear as a constraint that should be enforced by public authority to establish a fair competition between companies. Some algorithms which solve VRP with CO2 emissions as an objective function are discussed in e.g. (Dündar, Ömürgönülşen and Soysal, 2021; Moghdani *et al.*, 2021). Further challenges are discussed in the city logistics surveys (Savelsbergh and Van Woensel, 2016; Kaspi, Raviv and Ulmer, 2022; Lyons and McDonald, 2023). From the algorithmic point of view, synchronization and capacity handling in two-echelon systems is still a challenge, especially if combined with stochastic travel times and time-dependency.

A clear observation is that normal scale vehicle routing problems with realistic constraints are currently solved by metaheuristics and not exact methods. In the field of meta-heuristic, LNS seems to be a well-established method, appreciated for its performance and simplicity. This last criterion enables the integration of complex synchronization constraints. On some occasion, hybridizing LNS with a MIP solver to design a metaheuristic has proven useful to increase the efficiency of the algorithm.

3.4 Conclusion

The literature review showed that many surveys, case studies, simulations etc. have been conducted in all areas, but mostly with a very narrow focus of one or only a few different aspects. The combination of the logistics concepts, pillars and optimization of vehicle routing and location is not considered yet. It could be shown, that for the presented logistics concepts (Urban Consolidation Centres, Micro Hubs, Collecting Points, Alternative home delivery, Multimodal Last-mile Logistics, Innovative Vehicle Solutions, Use of autonomous vehicles, Metro based logistic underground, Physical Internet, Crowdlogistics and Load Pooling), the design of the final concept is important for the possible impacts of the solution.

All logistic concepts have advantages and disadvantages, which are needed to be weigh against each other, in order to design the “best” solution. Consolidation points like UCC or micro hubs are reducing the distance travelled per shipment, the environmental issues and the externalities like traffic congestion or emission. On the other hand, micro-hubs in particular are having the barrier to find beneficial value-added services and sustainable business models. They also involve a lot of different stakeholders at an early stage who do not always wish to collaborate and share their data. Finally, finding suitable locations for such facilities is also difficult due to the perceived externalities of logistics facilities in city cores. Collecting points as new places of deliveries are reducing the handling effort, if there is no failed delivery attempt, and a reduction of congestion and emissions is possible. On the other side, the new places of delivery are lowering the convenience for the customers, as they need to travel to the pick-up place which may cause delays of the receipt of the parcel. For alternative home delivery attempts, there is no need to collect the parcel at another location but there might be additional cost for the boxes and the acceptance of the system is low. Using cargo-bikes makes the operation independent from congested roads and access restrictions, but the charging infrastructure and the capacity of the cargo-bike is disadvantageous.

Most of the time, in order to improve the last-mile logistics, a combination of the different concepts is necessary. This combination of different concepts needs to be designed carefully (also regarding the underlying optimization problems), in order to find the best solution for each city. There is no “one fits all” solution, but different cities might have similar situations.

For the 5 pillars of DECARBOMILE, searching for "last-mile", city logistic", "urban logistic", "urban freight transport" and the name of the pillars lead to 22 000 results, from which only 470 seemed to possibly fit to the DECARBOMILE project. For further investigation, the scope needs to be set in a narrower way, but for a first overview of the whole field, it was important to conduct a wider search.

The research for the Pillars showed, that normally only one aspect of the pillar is studied. For example, for the business models, there is no overview of all possible business models, and the papers are normally describing only one business model in more detail.

There is already quite a lot of literature on **collaboration**, but mostly applied only theoretically due to the barriers of a lack of competent staff or insufficient IT capacity, financial stability insecurity or trust issues. It could be shown that it is important to incorporate all relevant stakeholders and to weigh up benefits and risks in advance. By using collaboration, positive impacts in terms of costs, working conditions, trust, security, reliability and service quality as well as ecological benefits (less emissions through decreased distances and shorter tour length) are possible.

As there are a lot of different **business models**, the literature review focused on the UCC and Sharing Economy. The business model always needs to be adapted to the local context and the logistics concepts are highly interrelated with the business models. Either the business model is designed first, while the logistics concept is developed afterwards, or it is done the other way round. UCC can improve the efficiency of the delivery and reduce travel distances and therefore also environmental impacts when overcoming the challenges of collaboration and the often-missing economic viability. Shared Economy (Shared Warehouse (like UCC), Crowdshipping and Logistics-as-a Service) can help to maintain a high-level service while reducing costs and can have environmental benefits like a better use of resources, reduced waste and number of vehicles and can increase the flexibility of the LSP. Therefore, ensuring the quality and reliability and compliance and having a backfall plan for possible shortages of drivers is important.

For the pillar of **urban integration** and space management it could be shown that the different solutions/logistics concepts have different extent in terms of urban integration, showing the link to land use. For this reason, conflicts between locational parameters and logistic conditions need to be considered. Urban integration is highly dependent from the local circumstances, making it impossible to find a one fits all solution. It affects a lot of different stakeholders, who need to be involved in the decision-making process. Urban Integration can include the public infrastructure, land use management, access conditions and traffic management and can lead to environmental as well as time benefits for several stakeholders. For overcoming the potential challenges of the difficulty of finding space in dense urban areas, where a lot of conflicting opinions of different stakeholder and legal, institutional and financial barriers need to be considered, it is important, to keep the stakeholders in mind and to develop adequate solutions for the different urban areas and its solutions like UCC, micro-hubs or smart lockers.

There is a wide range of possible **regulations** like Vehicle Restrictions, Congestion Charges, Load Factors, Off-Hours Delivery, Time Access Regulations or Low Emission Zones. They all have in common that they want to improve the traffic in the city and reduce environmental impacts. It needs to be considered that the regulations are affecting different stakeholder differently when e.g. offering logistics services in a city. Therefore, regulations should be developed regarding the different stakeholders and start with low-cost and effective methods, to reduce the pollutants quickly.

For the **digital infrastructure** pillar, it could be shown that there is already a lot of digital infrastructure offered which should automate operational tasks and the exchange of real-time data to enable collaboration between different sectors and stakeholders. By using DI, benefits for the environment and an improved flow of goods can be achieved. Examples for tools for the digital infrastructure are: Information and Communication Technology (ICT), Internet of Things (IoT), Intelligent Transport Systems (ITS), Digital Twin, Physical Internet, which all can have different advantages and disadvantages. Most of the time, not all options are being used in daily operations.

As the logistic operations have a potential for improvements, different optimization algorithms can be used. The aim of the optimization algorithms is mostly the minimization of logistics cost while also satisfying a set of operational or quality constraints.

For the **network design and facility location** it could be shown, that different characteristics (normally complex supply chains with multiple layers / tiers, multiple commodities, complex flows between the different facilities, multiple technologies or transportation modes, integration of strategic and tactical decision, more particularly with regard to storage, modelling of realistic costs and environmental considerations) are taken into account for solving the optimization problem.

The problem of locating urban micro hubs has not received as much attention as the vehicle routing problem in the optimization literature. The network algorithms can be applied to different cases like small-package parcels, E-Grocery Delivery Systems or non-hazardous recyclable goods. As they are complex, mostly metaheuristics are used, as optimal results are only found for very small instances. Some authors are proposing Continuous Approximation models (CA models) to estimate the delivery costs or number of kilometres needed to serve the customers. The approach can be used to estimate the costs and emissions in a large scale problem. For this, the number and type of facilities and their locations is determined and different vehicle classes (bikes, vans etc.) can be deployed. For the vehicle fleet design, a heterogeneous fleet can be minimized independently by solving appropriate vehicle routing problems. The location of smart lockers is mostly studied in combination with other optimization problems.

It could be shown that the location decision is dependent on a lot of other decisions and that the calculation of distances is important. For those locations, the sharing and reliability are important factors. As the system is dynamic, the parameters of the location problem are uncertain and variable, so a relocation might be necessary. For deciding on the network, the risk attitude of the decision makers should be considered. In the last years, the importance of ecological optimization objectives is risen, so that not only economic objectives are considered in the decision-making process.

Vehicle Routing problems with release dates are used for example for fast delivery operations. The objective of those VRP is the reduction of time and possible consolidation opportunities (synchronization of goods delivery and service) and can take into account multiple-depots, heterogeneous fleet, lateness cost and flexible time windows. The use of cargo-bikes has been received a little more attention in the literature recently, also in combination with micro-hubs, parcel lockers, 3D packing and routing or load dependent travel times. The cargo-bikes are suited for areas with a high-density population, high shares, small parcels and traffic restrictions. By using cargo-bikes, benefits for the environment and an improved liability could be identified. As most of the papers used the methodology of case studies, difficulties are rising for the transferability to other cities, as differences between the cities like climate differences, topography or the infrastructure (charging infrastructure, consolidation centres or bike lines) need to be kept in mind. For the two steps distribution process, being connected through satellites (two-echelon VRP), more and more features and complexity like multi depots, capacitated satellites, heterogeneous fleet or time windows have been added in the last years. For the combination of lockers and shared delivery locations, the customer preferences and sometimes capacity constraint or a location change of a mobile locker need to be considered. Different methods are used, that can optimally solve the VRP for a few satellites and up to 100 customers. For larger scale problem and more realistic run times, VRP are solved with metaheuristics instead of exact methods. The routing problem can be combined with logistic operations like packing but this requires extra computation times. While the environmental impacts of the two-echelon VRP is clear, further research is needed for the economic and social benefits of the system. Finally, we found that the literature is still scarce on the integration of regulation (LEZ, LTZ and parking locations) in VRP algorithms.

4. GENDER EQUALITY PLAN

4.1 Context

Ensuring diversity in DECARBOMILE is essential, but to achieve the impact desired, the diversity in the project needs to be accompanied by equity in all processes, such that processes and activities become accessible to everyone with the relevant interest. Diversity and equity are none without the other but must also consider inclusion. The shared appreciation of contributions must be anchored in the processes and in the spaces that the project operates in, such as meetings, workshops, interventions, etc, to build a successful project. DECARBOMILE strives to ensure that there are no imbalances in the gender and demographics of those who operate with and within its space. Such imbalances go against the beliefs and aims of the project, particularly within the collaboration pillar of its five pillars.

It is foreseen that a gender dimension is key in several aspects of the DECARBOMILE activities. To ensure its integration at all stages of the project, T2.1 will already tackle the gender aspect at the very beginning of the activities, then T2.4 will oversee their application at the validation stage of the DECARBOMILE solutions, use cases and business and governance models. Finally, the social dimension (including gender aspects) will be part of the social assessments of T8.1 and an integral part of the D8.3 guidebook for inter-disciplinary replication. As the central focus of the project, the use of cargo-bikes and decarbonised urban mobility is clearly impacted by gender dimension issues. Indeed, cargo-bikes are recognised as an egalitarian mode of transport, however there are still local aspects that impact how they are perceived and used in urban contexts regarding gender distribution (Riggs, William, and Jana Schwartz, 2018; Boterman, Willem R., 2020; Becker, Sophia, and Clemens Rudolf, 2018.). Building on this knowledge, DECARBOMILE will enforce stimulating participants on equal basis to attend the planned events, workshops and interventions defined in the proposal through a clear strategy defined early in the project. To achieve gender equality in every activity and aspect of the project, assessment of local cultural practices will be performed in WP2, while also guiding project partners to ensure a fair gender distribution in the use of various services to be deployed and put to use in the project. This element targets in particular logistics operators DPDHL, MIGROS and TRI. DECARBOMILE will also ensure gender-balanced accessibility, inclusion, and participation to the Living Labs by encouraging and supporting a wide range of groups and associations following the defined strategy that can influence the perception of the green last-mile logistics and will be considered for the societal acceptance analyses in T8.1. Apart from the technology used in the project, gender dimension issues also appear in decision-making processes. To this extent, the consortium recognises the importance of equality between genders as a central policy at both European and State levels and is firmly determined to honour the priorities set in EU “Strategic engagement for gender equality 2016-2019” & EU “Gender Action Plan” 2016-2020 by developing this Gender Equality Plan. The strategy promotes gender equality in decision-making processes, increasing women’s labour-market participation and the equal economic independence of women and men. CBS, in close collaboration with TUHH, will lead the process of gender dimension compliance, from the identification of cultural factors with local partners to the drafting of the gender equality plan, application in the workshops, events, meetings, as well as through the use of services in the project and in regard to policy aspects that might impact GE aspects.

A small disclaimer to the above introduction. The authors of this GEP acknowledge that within this document, gender is sometimes being treated as binary. Due to some legislative constraints and the ability to collect data regarding this issue, we would like to recognise that gender goes beyond the binary and that non-binary gender identities are considered through the actions of the project to acknowledge all gender.

All partners have a responsibility to embed the current GEP into their aspects of the project including any tasks, results, or deliverables. Any issues in the embedding of the GEP in the work of the partner should be addressed to the Project Coordinator. The executive board is responsible to ensure that GEP is followed. Any changes to the plan ought to be discussed and agreed with the entire consortium. To assist the embedding process, CBS & the Project Coordinator can facilitate dialogue and provide resources where necessary.

4.2 Objectives

To fulfil the ambition of ensuring diversity within the project, as well as equitable and inclusive spaces, DECARBOMILE will focus on the following priorities:

- Ensure to stimulate participants on an equal basis to attend the planned events, workshops, and interventions.
- Complete an assessment of local cultural practices, contributing to the overall GEP, including a gender review of the environments and spaces in which the project operates.
- Guide project partners to ensure a fair gender distribution in the use of various distribution services, such as cargo-bikes.
- Promote gender equality in decision-making processes.
- Developing measures to ensure environments are equally inclusive and attractive to all genders.

4.3 Measures and activities

To achieve our priorities and to nurture a culture of gender inclusion, the project should engage with and initiate a number of activities based on each priority. The activities and measures in place are as follows:

- Ensure that neither partner nor stakeholder are excluded or not invited to planned events, workshops, or interventions due to their gender identity. Invitations to such events should ensure a fair inclusion and mix of all genders.
- Assess local cultural practices by working closely with stakeholders and partners that will join or host events as part of the project to ensure the needs of all genders are met.
- Provide resources and support to guide project partners to ensure gender distribution in the use of decarbonized solutions, such as bikes and other possible electric services.
- Ensure gender diversity in decision-making processes through the principles of representation and participation. Coordinators and facilitators will ensure that each partner and/or stakeholder has their say, regardless of their gender identity.
- Ensure that language in communication, both oral and written, reflects the principles and inclusion promoted in this GEP, and respects a person's right to their gender identity and the pronouns the person uses.
- Provide clear guidelines for prevention, reporting and handling of any incidences of sexism or sexual harassment.

4.4 Priorities, implementation and targets

The table below provides an overview of priorities, activities, implementations, indicators, and targets as well as the monitoring process. Continuous discussion and implementation of these activities should be done by the consortium throughout all aspects of the project alongside the bi-annual reviews scheduled for each consortium meeting where the plan and its success or improvements will be discussed in plenary.

Table 17: Priorities, implementation and targets

Priority	Activities/measures	Implementation	Key Gender Indicators (KGIs)	Targets
Ensure to stimulate participants on an equal basis to attend the planned events, workshops, and interventions	Ensuring that neither partner nor stakeholder are excluded or not invited to planned events, workshops, or interventions due to their gender identity	Invitations to such events should ensure to use gender sensitive language and be distributed in places that are used by all genders	Aggregated and disaggregated data such as events' reports, forms and surveys, representing the gender composition of partners and stakeholders attending such planned events*	**No one gender should exceed 60% of total invites to such events***
Complete an assessment of local cultural practices, contributing to the overall GEP, conducting a gender review of the environments and spaces in which the project operates	Assessing local cultural practices by working closely with stakeholders and partners that will join or host events as part of the project to ensure the needs of all genders are met, e.g., gender specific bathrooms, women's only spaces, etc.	Survey to be designed and conducted with local stakeholders and partners Stakeholder collaboration will be initiated If local practices have been identified that are not inclusive, a guide of new ways of dealing with them can be developed	Use of the GEP instructions on this document/implementation of the new handling practices	**Creating environments where everyone feels respected and safe**
Guide project partners to ensure a fair gender distribution in the use of cargo-bikes and related services	Provide resources and support to guide project partners to ensure the fair gender distribution in the use decarbonised solutions and services for logistic distribution	A guide of resources will be available within the SharePoint for partners to refer to	Guide of resources will be reviewed prior to bi-annual consortium meetings The application of the guide is reviewed	**Equal access for all users of decarbonised solutions and related services**

Promote gender equality in decision-making processes	Ensuring all genders are involved in decision-making processes through the principle of representation and participation	Coordinators and facilitators will ensure that each partner and/or stakeholder has their say, regardless of their gender identity If necessary, secret ballots for important issues	Length of speeches in decision-making processes are balanced for each gender	**No gender should make up more than 60% of those making project decisions*** **Gender equality in decision-making processes should be reached by having a balanced distribution of participants in the steering committee[3] and in the Consortium meetings.**
Countering sexism	Definitions and illustrations will be elaborated and communicated Awareness raising Clear guidelines for all partners based on the guidelines available at the research institutions involved in the project	Use of appropriate language in communication Possible use of external training courses	N/A	**Non-discriminatory, appreciative environment**
Monitoring				
Annual review and monitoring	Bi-annual review with the consortium Annual review reporting of gender balance in the DECARBOMILE project	An agenda item at the bi-annual consortium meetings will be created to ascertain progress and report as part of the project alongside the annual review of gender balance	Through Reporting	Using the Gender equality plan as a guideline tool

[3] Currently there are 16 women and 15 men.

*At this time, we are only able to collect information based on the binary genders' identities due to employment and sensitive data legislation. The only available answers in the event of a survey being produced would be “men”, “woman”, and “do not wish to disclose”. Further enquiries are to be completed upon how this process could be improved to avoid excluding non-binary gender identities.

5. CONCLUSIONS

This baseline study of urban freight logistics provides a comprehensive overview of the situation in the four main project cities (Hamburg (DE), Istanbul (TR), Logrono (ES), Nantes (FR)), in light of the five pillars identified:

1. Mapping of the relevant local stakeholders among whom strong **collaboration** should be ensured,
2. Preliminary definition of the use cases on which **viable business models** will be built,
3. State of the art of the logistics flows, infrastructures, and equipment to showcase the importance of **urban integration**,
4. Understanding of the existing supportive **regulations** and legal frameworks, and
5. Overview of the current **digital infrastructure** used for management, planning and optimisation of logistic operations.

Through the research conducted (different benchmarks of relevant projects, initiatives and regulations across Europe) and the organisation of dedicated local workshops with key stakeholders, a set of barriers has been identified for cities in the implementation of sustainable last-mile logistics. While specificities have been analysed based on local context, the following challenges stood out across all four Living Labs: congestion, shortage of space and conflicts of use, lack of data and data sharing, and reluctancy to collaborate at both operational (hardware) and digital (software) levels. Specificities have also been analysed based on local contexts, in Living Labs and Satellite Cities.

The literature review carried out in the framework of this document shows that the combination of logistics concepts (consolidation centres, alternative deliveries, innovative vehicles, load pooling, optimization of vehicle routing and location, etc.) is not yet widely considered. They all have features that need to be weighed against each other to develop and implement comprehensive tailored solutions that meet cities' needs and business requirements for decarbonised last-mile logistics.

In addition, a wide range of restrictions (congestion charge zones, low emissions and limited traffic zones, etc.) can improve urban traffic and reduce environmental impacts of urban distribution of goods, while impacting differently stakeholders. At European level, most cities are implementing such restrictions, and bigger cities tend to have more restrictive regulations, although they don't seem to be well harmonised (in terms of methodology, quantification, types of vehicles affected, loading and unloading spaces, geographic zones, etc.). Nonetheless, it comes out that without public support and enabling regulations (including through the integration of logistics into the overall urban planning and space management strategy), innovative last-mile logistics models face difficulties to be efficient, operationally and economically.

Overall, the document demonstrates the importance and positive impact of collaboration and shared economy at technical, environmental and socio-economic levels: cost reduction, reduced number of vehicles and related pollution (emissions, noise), increased trust between stakeholders, and flexibility of the logistic service provider, etc.

With this baseline work and a better understanding of cities' needs and challenges related to green last-mile deliveries, we have been able to identify several potential use cases, which will be further detailed and validated in the upcoming project activities. Indeed, building on this diagnosis, focused discussions with project partners and external stakeholders (WP2), a visual benchmark of relevant side services to be implemented in the different use cases, and the development of related viable business models (WP5), will be carried out, hand in hand with Satellite Cities, and in line with our gender equality plan. With similar parallel work on the technical specifications of the use cases (WP3), project partners will seek to develop hardware solutions and equipment (WP4) needed for cities and operators to implement green last-mile delivery. System integration requirements and interoperability provisions will also be studied as part of WP6 in order to enable the full potential of sustainable last-mile logistics in European cities.

ANNEXES

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