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URBAN LOGISTICS AS AN ON-DEMAND SERVICE

BENCHMARKING BUSINESS/OPERATING MODELS AND BEST PRACTICES

ULaaDS D3.1: Benchmarking business/operating models and best practices

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Abstract

ULaaDS sets out to offer a new approach to system innovation in urban logistics. Its vision is to develop sustainable and liveable cities through re-localisation of logistics activities and re-configuration of freight flows at different scales. Specifically, ULaaDS will use a combination of innovative technology solutions (vehicles, equipment and infrastructure), new schemes for horizontal collaboration (driven by the sharing economy) and policy measures and interventions as catalysers of a systemic change in urban and peri-urban service infrastructure. This aims to support cities in the path of integrating sustainable and cooperative logistics systems into their sustainable urban mobility plans (SUMPs). ULaaDS will deliver a novel framework to support urban logistics planning aligning industry, market and government needs, following an intensive multi-stakeholder collaboration process. This will create favourable conditions for the private sector to adopt sustainable principles for urban logistics, while enhancing cities' adaptive capacity to respond to rapidly changing needs. The project findings will be translated into open decision support tools and guidelines.

A consortium led by three municipalities (pilot cities) committed to zero emissions city logistics (Bremen, Mechelen, Groningen) has joined forces with logistics stakeholders, both established and newcomers, as well as leading academic institutions in EU to accelerate the deployment of novel, feasible, shared and ZE solutions addressing major upcoming challenges generated by the rising on-demand economy in future urban logistics. Since large-scale replication and transferability of results is one of the cornerstones of the project, ULaaDS also involves four satellite cities (Rome, Edinburgh, Alba Iulia and Bergen) which will also apply the novel toolkit created in ULaaDS, as well as the overall project methodology to co-create additional ULaaDS solutions relevant to their cities as well as outlines for potential research trials. ULaaDS is a project part of ETP ALICE Liaison program.

Keywords

Sustainable urban freight transport; innovative solutions; hubs; emerging vehicle technologies; platforms; sustainability.

Copyright statement

Executive summary

This document provides the state-of-the-art and a benchmark of the business and operating models for sustainable on-demand urban logistics solutions. Information about these solutions is collected based on a thorough review of the academic and professional literature as well as a collection of best/validated practices of other innovation initiatives, from academic studies to latest insights on (commercial) research and development projects. The state-of-the-art and benchmarks are further developed by reviewing cases in other related projects funded by the EU, national and regional governments – several of which through first-hand experience by ULaaDS partners – and by gaining input from relevant stakeholders through workshops. The solutions most viable and relevant to the ULaaDS project are included in a benchmark, which serves as a foundation for other ULaaDS tasks and deliverables, such as the development of new operating models (WP3), the research trials (WP4), and impact assessment (WP5). The aim of the benchmark is to provide a thorough understanding on the innovation factors for success and failure of current examples of on-demand urban logistics solutions, creating a structured knowledge base detailing them.

This deliverable focuses on both the technical aspects (e.g., vehicles, hubs, IT) and operational aspects (e.g., shared vehicle use, operational planning) to adapt urban freight delivery systems to the requirements of on-demand and zero emission logistics solutions. The technical aspects include the physical dimensions of the zero-emission freight vehicles and the infrastructure in which they operate (e.g., hubs, modular containers, IT interconnectivity). The operational aspects include planning and scheduling of vehicle and hub operations, with particular focus on shared vehicle use and the business models that should drive such resource sharing. Section 1 sets the scope of the state-of-the-art, followed by an overview of the methodology in Section 2. An overview of the state-of-the-art is presented in three sections: Section 3 on hub locations and infrastructure, Section 4 on vehicle technologies, and Section 5 on platforms for the integrated management of urban freight transport. Benchmarks of the operating and business models for different solutions are presented in Section 6. The main conclusions are summarized in Section 7, followed by a list of reference projects and articles.

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1. Introduction

This deliverable presents the commercial and academic state-of-the-art of sustainable on-demand urban freight transport solutions and provides benchmarks for their operating and business models. Its main aim is to enable interested parties to build on the state-of-the-art and benchmarks when developing new solutions. Within ULaaDS, project partners can take the insights from this document into consideration when implementing and testing the logistics solutions and schemes to be trialled in the lighthouse cities.

Cities play an ever more important role in the economy. People work, live and spend their leisure time in the urban space, and a vast share of the gross domestic product is generated there. This success, however, also has its downsides. All this economic activity relies on the movement of goods into, out of, through and within the urban area (i.e., urban freight transportation). And as the economic activity in the urban area grows, so does the demand for urban freight transportation.
Like other economic sectors, urban freight transportation is confronted with the ; that is, economic activity enabled by digital marketplaces and technology companies, to fulfil consumer demands via immediate access to goods and services. Consumer expectations move in the direction of ever more convenience and delivery speed, which adds to the challenge of organizing those delivery services efficiently.
If business-as-usual continues, accessibility, quality of life and safety in urban areas will become severe issues. Already, urban freight vehicles form a major component of traffic, emissions, and other nuisances. With the expected growth in the demand for urban freight transport looming, a new approach to urban freight transport is needed to ensure the economic vitality and attractiveness of the urban space in the long term. This approach should focus on doing more with less; more online orders delivered at our homes, more restaurants supplied with fresh produce, more construction material and workers transported to building sites, and so on, with fewer vehicles and less – or preferably no – emissions.
The roadmaps of the two main European networks, ALICE and ERTRAC, specify that new logistics practices need to focus on the use of energy efficient vehicles, improve the safety of those vehicles and improve the reliability of urban freight transportation systems. This document lists several urban freight transportation practices that potentially meet those criteria and provides a benchmark to explore their operating and business models. The precise scope of the logistics practices considered is explained below.

1.1 Scope of the state-of-the-art and benchmarks

The focus of the state-of-the-art and benchmarks of best practices is on those logistics practices that purposefully address the major challenges generated by the transition towards an on-demand economy in urban areas, ultimately contributing to zero-emission urban freight transport in 2030. Generally, the sustainability of urban freight transport can be improved via two distinct but interrelated "routes". First, polluting transport resources (e.g., delivery vans with internal combustion engines) can be replaced by zero-emission vehicles (e.g., cargo bikes, electric vehicles). Second, existing transport resources – be it zero-emission or not – can be used more efficiently by sharing them across multiple users. Both types of routes are in scope of the state-of-the-art and benchmark presented in this deliverable.

Logistics practices relevant to ULaaDS should be geared towards the realisation of a multi-layered network for urban freight transportation, and thus contribute to the materialisation of the Physical Internet. The Physical Internet is a vision towards a fully open logistics system founded on physical, digital and operational interconnectivity (Montreuil, 2011). It aims to change freight transportation by a full consolidation of goods from different suppliers and pool the available logistics resources and assets, which allows using them more efficiently in an order of magnitude. ETP ALICE puts the Physical Internet front and centre in its roadmap towards zero-emission logistics in 2050[1].

ULaaDS focuses on two categories of logistics solutions, namely i) collaborative delivery models – aimed at enhancing logistics efficiency and enabling multi-modal urban freight transport; and the ii) integration of urban freight and passenger transportation networks. These are further specified in five different logistics schemes as shown in Table 1.1. Collaborative delivery models include logistics schemes based on encapsulating goods in standardised and modular containers (1), the integration of crowd-sourced delivery services (2), and the use of city-wide platforms for integrated management of urban freight transport (3). The integration of passenger and urban freight transport services includes logistics schemes based on location and infrastructure sharing (4), and vehicle capacity sharing (5).

Table 1.1 ULaaDS solution categories and logistics schemes

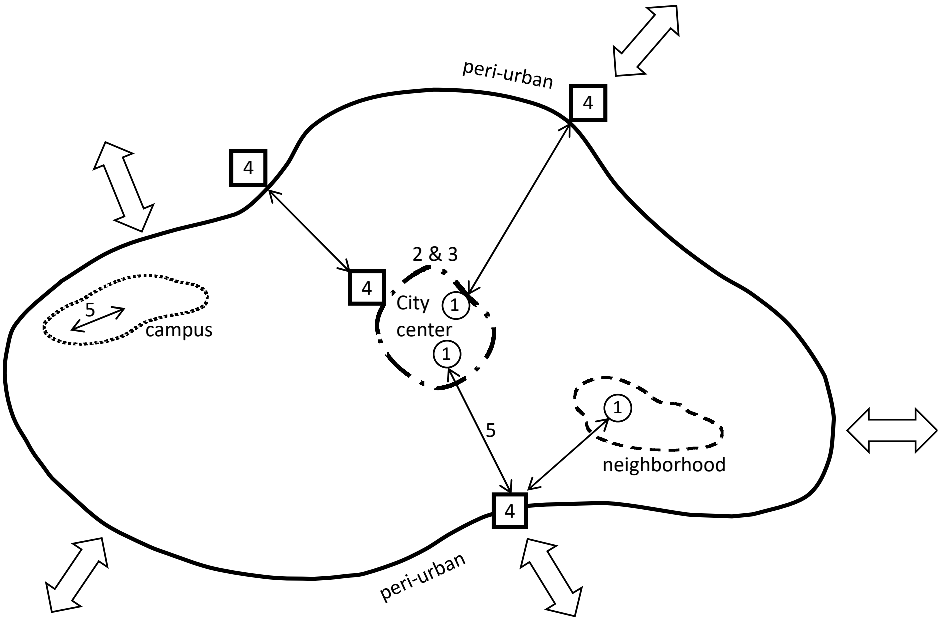
Solution	Scheme
1) Collaborative delivery models to enhance logistics efficiency and multimodal mobility in cities	1. Containerised urban last-mile delivery 2. Logistical network integration of crowd-sourced bike couriers 3. City-wide platform for integrated management of UFT
2) Effective integration of passenger and urban freight mobility services and networks	4. Location and infrastructure capacity sharing 5. Transport vehicle capacity sharing

Different logistics schemes fit different parts of the multi-layered network shown in Figure 1.1. Within the ULaaDS research trials, location and infrastructure sharing (4) takes place both near the city centre and in the peri-urban area – in smaller-scale as well as large-scale set-ups. Possibilities for trials with transport vehicle sharing (5) are explored in a closed environment within the urban area and for the transport from the shared location in the peri-urban area to the city centre, where containerisation (1) will also be used. Platforms to integrate bike couriers (2) and manage urban logistics (3) are focused on the city centre.

[1] http://www.etp-logistics.eu/alice-launches-the-roadmap-towards-zero-emissions-logistics-2050/

Figure 1.1 Multi-layered network structure of Physical Internet-based urban freight transportation

Figure inspired by Crainic & Montreuil (2016)



1.2 Reading guide

To provide the reader with a complete overview of the state-of-the-art sustainable on-demand urban freight transport (UFT) practices that are potentially useful for the ULaaDS project, and to provide a benchmark of their underlying operating and business models, this deliverable is structured around four main sections. The first three offer an overview of state-of-the-art practices in urban logistics, organised under the following main categories: (1) hubs location and infrastructure for UFT; (2) vehicle technology; and (3) platform technology. Each of these sections follows a similar structure, starting with a broad overview of practices available, then narrowing down to those more relevant for ULaaDS. A few examples are discussed in-depth, analysing their operating and business models in the fourth main section (*6. Benchmarking operating and business models*).

Table 1.2 offers an overview of the practices included in the state-of-the-art, and the way they connect to the ULaaDS schemes and solutions that are benchmarked. Some of these practices are directly linked to an ULaaDS scheme, like in the case of public smart city platforms, which are an example of City-wide platforms for integrated management of urban freight transport (3). Other practices can be elements of different schemes, like in the case of cargo bikes, which could be integrated in containerized urban last mile delivery (1), the integration of crowdsourced bike couriers (2), and transport vehicle capacity sharing (5).

Table 1.2 Overview of practices included in this benchmark and their connection to the ULaaDS schemes

	Practices benchmarked	(connection to) ULaaDS Schemes
Hubs location and infrastructure for UFT	Large scale hubs	Location and infrastructure capacity sharing (4) City-wide platforms for integrated management of UFT (3)
	Urban consolidation centres	
	Microhubs and mobile depots	
	Collection and delivery points	
	Location and infrastructure sharing	Location and infrastructure capacity sharing (4) Transport vehicle capacity sharing (5)
Vehicle technology for UFT	Cargobikes	Containerized urban last mile delivery (1) Logistical network integration of crowdsourced bike couriers (2) Transport vehicle capacity sharing (5)
	Electric Light Commercial Vehicles	Containerized Urban Last Mile Delivery (1) Transport vehicle capacity sharing (5)
	Autonomous vehicles	Location and infrastructure capacity sharing (4) Transport vehicle capacity sharing (5)
	Containerization	Containerized urban last mile delivery (1)
Platform technology	City driven platforms	City-wide platforms for integrated management of UFT (3)
	Commercially driven platforms	Logistical network integration of crowdsourced bike couriers (2) Transport vehicle capacity sharing (5)
	Community driven platforms	Logistical network integration of crowdsourced bike couriers (2) Transport vehicle capacity sharing (5)

1.3 Intended audience

The state-of-the-art provides a contemporary and comprehensive overview of novel logistics practices relevant for urban freight transportation. It is written with a broad audience in mind and could form an inspiration for anyone working on sustainable delivery models in a city logistics context. The benchmarking of the ULaaDS solutions and logistics schemes – which includes novel practices from the state-of-the-art – is primarily geared towards the technology and service providers offering those schemes, as well as to the lighthouse cities in which they are trialled. Satellite cities and other interested parties can also benefit from the insights from those benchmarks.

1.4 Relation to other ULaaDS work packages

Apart from serving as a source of information and knowledge for all project partners and potential interested readers, this deliverable will also have a clear role in relation to other WPs in the ULaaDS project.

To start with, it is a natural prerequisite towards the completion of “D3.3 Novel business/operating models and mapping to research trial sites”, which will build upon T3.1 outcomes to identify and primarily define the business and operating models that will be trialled in UlaaDS.
In addition, the state-of-the-art included in this deliverable will also serve as input for the WP2 360º Observatory, serving as useful content to be included in the observatory itself. The aforementioned serves as a living repository of the urban logistics world and includes best practices, trends, reports, events and much more, not only for internal use, but open to anyone interested in the topic.
Last but not least, the outputs of this deliverable will mostly serve WP4, focused on the trial definition and deployment. This deliverable provides insights on existing logistics practices, including their operating and business models, and therefore contributes to the design, validation, and trialling of the ULaaDS solutions and schemes. All of this is a crucial part not only of the deployment of the trials, but also of the whole impact and replicability side of the project, which falls into WP5.
In all, this deliverable holds links and relations with many other tasks and WPs in the project and its aim is to contribute as much as possible to the overall success of ULaaDS, including dissemination and outreach of such.

2. Methodology

In line with the main aim of the deliverable to provide a state-of-the-art of novel practices for sustainable urban freight transport and benchmark their operating and business models, the methodological approach is focused on gaining an overview that is both comprehensive and contemporary. To this end, the main steps taken to develop the state-of-the-art are to review the relevant academic and professional literature, and to solicit input from ULaaDS project partners. The result is a broad – albeit not exhaustive – of novel logistics practices that serve as input for the benchmarking of the operating and business models for the ULaaDS solutions and schemes. These benchmarks are based on a review of several reference projects (EU, national, and regional) and a study of the academic literature.

2.1 State-of-the-art

The state-of-the-art of novel practices for sustainable urban freight transport is compiled using four methods in an iterative fashion. These are: 1) a study of the academic literature, 2) a study of consultancy reports and deliverables from reference projects, 3) the use of online search engines to further explore examples from academic papers and practical applications, and 4) workshops with ULaaDS project partners to solicit feedback on the identified practices and to identify new ones.

2.1.1 Academic literature study

Starting from important foundational academic articles on urban freight transport management (Holguín-Veras et al., 2020a; 2020b) and the Physical Internet (e.g., Montreuil, 2011, Crainic & Montreuil, 2016) a first overview of novel logistics practices with potential relevance for ULaaDS was made. This overview included a broad range of different transhipment and storage facilities, emerging vehicle technologies, and digital platforms that became the basic structure of the state-of-the-art description.

Since the goal of this deliverable is not to provide an exhaustive overview of all academic literature written on each of the practices included, a structured literature review approach was deemed unsuitable. Rather, the initial overview was used to come up with a list of specific keywords for several literature searches, which were conducted using Google Scholar. For each type of logistics practice, a series of different keywords were used, such as "cargo bikes", "cargo cycles", "cycle logistics", "cargo cycle operations" for the practice of using cargo bikes in urban freight transport. Furthermore, a snowballing technique was used to identify academic articles with further information on these practices and to find new, closely related practices.

2.1.2 Consultancy reports and reference projects

Already during the development of the ULaaDS project proposal, a list of relevant reference projects was developed. This list served as a starting point to identify new logistics practices – not yet identified from searching the academic literature – and examples of logistics practices that were already identified. All ULaaDS project partners were asked for reference projects not yet identified, which led to the inclusion of several new projects in our search. Also, an inventory was made of relevant recent industry and consultancy reports. These were mostly identified from reference lists in the academic articles and via Google web searches.

2.1.3 Web searches

Google web searches were conducted to identify further information on the logistics practices in the state-of-the-art. These searches were mainly aimed at specific practices. For example, after learning about a demonstration project with an autonomous vehicle in Mechelen from the reference project ALEES, and a study of the academic literature on autonomous vehicles for urban freight transport (e.g., Jennings & Figliozzi, 2019), the Nuro R2 robot was identified as an interesting best practice. Further details about this delivery robot and its applications were collected from the official webpages of Nuro and various news reports. Similar iterative steps were taken for the other practices included in the state-of-the-art.

2.1.4 ULaaDS partner workshops

Two ULaaDS General Assembly meetings were used to present the preliminary state-of-the-art and to solicit input from all ULaaDS project partners. Specifically, a first version was presented during the 2nd General Assembly meeting, held on 14-12-2021, while a final draft was presented on the 4th General Assembly meeting, held on 19-05-2021. The benefit of these meetings is that all – or most – project partners are available, so it enabled reaching a broad audience. Several new practices were identified from these meetings, such as the cargo bike sharing platform operational throughout Germany.

Furthermore, four workshops were organized with the specific purpose of soliciting input from project partners on several classes of logistics practices that are part of the state-of-the-art:

- 18 February 2021: Hub locations and infrastructure.
- 4 March 2021: Cargo bike logistics
- 18 March 2021: Digital platforms for sharing logistics resources and managing urban freight transport
- March 31: Autonomous vehicle technology for urban freight transport

Each of these workshops followed a similar structure. Based on the initial state-of-the-art created from academic literature and web searches, a presentation was prepared with an introduction of this class of logistics practices and a first overview of the practices identified. This presentation formed the starting point for an open discussion about the scope of the class of practices as well as the identification of other existing practices on the radar of the ULaaDS project partner. After the workshops, several e-mail exchanges resulted in yet more practices for the state-of-the-art. All workshops were organized by the University of Groningen and attended by representatives from Bax & Company, Fraunhofer IML, Transportøkonomisk institutt, Miebach Consulting, and VIL.

2.2 Benchmarking

The operating and business models are not benchmarked for each logistics practice included in the state-of-the-art individually. Rather, the benchmarking focuses on the five ULaaDS schemes for sustainable urban freight transport, which are grouped into two main solutions. Each of the schemes can consist of multiple practices from the state-of-the-art. What is more, the benchmark considers the adoption of alternative practices and its implications on the operating and business model.

2.2.1 Sustainable business model canvas

A frequently used framework for developing a company's way of organizing its operations and creating, delivering, and capturing value is the business model canvas (Osterwalder and Pigneur, 2010). The classic version of the business model canvas consists of nine building blocks (see Figure 2.1). Its way of visualising these made it very popular, particularly for brainstorming about bringing an innovative product or service to market.

Figure 2.1 The business model canvas (Osterwalder and Pigneur, 2010)

Key partnerships	Key activities	Value proposition	Customer relationships	Customers
	Key resources		Distribution channels	
Budget cost			Revenue streams	

Given the focus of ULaaDS on innovative logistics solutions for sustainable urban freight transport, this deliverable uses an extended version of the business model canvas. One that focuses not only on the traditional building blocks of the business model canvas, but also on societal and environmental risks and benefits. This version of the model is proposed in Timeus et al. (2020) and is based on the triple layered business model canvas of Joyce & Paquin (2016). It includes 14 building blocks, including a mission statement, variants on the traditional business model canvas, and the environment and societal risks and benefits (see Figure 2.2).

Figure 2.2 Sustainable business model canvas (adapted from Timeus et al., 2020)

Mission statement: What is the ultimate goal that the solution seeks to achieve				
Key partnerships: Who can help the solution provider deliver the proposed value to the beneficiaries? Who can access key resources that the solution provider does not have?	**Key activities:** What must the solution provider do to create and deliver the proposed value?	**Value proposition:** What specific benefits are created and what specific problems does the proposed solution solve or alleviate?	**Buy-in & support:** Whose buy-in is needed in order to deploy the solution (legal, policy, procurement, etc.)?	**Beneficiaries:** Who will directly benefit from the proposed solution?
	Key infrastructure and resources: What key resources does the solution provider have to create and deliver the proposed value? What infrastructure does it need? What is the key regulatory framework required?		**Deployment:** How will the solution provider – in collaboration with the city – solve or alleviate the problems of the Value proposition specifically?	
Budget costs: What costs will the creation and delivery of the proposed solution entail?			**Revenue streams:** What sources of revenue for the city does the proposed solution provide?	
Environmental costs: What negative environmental impact can the proposed solution cause?			**Environmental benefits:** What environmental benefits will the proposed solution deliver?	
Social risks:			**Social benefits:**	

What are some of the potential social risks that the proposed solution entails? Who is most vulnerable as a result?		What social benefits will the proposed solution bring about? For whom will these benefits materialize?

For each of the five ULaaDS schemes, the benchmark includes a discussion of the main operating model – possibly weighing alternative logistics practices from the state-of-the-art. The extended version of the business model canvas will be filled out based on the information gathered for the state-of-the-art and additional academic articles and industry reports with a specific focus on the operating and business models of the different logistics practices, schemes, and solutions. It is important to bear in mind that the business model canvas approach is meant to be a high-level planning tool, rather than a detailed method to provide a concrete and precise business case. Such detailed business cases will be developed in future tasks within the ULaaDS project (T3.3, to be reported in D3.3) based on the more broadly defined business model canvasses in this deliverable.

3. Hub locations and infrastructure for urban freight transport

This section discusses different types of hubs used for sustainable urban freight transport. It also presents recent logistics practices related to the sharing of hub locations and transport capacity infrastructure.

3.1 Types of hubs for urban freight transport

In the context of city logistics, hubs are an important element in the sustainability and efficiency of urban freight transport. Many European cities therefore stimulate the use of hubs for freight transported into, out of or within their city boundaries. Essentially, a hub facility serves as a transhipment point (i.e., goods move from one transport mode to another) or consolidation point (i.e., goods are unloaded and regrouped in a different way) in a transportation network. Networks with hubs benefit from economies of scale in the transportation between hubs. But, those efficiencies have to be balanced against the fixed and operational costs involved with operating the hubs (Campbell, 1996).

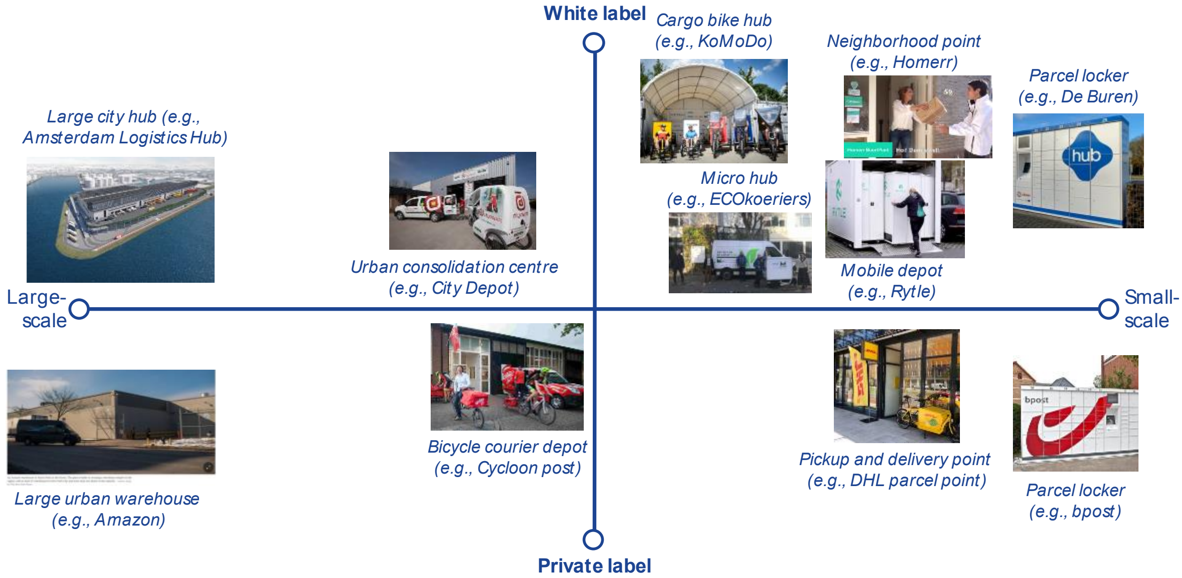
There are many different types of hubs, each with different targets, services and goals. On the one hand, the variety in hubs is very useful, because there exist hub solutions for many different challenges faced by a city and its region. On the other hand, this variety is complicating as it may result in Babylonian confusion; different people involved in a particular hub initiative may have another type of hub in mind when discussing the initiative and may end up choosing a solution that does not fit the challenge at hand. This section therefore provides an overview of the broad spectrum of hubs that exist. Different types of hubs are distinguished based on their scale, ownership structure (i.e., private label or white label), functionality, location, and infrastructure.

3.1.1 Scale and ownership structure

Figure 3.1 plots different types of hubs from largest-scale (left of the figure) to smallest-scale (right of the figure), and distinguishes between private label (bottom of the figure) to white label (top of the figure). Private label here implies that the hub is operated by or for a single user or brand, while a white label hub is operated without a brand and open to many different users. The purpose of the figure is to provide a conceptual foundation for distinguishing among hub initiatives.

The discussion about scale and private or white label is a precarious one, with many nuanced differences across hub initiatives. What is relatively large-scale for one, may feel small for another. The discussion about private or white label is also not binary. A depot of a supplier of a particular brand, can probably be seen as private label hub; a micro-hub potentially open to all who want to deliver through it probably as white label. But, in between there are many different shades of grey. A logistics service provider with a depot at the edge of the city is usually not considered a hub, for example, but may deliver goods from a vast number of different customers into the city, and as such could be considered the equivalent of white label. The same holds try for the warehouse of a large online platform, although in that case, all shops and deliveries are under the control of the platform operator. All in all, it is important to note here that the hubs mentioned in the figure are mere examples.

Figure 3.1 A continuum of hub initiatives with different scales and branding



On the left-hand-side of Figure 3.1 are the large-scale hubs. With a size of 5000 square meters or more, and the need for access by large trucks, they are generally located outside the city centre. Inside, large-scale hubs are fully equipped as warehouse and/or distribution centres with increasing levels of automation. Handling of materials is mostly done at a pallet or roll carrier level, and for companies handling parcels, these hubs also serve as (automated) sorting centres. In this category are the warehouses of suppliers that are located at the edge of the city (on the private label side) and the depots of the larger logistics service providers (closer to the white label side of the figure). Many large-scale hubs are used for longer-term storage of goods as well.

The initiatives discussed in the sphere of sustainable urban freight transport are often smaller in scale, albeit that at their scale they offer functionalities similar to the large-scale hub facilities discussed above. Most discussed in the academic and professional literature is the urban consolidation centre. At least conceptually, these urban consolidation centres are still relatively large in scale. There are, however, many relatively small-scale logistics service providers that operate a hub facility that could be seen as an urban consolidation centre. Examples include Cycloon, a bicycle courier company in the Netherlands. Usually, these are perceived by local governments as private label hubs, and not as urban consolidation centres. This type of hubs are, nevertheless, important elements in the system towards sustainable urban freight transport. Urban consolidation centres are often about 500 to 1000 square meters in size and allow for some short-term storage of goods – if goods are stored, this is typically done for less than a day. Material handling is mostly done manually and at the level of individual parcels. The material handling equipment is often less advanced than in the larger scale hubs and typically include a few pallet racks or shelves for sorting purposes or temporary storage.

More recently, local governments and industry alike have shifted their attention to even smaller-scale hub initiatives. Often, these initiatives are also located closer to, or even within, the city centre. Closely to city centres, we observe the emergence of several so-called micro-hubs. Essentially small-scale versions of the somewhat larger urban consolidation centres. They serve the purpose of enabling a model shift from larger, often diesel-powered vans to cargo bikes or environmentally friendly light electric vehicles. The rational is that those vehicles are operated most efficiently when they are constantly making deliveries and waste as little time as possible driving from and to the hub. The larger depots are often too far from the delivery area, and even the larger urban consolidation centres are often still too far to make these modes operationally viable. Depending on the specific delivery addresses and demand volumes, the depots can be located in different places each day, and the depot holds containers with parcels for multiple bicycle couriers who can operate efficient routes from the mobile depot.

Several innovative hub concepts from industry move their way into the city centre and residential neighbourhoods. Parcel delivery companies, for example, invest in their network of pickup and delivery locations. Consumers can choose to get their parcel delivered to such a location and come pick it up themselves. The locations are also open for parcel returns. Increasingly, parcel delivery companies also use the pickup points to avoid a costly2 second home delivery attempt. If the consumer is not at home during the agreed delivery time window, the parcel is dropped off at the pickup point. Networks of pickup and delivery locations are manned options – sometimes branded by the specific parcel delivery company, sometimes operated from within a retail shop, and recently increasingly operated from within the homes of local residents. There are also unmanned pickup and delivery points, the so-called parcel lockers. Parcel lockers can be private label, often operated by a single parcel delivery company, or large e-commerce platform or white label. In the latter case, the locker is operated by a third-party and essentially open to all potential users. Both types have their challenges and benefits as will be discussed later in this chapter.

3.1.2 Hub locations

The scale of the hub is often related to the location of the hub as well. Freight flows generally become more and more fine-grained when getting closer to the final receiver, who is often located in a residential area or the city centre. Fine-grained means that each receiver will only require a few goods, while – particularly in densely populated areas – there may be many different receivers. Often, those few goods per receiver were once combined with many other goods in earlier stages of the supply chain. In those stages of the supply chain, significant economies of scale are achievable by using large transportation modes. However, these modes are often not suitable or operationally practical as the transport gets closer to the final customer. Indeed, in highly dense areas, small vehicles (e.g., cargo bikes or light-electric vehicles) are operationally more efficient than vans or trucks. Hub locations are then needed to organize the required transhipment and shift in transport mode. If smaller vehicles are deemed too expensive in operation, this usually stems from the fixed and operational costs required to operate the hub, not the smaller vehicles themselves.

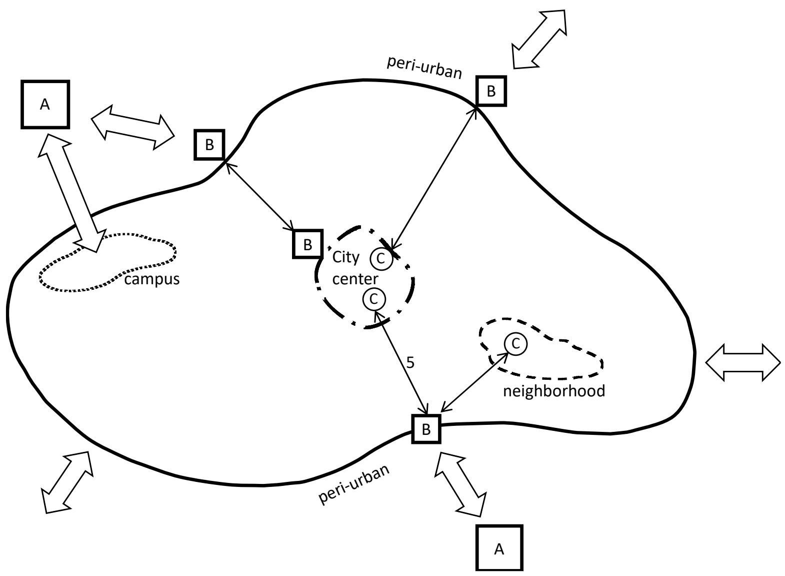
In attempts to lower the fixed and operational costs associated with hubs, two opposing, simultaneously occurring trends can be observed. First, larger-scale hubs are located closer to densely populated areas. While the fixed cost (e.g., land and construction costs) is high, the scale and often highly automated processes reduce the cost per parcel handled. Second, small scale hubs are established within city centres and residential homes with the sole purpose of enabling efficient use of smaller vehicles. Either these hubs require little material handling (e.g., because parcels are

[2] Recent studies (Loqate, 2021) show that between 6 and 8% of first-time deliveries fail, at an average cost of $17.20 (US), €14.69 (Germany), and £11.60 (UK) each.

pre-sorted in a larger scale hub upstream in the supply chain) or the material handling is done manually to avoid the space and investment needed with automation (which is not justified because of the small scale of the operation). Companies make different choices in their network design, which results in a mixed landscape. Generally, larger hubs are located in peripheral areas while residential areas and the city centre see mostly very small-scale hubs, as shown in Figure 3.2.

Figure 3.2 A multi-layered network of hub locations

Note the larger boxes (A) represent large-scale hubs, while the smaller boxes (B) represent urban consolidation centres and/or micro-hubs, while the circles (C) represent micro-hubs, mobile depots and/or parcel pickup points. In reality, networks include many of these locations.



3.1.3 Hub functionalities

The main functionality of hubs in transportation networks is to serve as mode transhipment and/or consolidation point. At many hub locations, other functionalities are offered too. These functionalities can be directly or indirectly related to the core logistics processes, but can also provide functionalities for consumers:

- Direct logistics functionalities
    - Storage: Enable short-term or long-term storage facilities for users of the hub.
    - Packing: Offer (re-)packing of goods, for example, receive boxes of goods and repack them into single parcels for home delivery.
    - Reverse logistics: Organize processes related to reverse logistics, such as pick up of goods at consumer homes and the inspection of returned goods.
- Indirect logistics functionalities
    - Fuelling options (diesel, LNG/CNG, hydrogen) for vehicles that access the hub.
    - Charging facilities for electric vehicles.
    - Restroom for drivers/couriers.
- Functionalities for consumers
    - Public toilet

- Changing room

3.1.4 Target urban freight flows

Hubs also target different urban freight flows. In the Outlook City Logistics[3], CE Delft and TNO distinguish among seven different freight flows with a considerable impact on the urban space:

- Parcel and home delivery (i.e., post and parcels delivered as a result of e-commerce operations).
- Facility goods (i.e., urban freight transport involved with products used by large offices, such as printing paper, hot drinks, sanitary products, and furniture).
- HoReCa logistics (i.e., urban freight supplying hotels, restaurants and catering mostly with fresh food products).
- Service / renovation logistics (i.e., the urban freight flows involved with a wide array of repairers, including plumbers, painters, handymen, etc.).
- Supermarket logistics (i.e., freight flows involved with the supply of supermarkets in the urban area).
- Waste management (i.e., waste collection of different users of the urban space, including residents, offices, shops, restaurants, hotels, etc.).
- Construction logistics (i.e., urban freight flows stemming from the transport of construction material to building sites).

3.1.5 Comparison of different hub solutions

This section outlined the broad array of different hub solutions that exist, including differences in scale, ownership structure (i.e., private or white label), functionalities, and target freight flows. Table 3.1 shows an overview of the different types of hub examples discussed. This overview considers four different types of hubs, where each type may include multiple configurations.

Table 3.1 Overview of the different types of hubs

The structure of the overview is adapted from Merchán and Blanco (2015) and adjusted for the purpose of ULaaDS. The content of the table is based on an overview of the academic literature discussed in Section 3.2.

	Large-scale hub facilities	**Urban consolidation centres**	**Micro-hub and mobile depots**	**Collection and delivery points**
Size	5000 m2 +	500-1000 m2	25-250 m2	<10 m2
Location	Industrial/logistics park	Peri-urban or at outer core of city centre	Edge of city centre, or inside city centre	Inside city centre and neighbourhoods
Geographic reach	City and region	Extended city centre	(Part of) city centre or neighbourhood	Neighbourhood or block
Inbound vehicles	Large trucks	Trucks	Vans	Vans, light electric vehicles, or cargo bikes

[3] Outlook City Logistics 2017 (https://kennisbank.topsectorlogistiek.nl/projecten/annual-outlook-zero-emission)

Outbound vehicles	(Smaller) trucks or vans	Vans, light electric vehicles, or cargo bikes	Light electric vehicles, or cargo bikes, pedestrian	Customers pick up parcels
Material handling	Fully equipped, highly automated	Manual (with support of some non-automated equipment)	Manual	Manual
Handling level	Pallet or roll carrier	Parcel	Parcel	Parcel
Storage	Yes (>24 hours)	Yes (<24 hours)	No	No (albeit customers get some time to pick up)

The focus in ULaaDS is on providing solutions to mitigate the challenges arising from the on-demand economy. These effects are mostly seen in parcel and home delivery, and to a certain extend in facility and HoReCa goods (albeit the latter often requires specialized equipment to deal with freshness, as well as health and safety concerns). The scope of the ULaaDS hub solutions will thus be targeted primarily at parcel and home delivery. Within the ULaaDS project, the focus on hubs mainly stems from their role in facilitating the deployment of novel, feasible, shared and zero-emission logistics solutions addressing the major challenges generated by the on-demand economy. Indeed, making effective use of hubs should accelerate the deployment of those solutions. In principle, this could include hubs at all scales and locations, ranging from large-scale logistics facilities far out of the city centre, to (mobile) parcel lockers within the city centre or residential neighbourhoods. Also, both ownership structures could be associated with different facilitators and impediments to the uptake of new solutions. Given the scope of ULaaDS, the interest in hubs mostly resides from their core logistics functionalities, but other functionalities will be considered.

3.2 Location and infrastructure sharing

Hub locations and infrastructure can also be shared across transport sectors and thereby used for multiple purposes. A salient example from the private sector is the Amsterdam Logistics Hub, where many different users, potentially from different transport sectors, can organize their hub operations – ranging from construction logistics to e-commerce fulfilment to service logistics. In the public sphere, there is increasing attention for combining freight with passenger transportation infrastructure. One example is the Mobihub concept4, a transport hub where multiple (shared) transport modes, such as different bus lines, shared or private cars and bicycles, are linked. These hubs are often expanding the functionality offered to their users, including charging stations for electric cars, restrooms and HoReCa services. Given their location – often close to an urban, or even residential area – these hubs are particularly well suited to include important urban freight solutions, such as parcel lockers to pick up or drop off goods ordered online.

3.3 State-of-the-art

This section presents the state-of-the-art in hub locations and infrastructure discussed before. For practical reasons and to keep the overview comprehensible, the state-of-the-art includes a few recent examples and is by no means exhaustive.

[4] https://mobihubs.eu/

3.3.1 Large-scale hub facilities

Large-scale hubs are facilities often located at industrial or logistics parks in the peri-urban area, or somewhat farther outside a city. In the academic literature on city logistics, these facilities are seldom addressed (e.g., Neghabadi et al., 2019, Savelsbergh & van Woensel, 2016), but they play a critical role in addressing the demand for urban freight transport. Outside the realm of city logistics, there is a vast body of literature on the role of large-scale hubs in transportation networks, mostly in the fields of operations research (e.g., Campbell & O'Kelly, 2012, Guastaroba et al., 2016) – which focuses on solving a wide variety of optimization problems in the location and use of hubs – and transportation geography (e.g., Fleming & Hayuth, 1994) – which mostly focuses on spatial planning implications of hubs.

With the rise of the on-demand economy, private companies are investing in their distribution networks to better serve changing customer demands5. Increasingly, these investments entail establishing warehouses and distribution centres in – or closer to – urban areas. The examples addressed below include Amazon's move into the metropolitan area of New York and the Amsterdam Logistics Cityhub. Both initiatives involve hubs with a floor space of around 100.000 m2 and more than 100 million euro investment per hub. An Amazon warehouse can be seen as a private label hub, although Amazon of course fulfils the logistics operations for many different shops selling through its platform. The Amsterdam Logistics Cityhubs is seen as a white label imitative, but ultimately aims to attract several different customers that will operate from that facility.

3.3.1.1 Amazon

Introduction	
Name	Amazon warehouses New York
Figure	 An Amazon warehouse in Hunts Point in the Bronx. The giant retailer is creating a warehouse empire in the region, with at least 12 warehouses in New York City and more than two dozen in the suburbs. Andrew Seng for The New York Times
Short description	Amazon is moving its warehouses into urban areas to better serve on-demand delivery of its parcel to consumers in the metropolitan area of New York. It includes 12 warehouses in the different boroughs of New York. In doing so, Amazon can save about 20% on delivery expenses, as detailed in the Deloitte report "Urban fulfilment centers".
Start date	2019
End date	On-going

[5] https://www.nytimes.com/2019/10/27/nyregion/nyc-amazon-delivery.html

Websites/reference	https://www.nytimes.com/2021/03/04/nyregion/amazon-in-new-york.html?smid=li-share https://www.nytimes.com/2019/10/27/nyregion/nyc-amazon-delivery.html https://www2.deloitte.com/content/dam/Deloitte/us/Documents/process-and-operations/us-urban-fulfillment-centers.pdf
Initiative structure	Private initiative
Scale	
Size of the facility	The largest facility of the 12 Amazon warehouses in the metropolitan area of New York is around 100.000 square meters.
Number and type of vehicles	Many large trucks on inbound side, and hundreds of delivery vans on outbound side.
Ownership structure	
White or private label	Private label (albeit through Fulfilment by Amazon, third-party shops can ship their goods via these warehouses).
Location and infrastructure	
Location	Urban (e.g., in Hunts Point in the Bronx, New York).
Infrastructure	No sharing with public transportation possible.
Target	
Target freight flow	Parcel delivery to shops and mostly consumers at home.
Functionality	
Direct	Transhipment, storage, reverse logistics
Indirect	Charging stations delivery vans, restrooms for drivers.
Functionality for consumers	None

3.3.1.2 Amsterdam Logistic CityHub

Introduction	
Name	Amsterdam Logistic CityHub
Figure	
Short description	The Amsterdam Logistic Cityhub is a large white label city hub in the Port of Amsterdam, about 1 km from the main city ring road, and about 7 minutes sailing to Amsterdam Central Station. Its inception took place late 2019, when two investors invested 160 million euros into a logistics facility with space for about 30 companies.
Start date	2022
End date	Under construction
Websites/reference	https://www.amsterdamlogisticcityhub.nl/ https://www.logistiek.nl/distributie/nieuws/2019/09/zakenduo-pompt-160-miljoen-euro-in-stadsdistributiehub-voor-amsterdam-101169253 https://www.logistiek.nl/warehousing/nieuws/2020/12/amsterdam-logistic-cityhub-heeft-eerste-gebruiker-binnen-101176322
Initiative structure	Private initiative

Scale	
Size of the facility	About 220.000 square meter facility spread over two floors with 200 loading docks and a private quay of 180 meter.
Number and type of vehicles	Many large trucks and vessels on inbound side, and hundreds of smaller delivery vans, electric bicycles, and boats on outbound side.
Ownership structure	
White or private label	White label. It will lease logistics space to about 30 companies. Its first occupant is construction firm VolkerWessels that plans to operate a construction logistics hub from inside the Amsterdam Logistic Cityhub.
Location and infrastructure	
Location	Peri-urban in the Port of Amsterdam.
Infrastructure	No sharing with public transportation possible.
Target	
Target freight flow	Investors do not focus on a particular urban freight flow. The first occupant is a construction firm, but also e-commerce firms are targeted.
Functionality	
Direct	Transhipment, storage, reverse logistics
Indirect	Charging stations delivery vans, restrooms for drivers, office space, roof garden with restaurant.
Functionality for consumers	None

3.3.2 Urban consolidation centres

Urban consolidation centres are hub facilities at the edge of a city, or city centre, where the goods from multiple logistics service providers and suppliers are unloaded from (often larger) trucks, sorted and loaded onto (often smaller, eco-friendly) vehicles for efficient transportation into the city (Allen at al., 2012). There have been many prior experiments and pilot projects with urban consolidation centres in Europe. We refer the reader to Allen at al. (2014) and Björklund & Johansson (2018) for an overview with many of these initiatives. Below, the state-of-the-art focuses on a number of more recent initiatives, mostly in the regions of the lighthouse cities for ULaaDS. These include the Goederenhub Groningen Eelde (the Netherlands), CityDepot (Belgium), and SimplyMile (the Netherlands).

3.3.2.1 Goederenhub Groningen Eelde

Introduction	
Name	Goederenhub Groningen Eelde
Figure	
Short description	In 2018, a local entrepreneur started the Goederenhub Groningen Eelde, near Groningen, the Netherlands. The hub made use of existing

	infrastructure at the site of Royal FloraHolland (a large flower auctioning), near the airport of Groningen and about 20-minute drive by van to the city centre. After one-and-a-half year in operation, the Goederenhub Groningen Eelde stopped operations by the end of 2019 due to a lack of a sustainable business model. It took too much time to entice potential users to actually use the hub, leading to high business development cost and freight volumes too low to run a cost-effective logistics operation.
Start date	2018
End date	2019
Websites/reference	https://goederenhubs.nl/ https://www.rtvdrenthe.nl/nieuws/135978/Goederenhub-geopend-in-Eelde https://northsearegion.eu/surflogh/pilots/goods-hub-eelde-in-drenthe/
Initiative structure	Public-private partnership between the Province of Drenthe (public) and Goederenhubs Nederland (private) as part of EU Interreg project Surflogh.
Scale	
Size of the facility	Flexibel (part of a very large logistics facility for flower auctioning and distribution). Dedicated one dock door with space behind it for temporary storage (ca. 45 m^2); and office space (ca. 20 m^2).
Number and type of vehicles	1 delivery van (Euro-6).
Ownership structure	
White or private label	White label (albeit the hub operates under a parent company, Goederenhubs Nederland, which is essentially open to all suppliers and carriers).
Location and infrastructure	
Location	Peri-urban near the Groningen Eelde airport (about a 20-minute drive by highway to the city centre of Groningen).
Infrastructure	No sharing with public transportation possible.
Target	
Target freight flow	Supplying small shops in city centre of Groningen (ranging from one or a few parcels to a few pallets).
Functionality	
Direct	Transhipment, storage, reverse logistics
Indirect	Restrooms for drivers.
Functionality for consumers	None

3.3.2.2 CityDepot

Introduction	
Name	CityDepot

Figure	
Short description	CityDepot saw its inception during a pilot phase in Hasselt, Belgium, in 2011 and become fully operational in 2012. It is active in 7 Belgium cities (Antwerpen, Charleroi, Hasselt, Luik, Brussel, Gent, Leuven). CityDepot was acquired by bpost in 2015 and sold to BD Logistics by January 2020 and intends to open new hubs near several Belgium cities in 2021.
Start date	2011
End date	On-going
Websites/reference	https://www.citydepot.be/ https://www.flows.be/nl/logistics/citydepot-start-pilootproject-voor-stadsdistributie-brussel https://trends.knack.be/economie/bedrijven/bpost-doet-citydepot-van-de-hand/article-news-1541355.html?cookie_check=1619369135
Initiative structure	Started as a public-private partnership in collaboration with the municipality Hasselt. Later, it was acquired by bpost and currently CityDepot is part of private company BD Logistics.
Scale	
Size of the facility	The different hub locations differ in size but are mostly medium sized (with about 2 or 3 dock doors, and 500-1000 m^2 floor space for regrouping and temporarily storing goods.
Number and type of vehicles	Hubs of CityDepot are supplied with goods from different suppliers by truck. CityDepot operates a fleet of around 40 vehicles to deliver the goods into the cities it operates. These vehicles include CNG and HVO trucks and delivery vans, electric delivery vans and cargo bikes.
Ownership structure	
White or private label	CityDepot is owned by logistics service provider BD Logistics and is seen as operating white label urban consolidation centres.
Location and infrastructure	
Location	Peri-urban, at the edge of seven Belgium cities.
Infrastructure	No sharing with public transportation possible.
Target	
Target freight flow	CityDepot is open to transporting all urban freight flows. It mostly handles single roll containers or parcels of different shapes and sizes.
Functionality	
Direct	Transhipment, storage, reverse logistics
Indirect	Restrooms for drivers.
Functionality for consumers	None

3.3.2.3 SimplyMile

Introduction	
Name	(formerly) SimplyMile, currently StadslogistiekNL
Figure	
Short description	After operating a hub in Amsterdam since 2014, Van Deudekom – originally a moving company – founded SimplyMile: a network of urban consolidation centres throughout the Netherlands. In 2020, it was operational in 9 cities in the Netherlands (Amersfoort, Amsterdam, Den Haag, Groningen, Maastricht, Nijmegen, Tilburg, Utrecht, and Zwolle). After its bankruptcy in 2021, six locations are now operated by PostNL under the brand Stadslogistiek (Amersfoort, Den Haag, Maastricht, Nijmegen, Tilburg, Utrecht). Stadslogistiek is operated as a new business venture from within PostNL to further develop the business and explore the business model.
Start date	2018
End date	2021, currently continuing as Stadslogistiek.
Websites/reference	https://simplymile.nl/ https://www.logistiek.nl/ketensamenwerking/artikel/2021/03/simplymile-is-failliet-zo-gaan-de-stadshubs-verder-101177276 https://stadslogistiek.nl
Initiative structure	A network of private logistics companies (mostly moving companies) in different cities. Partnered with PostNL for zero-emission last-mile distribution.
Scale	
Size of the facility	Flexible, making use of space inside existing logistics facilities of moving companies.
Number and type of vehicles	Most SimplyMile locations relied on vehicles of its partner PostNL for the last-mile deliveries. Some locations used their own vehicles. Currently, Stadslogistiek uses 100% electric trucks, delivery vans and cargo bikes.
Ownership structure	
White or private label	SimplyMile operated as a white label initiative that was owned by independent logistics companies. Currently, the system of hubs is operated under PostNL. Each hub is operated in collaboration with an existing logistics company (the same companies as under the SimplyMile ownership).
Location and infrastructure	
Location	Peri-urban, at the edge of nine cities in the Netherlands.
Infrastructure	No sharing with public transportation possible.
Target	
Target freight flow	Open to transporting all urban freight flows, mostly handling single roll containers or parcels of different shapes and sizes.
Functionality	
Direct	Transhipment, storage, reverse logistics

Indirect	Restrooms for drivers.
Functionality for consumers	None

3.3.3 Micro hubs and mobile depots

Micro-hubs and mobile depots act as de facto urban consolidation centres but are often smaller in size and focus mostly on B2B and B2C parcel delivery. Their main focus is usually on enabling cargo bike deliveries, or deliveries with light electric vehicles, and are therefore located much closer to – or within – their final delivery area. As a result, micro hubs are not easily accessible for large trucks and are therefore often supplied by delivery vans from nearby warehouses or large-scale hubs. Because of their relatively small scale, several companies have experimented with – or even built their business model around – the use of mobile depots. Mobile depots are either trailers with a loading dock (and potentially some warehousing and office space), or containers, that are moved to a delivery area by a truck. The goods are delivered from the trailer or container by multiple milk runs – often using environmentally friendly delivery vehicles, such as cargo bikes.

There have been many prior experiments and pilot projects with micro hubs and mobile depots in Europe. Examples include the cargo bike hub used in the KoMoDo project and several micro-hub initiatives such as the ECOkoeriers hub in Mechelen. Mobile depot concepts, such as the one from project partner Rytle, form the latest innovation in this domain. In the past, also TNT Express experimented with such a setup.

3.3.3.1 Micro depot

Introduction	
Name	KoMoDo project
Figure	
Short description	In a research project that started in 2018, several large parcel delivery companies (DHL, DPD, GLS, Hermes, and UPS) experimented with cargo-bike deliveries from a location in Berlin-Prenzlauer Berg. The parcel delivery companies supplied the micro-hub with parcels that switched mode to cargo bikes for delivery in a 3 km radius around the site.
Start date	2018
End date	2019
Websites/reference	https://www.komodo.berlin/ https://www.urbanelogistik.de/komodo/
Initiative structure	The research project was funded by the German "Nationale Klimaschutzinitiative des Bundesministeriums für Umwelt, Naturschutz und nukleare Sicherheit". The site was operated by the Berliner Hafen- und

	Lagerhausgesellschaft mbH (BEHALA) and the research supported by LNC Logistic NetworkConsultants GmbH. At the end of the research project, BEHALA and the parcel delivery companies agreed to keep using the micro-depots until the end of 2019 without further funding.
Scale	
Size of the facility	The project used seven 40-foot maritime containers (about 30 m^2 each) which had a fixed location in Berlin-Prenzlauer Berg. Each parcel delivery company used its own micro-depot (one or two 40-foot containers).
Number and type of vehicles	In the year of the research project, up to 11 cargo bikes were used per day (driving over 38000 km and delivery around 160000 parcels).
Ownership structure	
White or private label	Private label. Each parcel delivery company involved operated its own micro-depot(s). The logistics site was operated by BEHALA and shared by the parcel delivery companies.
Location and infrastructure	
Location	Urban, in the Berlin-Prenzlauer Berg neighbourhood.
Infrastructure	No sharing with public transportation possible.
Target	
Target freight flow	KoMoDo targeted home delivery of e-commerce parcels.
Functionality	
Direct	Transhipment, reverse logistics
Indirect	None
Functionality for consumers	None

3.3.3.2 Mobile hub in semi-trailer

Introduction	
Name	TNT Express
Figure	
Short description	As part of the European FP7 project STRAIGTHSOL, TNT Express experimented with a mobile depot in Brussels. For a period of 3 months, the depot was placed in a park and was used for deliveries in three neighbourhoods (Schaarbeek, Etterbeek and Sint-Joost-ten-Node), covering a total area of 12 km^2. The mobile depot was designed by TNT and the Dutch Technical University Delft.
Start date	2013
End date	2013
Websites/reference	http://www.straightsol.eu/

Initiative structure	STRAIGHTSOL was an EU-funded project, comprising seven innovative cutting-edge urban freight demonstrations, out of which the TNT Express mobile depot was one. The whole project ran from September 2011 to August 2014.
Scale	
Size of the facility	The mobile depot had the size of a semi-trailer (appr. 30m^2) and included a small office. The electric tricycles are stored at the depot of the cycle courier company involved with the deliveries, which in this example is a different company.
Number and type of vehicles	During the pilot project, 4 electric tricycles were used to do the deliveries. The mobile depot was loaded at the main TNT Express depot near Brussels and driven into the city each morning.
Ownership structure	
White or private label	Private label. The mobile depot was designed and used for TNT Express deliveries alone.
Location and infrastructure	
Location	Urban, in Parc du Cinquantenaire in Brussels.
Infrastructure	No sharing with public transportation possible.
Target	
Target freight flow	The mobile depot of TNT Express targeted home delivery of e-commerce parcels.
Functionality	
Direct	Transhipment, reverse logistics
Indirect	Office space
Functionality for consumers	None

3.3.4 Collection and delivery points

Collection and delivery points – where customers can collect and return online purchases – are increasingly important for parcel delivery companies (Weltevreden & Rotem-Mindali, 2009, Zenezini et al., 2018). We distinguish between three different types of these collection and delivery points:

- Pickup and drop off points are usually operated from local small businesses (e.g., shops, postal offices, petrol stations) selected by a parcel delivery company or from dedicated stores with the company brand. During opening hours, customers can come in to check in at the counter and either pick up or drop off one or more parcels. Pickup points are also known as, for example, parcel shop, service point, and pick up and drop off point.
- Parcel lockers are unmanned machines where delivery companies can place parcels in separate reception boxes that can be opened by the customer with a reference code or via an application on their phone (Iwan et al., 2016, Moroz & Polkowski, 2016). Parcel lockers are operational for 24 hours a day and can be located both in private and public space (Vakulenko et al., 2018, Lemke et al., 2016; Oliveira et al., 2019). Parcel lockers are also known as, for example, automated parcel machines, automated delivery stations, and locker banks.
- Neighbourhood hubs are recruited and managed by start-up companies, such as Homerr and ViaTim, and operated by local residents from their homes. A parcel delivery companies can drop off multiple parcels at these hubs, which are then either delivered by the neighbourhood hub operator or picked up by the customer – each with a different

financial compensation from the parcel delivery company to the neighbourhood hub operator. Neighbourhood hubs are also known as neighbourhood points, and pick up and drop off point.

The use of collection and delivery points is mostly past the stage of pilot testing and experimentation. Some specific practices, however, are still novel and require additional study. These are mostly white label or crowd-based. The state-of-the-art below therefore focuses on those types of schemes, while private label pickup points and parcel lockers are left outside the scope.

3.3.4.1 Parcel lockers near supermarkets

Introduction	
Name	Albert Heijn + PostNL + Bol.com parcel lockers
Figure	
Short description	Customers can already pick up their Bol.com parcels at the service counters inisde Albert Heijn supermarkets since 2013 (both brands are part of the Ahold Delhaize parent company). In 2021, they start a test with PostNL parcel lockers at 5 Albert supermarkets. The test involves parcel lockers of different sizes (16-49 boxes) and two of the five parcel lockers are placed outside the supermarket to enable 24/7 access.
Start date	2021
End date	On-going
Websites/reference	https://www.postnl.nl/over-postnl/pers-nieuws/nieuws/2021/albert-heijn-bol-en-postnl-doen-proef-met-pakketautomaat.html https://www.logistiek.nl/e-fulfilment/nieuws/2021/05/albert-heijn-bol-com-en-postnl-testen-pakketautomaat-101178779
Initiative structure	The test is a fully private imitative between Albert Heijn, Bol.com and PostNL.
Scale	
Size of the facility	A single locker system is placed inside or outside a supermarket (different locations have differently sizes lockers).
Number and type of vehicles	The parcel lockers are supplied by delivery vehicles of PostNL. Consumers pick up their parcel at the locker. Due to their location in/near supermarkets, the intention is to attract as many consumers as possible to combine their trip to the supermarket with picking up their parcel. Additionally, the Dutch network of supermarkets is dense, so many people living in cities can access a supermarket by bike or on foot.
Ownership structure	

White or private label	Private label. Bol.com customers can choose these lockers as delivery location when ordering. The lockers can also be used to return or send other parcels with a PostNL label.
Location and infrastructure	
Location	Urban. The parcel lockers are placed in/near supermarkets.
Infrastructure	No shared infrastructure is used.
Target	
Target freight flow	The parcel lockers target home delivery of e-commerce parcels.
Functionality	
Direct	Reverse logistics
Indirect	None
Functionality for consumers	None

3.3.4.2 Neighbourhood hub

Introduction	
Name	ViaTim
Figure	
Short description	ViaTim operates a network of over 500 neighbourhood hubs, collection and delivery points operated by local residents, in the Netherlands. Hub operators are available to receive parcels from different parcel delivery companies for (i) pickup by the customer or (ii) delivery to one of the residents in their neighbourhood. They also offer options to consumers for dropping off parcels (reverse logistics). The company was founded in 2016 and cooperates with parcel delivery companies DHL and DPD.
Start date	2016
End date	On-going
Websites/reference	https://zakelijk.viatim.nl/ https://www.viatim.nl/over-ons/
Initiative structure	A private company initiative with no subsidy or public-private partnerships.
Scale	
Size of the facility	A neighbourhood hub is small, usually operated from a local resident’s home or garage.
Number and type of vehicles	Neighbourhood hubs are supplied by parcel delivery companies by means of their delivery vehicles. Customers either pick up the parcel at the hub (using their own transportation means) or the hub operators do the final delivery – often by foot.
Ownership structure	
White or private label	White label. The network is operated and managed by ViaTim, but open to all (parcel delivery) companies.

Location and infrastructure	
Location	Neighbourhoods
Infrastructure	Sharing with public transportation is not possible.
Target	
Target freight flow	The parcel lockers target home delivery of e-commerce parcels.
Functionality	
Direct	Reverse logistics
Indirect	None
Functionality for consumers	None

3.3.5 Location and infrastructure sharing

To optimise the existing overall urban transport capacity, freight and passenger transport can be integrated and combined. The practices below illustrate three options for doing so:

- Placing parcel lockers in locations with significant footfall (e.g., transit hubs);
- Integrating parcel lockers in mobihubs, a concept which refers to highly visible, safe, and accessible spaces where public, shared and active travel modes are co-located alongside improvements to public realm and relevant enhanced community facilities[6];
- Cargohitching practices, which refer to cargo that hitches a ride on a vehicle transporting persons or persons taking a ride on a vehicle transporting cargo.

The fourth practice in this section is an example of infrastructure sharing. Combining a last-mile co-warehouse with a co-working space, it allows small entrepreneurs to rent flexible storage space and fulfil shipment orders for their e-commerce operations.

3.3.5.1 Parcel lockers on public transit hubs

Introduction	
Name	De Buren parcel lockers on public transit hubs
Figure	
Short description	White label parcel lockers from “de Buren” are located on three public transportation hubs in the province of Drenthe (the Netherlands). The parcel lockers are supplied with parcels from DHL and can be used by other (parcel

[6] https://como.org.uk/wp-content/uploads/2019/10/Mobility-Hub-Guide-241019-final.pdf

	delivery) companies. Consumers receive an automatic message when their parcel is ready for pick up through a platform operated by de Buren.
Start date	2020
End date	On-going
Websites/reference	https://www.deburen.nl/ https://www.rtvdrenthe.nl/nieuws/166611/Pakketkluizen-in-Drenthe-Op-elk-moment-van-de-dag-je-bestelling-uit-de-muur-halen
Initiative structure	The initiative is a pilot project as part of the EU Interreg project Surflogh. De Buren won a public tender to place white label parcel lockers on three public transportation hubs in the province of Drenthe (the Netherlands). As part of this tender, the province acquired the parcel lockers and takes a share in the revenue generated by consumer use (kick back fee).
Scale	
Size of the facility	A single locker system is placed on each of the three public transportation hubs.
Number and type of vehicles	The parcel lockers are supplied by delivery vehicles of DHL and other companies using the lockers to reach consumers in the area. Consumers pick up their parcel at the locker. Due to their location on public transit hubs, the intention is to attract as many consumers as possible to use public transport or combine their trip to the public transportation hub with a trip to the locker.
Ownership structure	
White or private label	White label. The parcel locker is open for use by any company with an account at the operator Van Buren.
Location and infrastructure	
Location	Rural. The parcel lockers are placed on three public transportation hubs in rural areas, near villages in the province of Drenthe.
Infrastructure	Sharing with public transportation is possible and encouraged.
Target	
Target freight flow	The parcel lockers target home delivery of e-commerce parcels.
Functionality	
Direct	Reverse logistics
Indirect	None
Functionality for consumers	None

3.3.5.2 Mobihubs

Introduction	
Name	Mobian
Figure	
Short description	Mobian offers Mobihub services, where different mobility solutions are integrated at a single hub location. Mobian provides a mobile application which allows it users to easily reserve a bicycle, electric bicycle, electric cargo-bike – and soon also a shared electric car. Mobian is currently expanding both its network (i.e., the mobihub locations) and mobility solutions (e.g., electric shared car).

Start date	Unknown
End date	On-going
Websites/reference	https://nl.mobian.city/locations
Initiative structure	A private company
Scale	
Size of the facility	A neighbourhood hub is small, usually operated from a local resident's home or garage.
Number and type of vehicles	Neighbourhood hubs are supplied by parcel delivery companies by means of their delivery vehicles. Customers either pick up the parcel at the hub (using their own transportation means) or the hub operators do the final delivery – often by foot.
Ownership structure	
White or private label	Private label
Location and infrastructure	
Location	Peri-urban and urban
Infrastructure	Mobian location share space with public facilities (e.g., Park & Ride and public transit hubs)
Target	
Target freight flow	People, including repairmen
Functionality	
Direct	Reverse logistics
Indirect	None
Functionality for consumers	None

3.3.5.3 Cargo hitching

Introduction	
Name	Parcel transport using bus line
Figure	
Short description	In a demonstrator project, parcel transport is organized via a bus route. About 100 households in the Dutch village of Millingen joined this project. Instead of home delivery, they let their parcel be delivered at the urban consolidation centre of Binnenstadsservice Nijmegen from where they are transported by a bus line to a bus stop in Millingen where the parcels are dropped off at a local shop.
Start date	2017
End date	2017
Websites/reference	https://issuu.com/tkidinalog/docs/cargo_hitching_magazine_digitaal_sp

	https://www.gelderlander.nl/nijmegen-e-o/pakketjes-liften-met-lijnbus-naar-ooij~af939c9e/?referrer=https%3A%2F%2Fwww.google.com%2F
Initiative structure	Initiative is started by Binnenstadsservice Nederland as part of the TKI Dinalog (Netherlands Science Organization) funded research project “Cargo Hitching”. Connexion (bus operator), Lekkerland (supplier), and Pluryn (healthcare organization with potential workers with a disadvantage on the labour market) are also involved.
Scale	
Size of the facility	The hub of Binnenstadsservice in Nijmegen is an urban consolidation centre. The local shop is small.
Number and type of vehicles	Parcels are delivered to the urban consolidation centre by delivery van. Parcels are moved in large bags (see picture) or roll container under supervision of workers from Pluryn in a bus line to the shop in Millingen. Customers pick up their parcels at the local shop.
Ownership structure	
White or private label	White label
Location and infrastructure	
Location	Rural
Infrastructure	Existing bus lines 80 and 82 are used for transport of parcel to Millingen
Target	
Target freight flow	E-commerce deliveries
Functionality	
Direct	None
Indirect	None
Functionality for consumers	None

3.3.5.4 Saltbox – last-mile coworking warehouse

Introduction	
Name	Saltbox
Figure	
Short description	Saltbox started its last-mile co-warehouse co-working in Atlanta, USA. Its aim is to provide space for small online retailers whose businesses operate digitally, but who also require physical storage space. The advantage is that memberships are flexible, allowing users to adapt to seasonal fluctuations or other uncertain conditions. Besides, the site includes private phone booths, a photography studio and on-demand logistics services. Customers can work directly with Saltbox to handle order shipments.
Start date	2019
End date	Ongoing

Websites/reference	https://www.saltbox.com https://www.inboundlogistics.com/cms/article/logistics-and-the-sharing-economy/
Initiative structure	Private startup in Atlanta, currently expanding (opened a second location in Dallas, and planning eight more throughout 2021)
Scale	
Size of the facility	Atlanta: 27,000 feet^2 (2508 m^2); Dallas: 66,000 feet^2; largest location planned for 110,000 feet^2 (1ha)
Number and type of vehicles	N/a
Ownership structure	
White or private label	White label
Location and infrastructure	
Location	Urban and suburban
Infrastructure	No sharing with public transport is possible.
Target	
Target freight flow	E-commerce deliveries
Functionality	
Direct	Warehouse space, co-working space, access to operations specialists who can deal with fulfilment, parcel receiving & sorting, kitting & assembly, returns processing, and process optimization
Indirect	Community space, conference rooms, photo studio, kitchen, events
Functionality for consumers	None

4. Vehicle technology for urban freight transport

This section discusses different types of vehicle technology relevant for sustainable urban freight transport. It also presents a state-of-the-art with practices relevant to the ULaaDS project.

4.1 Types of vehicle technology for urban freight transport

In the context of urban freight transport, two types of vehicle technologies are emerging. First, we discuss the trend toward zero-emission road-based vehicles that are operated by a driver (i.e., non-autonomous vehicles). Second, we discuss the autonomous vehicles – both unmanned aerial vehicles (UAVs, also known as drones) and road-based vehicles.

4.1.1 Non-autonomous road-based vehicles (zero-emission)

The spectrum of zero-emission vehicles suitable for urban freight transport is broad – ranging from a simple bicycle (for delivering a few parcels) up to battery electric and hydrogen electric trucks (de Oliveira et al., 2017). Here, we distinguish between cargo bikes and electric light commercial vehicles. Urban freight transport by means of cargo bikes is commonly referred to as "cycle logistics", "cargo cycle operations", or "cargo bike operations", but generally concerns the movement of freight within cities using any type of pedal cycles – irrespective of the size of the vehicle, the number of wheels, loading capacities, etc. (Schliwa et al., 2015, Ørving et al., 2019, Giglio et al., 2021). Light commercial vehicles in general are vehicles used for commercial purposes with a gross vehicle weight of no more than 3,5 metric tonnes, which the EU defines as N1 vehicles. The N1 vehicles are further subdivided into three classes: small (N1 – I; with a gross weight ≤ 1305 kg), medium (N1 – II; with a gross weight between 1305 – 1760 kg), and large (N1 – III; with a gross weight between 1760 – 3500 kg). Larger still are the – battery or hydrogen – electric trucks, which are outside the scope of the ULaaDS project.

4.1.1.1 Cargo bikes

It is widely believed feasible to shift a considerable part of the urban freight transport trips from motorized vehicles (diesel vans and trucks) to cargo bike. Indeed, early estimates suggested that up to 25% of all motorized trips related to the pickup and delivery of goods can be replaced with bicycle transport (Wright and Reiter, 2016). While these major shifts have not yet occurred, it is unmistakable that bicycle transport is gaining strong momentum. Table 4.1 presents a classification of the different types of cargo bikes that are currently in operation, including the physical dimensions of the vehicles, their loading capacities and ability to be part of a modular system. For each type of cargo bike there are different manufacturers and models.

Table 4.1 Overview of the (e-)cargo bike solutions

	Bike	Small (e-) cargo bike	Medium (e-) cargobike	Medium e-cargobike (with trailer)	Large e-cargobike	Large e-cargobike
Number of wheels	2	2	2	4	3	4 or more
Width	60 cm	60 cm	70 cm	100 cm	120 cm	90 cm
Length	185 cm	185 cm	275 cm	550 cm	270 cm	up to 305 cm
Height	120 cm	120 cm	110 cm	155 cm	200 cm	155 cm
Range	Biker stamina	50-70 km	100 km	100 km	60 - 100 km	50 km
Electric (support)	No pedal support	Pedal support (optional)	Pedal support (optional)	Pedal support	Pedal support	Pedal support
Max speed	Biker stamina	25 km/h	25 km/h	20 km/h	25 km/h	25 km/h
Max loading capacity (weight)	22.5 kg	15 kg (max front loader) + 22.5 kg on back	100 kg	360 kg	200 kg	200 kg
Max loading capacity (volume)	30 L	30 L	300 L	1.5 m^3	2 m^3	2 m^3
Load carrier (compatibility)	N/a	N/a	N/a	N/a	EU Pallet & Rytle HUB	EU Pallet
Modular	No	No	No	No	Yes	Yes
Example	Any (personal) bicycle	Ebike4delivery	Urban arrow L	Larry vs Harry Bullitt + Carla Cargo	Rytle Movr25	Velove Armadillo
Example (figure)						

The momentum for cargo bikes is partially spurred by local, national and European authorities' initiatives to stimulate the use environmentally sustainable, safe, and societally accepted vehicles within cities. In addition, the use of cargo bikes is also driven by operational and business model aspects. In particular, the German projects "Ich ersetze ein Auto" (I'm replacing a car, in English) and "Ich entlaste Städte" (I'm taking the load off cities, in English) generated important first insights into the drivers and barriers for adopting cargo bikes. The "Ich ersetze ein Auto" project ran from April 2012 through June 2014 during which parcel delivery companies tested different cargo bikes (Gruber et al., 2014). The "Ich entlaste Städte" project ran from mid-2017 through the end of 2019 and enabled over 800 businesses to test cargo bikes for commercial use – 152 cargo bikes were used in total.

Cargo bikes are applied in different market segments, such as postal services, parcel delivery, and service logistics, where they can be used cost-effectively and time-efficiently (Rudolph & Gruber, 2017). Thoma & Gruber (2020) distill seven factors that drive or impede the use of cargo bikes:

+ Cost benefits: The purchasing costs of cargo bikes is relatively low, and they are more efficient and reliable in their operations – they move more smoothly through traffic, find a parking spot easily, etc.

+ Soft benefits: Many couriers like working on a cargo bike. It is good both for their health and for other citizens in the delivery area (as they are 0 emission, and they also make cycling more visible). Consequently, cargo bikes also improve the image of the companies using them.

+ Urban advantages: Especially in historic city centres, or other areas with narrow streets and access impediments, cargo bikes are much more flexible than other vehicles. They comply with most local regulations and ambitions towards zero-emission zones.

- Infrastructure constraints: The lack of an appropriate infrastructure is an important impediment for the use of cargo bikes. This may result in safety issues for the couriers driving them, as well as high investment cost involved with changing the distribution network such that cargo bikes can be used effectively.

- Vehicle limitations: Cargo bikes are smaller than traditional delivery vehicles - resulting in lower loading capacity, and they have a smaller spatial coverage (e.g., due to range limitations).

- Worries and perils: Many cargo bike users worry about theft and payload damage issues, as well as the effort and costs involved with implementing cargo bikes in the operation.

- Courier concerns: While many couriers like the prospects of operating a cargo bike, there are concerns about employee acceptance, the handling experience and experience required to operate a cargo bike.

4.1.1.2 Electric Light Commercial Vehicles

Some of the operational and business model implications, as well as the environmental and societal impact associated with cargo bikes do hold for electric commercial vehicles as well. Yet, electric commercial vehicles are more like a one-to-one replacement of diesel fuelled conventional vehicle alternatives than cargo bikes are. The benefits of electric commercial vehicles are less pronounced than cargo bikes. For example, these vehicles still require considerable parking space and cannot enter bicycle lanes. However, so are the downsides: while shorter in range and lower in loading capacity than diesel vans, electric vehicles often have a much larger range and capacity than cargo bikes. An overview of the electric light commercial vehicles available is shown in Table 4.2.

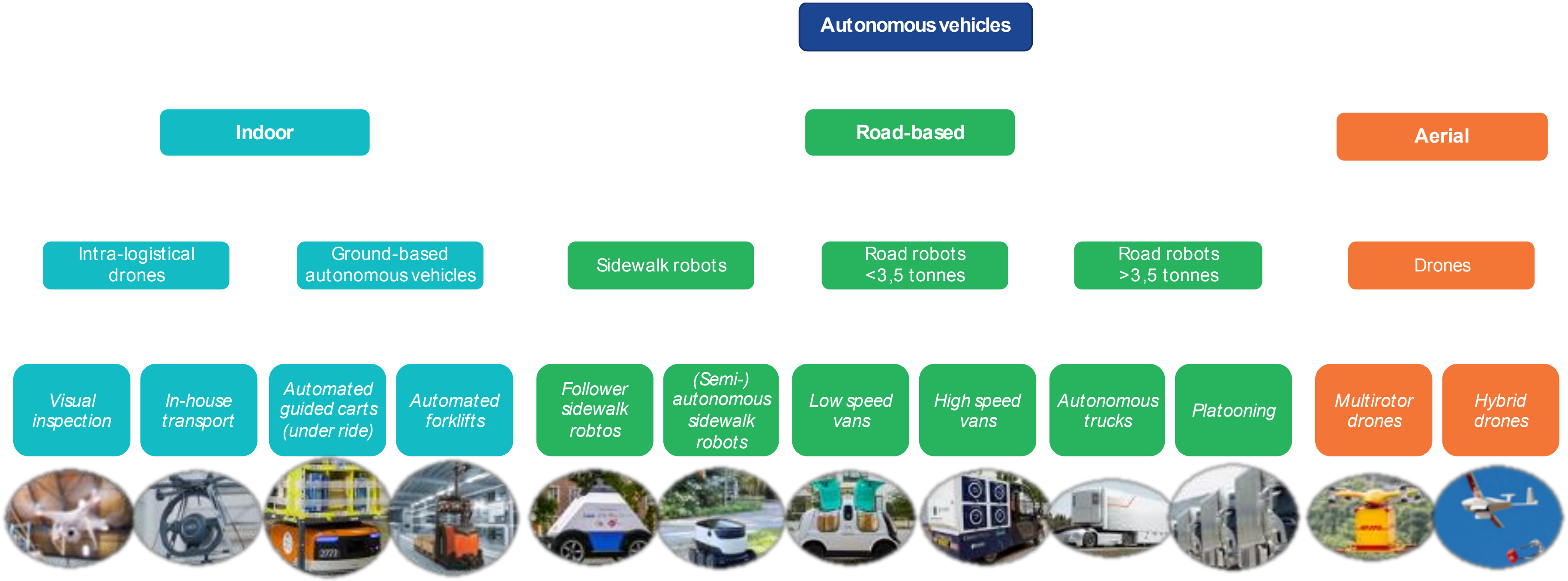
Table 4.2 Overview of electric light commercial vehicles

	eLCV N1-I (small)		eLCV N1-II (medium)	eLCV N1-III (large)
Number of wheels	3	4	4	4
Width	130 cm	150 cm	210 cm	235 cm
Length	240 cm	350 cm	430 cm	590 cm
Height	120 cm	200 cm	180 cm	270 cm
Range	100 km	87 km	200 km	170 km
Max speed	45 km/h	65 km/h	130 km/h	80-100 km/h
Gross weight	N/a	1100 kg	1675 kg	3500 kg
Max loading capacity (weight)	200 kg	600 kg	600-650 kg	970 kg
Max loading capacity (volume)	750 L	1,25 m^3	3-4 m^3	10,7 m^3
Example	Tripl	Goupil G2	Renault Kangoo ZE	Mercedes-Benz eSprinter
Example (figure)				

4.1.2 Autonomous vehicles

The recent years saw an enormous increase in research and development in autonomous vehicle applications for logistics purposes. Most of these applications spun off from developments in autonomous passenger vehicles – mostly self-driving cars (e.g., Waymo) – and earlier automated guided vehicle technologies. Much like the emerging zero-emission vehicle technology discussed in Section 4.1.1, the spectrum of autonomous vehicle technology applications is vast, ranging from indoors, road-based to aerial, from small to large, and from relatively slow moving to ultra-fast. Figure 4.1 provides a classification of autonomous vehicle technologies that are relevant for freight transport and logistics. The smaller road-based vehicles, in particular, have potential suitability for sustainable urban freight transport and thus fit the ULaaDS scope well. Few of these applications are currently beyond the demonstration or pilot phase, and their adoption in the coming years is still highly uncertain. Estimates range from near full adoption to 20% or less in the next 25 years, depending on the speed of technology improvement, changes in public opinion, and sales price developments (Simpson & Mishra, 2020).

Figure 4.1 Typology of autonomous vehicles for (Urban) Freight Transport[7]



[7] Typology is inspired by Touami, S. (2020), the ALEES project, and Wawrla et al. (2019).

As shown Figure 4.1, developments in autonomous vehicles occur on many fronts. One of those fronts is the use of drones within warehouses and production sites, where the application of automated guided vehicles has been the norm, rather than an exception. Already in 2012, Amazon bought Kiva Systems – a company that developed so-called “under rides” or automated guided carts that move underneath a cart, shelf or trolley and transport it from one location to another (typically a pick station). Automated forklifts, pallet jacks, tow tractors and reach trucks are used in many general warehouse facilities. More recently, there have been developments to use drones for logistics purposes within the walls of facilities, mainly for visual inspection (e.g., inventory audits, stock taking, and safety surveillance) or intra-logistics, moving for example spare parts from a warehouse to the production line (Wawrla et al., 2019).

A second class of autonomous vehicles for freight transport relates to unmanned aerial vehicles (UAVs), better known as drones. New patents, developments and pilot applications have dominated the logistics news for years. See, for example, several developments related to Amazon Prima Air, which was first announced in 2013, began testing in 2015, developed into an Amazon subsidiary in 2016, was scheduled for launch by the end of 2019, received FAA approval in 2020, and may soon launch at some scale. Technically, there is a difference between multirotor drones (typically quad-, hexa- or octocopters) and hybrid drones (small, unmanned airplanes with wings and propellors that typically take off from a launch plate). Integrating drones into urban freight transportation network is not trivial and different type of operating models exist (Moshref-Javadi & Winkenbach, 2021). Because of their typically limited volume and weight capacity as well as a relatively short range, drones could be applied in a setting where they move back and forth between a (mobile) depot and a customer, one order at a time. Either all deliveries (in a part of the distribution network) can be delivered by drone, or the deliveries can be split over the vans and drones that are available. Alternatively, drone operations can be integrated within the vehicle routes of a delivery van, where the drones either depart from the van as it moves or when it has stopped somewhere for a delivery. While it is potentially interesting to apply drone technology in an urban freight transportation setting from an economic (Moshref-Javadi & Winkenbach, 2021) and ecological (Figliozzi, 2020) point of few – especially for time critical last-mile e-commerce deliveries – regulatory and societal concerns will likely hinder rapid adoption.

A third class of autonomous vehicles, and most relevant to ULaaDS, are the road-based autonomous vehicles. These, in turn, can be classified further according to their size from small sidewalk robots, light commercial vehicles to large trucks or even platoons of multiple trucks, where autonomous vehicle technologies are applied to enable driving a group of vehicles together, at the least by controlling the distance between vehicles in the group and possibly even omitting drivers from vehicles that follow (Larsen et al., 2019). Another way to classify autonomous road-based vehicles is based on their level of automation. SAE International (formerly known as the Society of Automotive Engineers) defined six levels of automation, from no automation (Level 0) to full automation (Level 5). Levels 0 through 2 require a person actively driving the vehicle, with increasing levels of technological features supporting steering and/or (de-)acceleration. Levels 3 through 5 do not require a person actively driving the vehicle, although a driver’s presence may still be needed. In Level 3, the driver takes over when requested, whereas in Level 4 the vehicle is operated fully autonomously under specified conditions. Level 5 enables a vehicle to drive autonomously under all conditions and can be seen as fully autonomous.

Figure 4.2 SAE J3016 Levels of driving automation[8]

4.1.3 Containerization

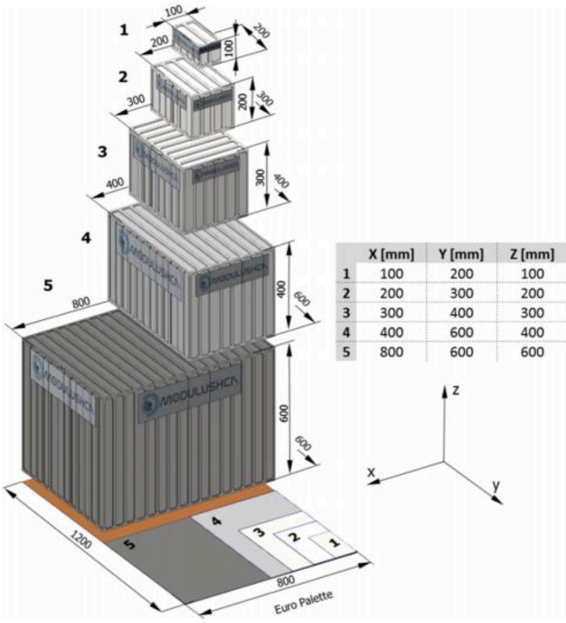
Due to the more fine-grained distribution network needed to operate cargo bikes, light commercial vehicles, and/or autonomous vehicles efficiently, material handling operations play a more important role. Given the lower volume capacity of these vehicles, fitting as many parcels as possible into the loading space available becomes more important to operate efficient routes. The more parcels fit, the more deliveries can be incorporated into a single tour, which reduces the number of vehicles and – in the case of non-autonomous vehicles – couriers needed. To reduce the stop time at the delivery location, these parcels must also be loaded such that they are easily retrieved during the route, for example by sorting them according to a last-in-first-out policy in sequence of the route. Yet, fitting many parcels in a tiny space considering the sequence of deliveries takes considerable material handling experience and time. And, given the scale of the last-mile deconsolidation and transhipment points, these material handling processes are not easily automated – that is, not cost effectively. Consequently, the real operating cost benefits of smaller road-based vehicles are not only countered by additional facility costs, but also be additional handling costs.

One fruitful way to mitigate the negative impact of material handling is to work with standardized loading units and pre-sorting of parcels. Such standardized loading units would allow early sorting at an aggregation level lower than usual (e.g., a delivery van or a roll container), for example in a box

[8] www.sae.org

that can easily be mounted on a cargo bike. Early here refers to a larger distribution network facility, such as a sorting centre, where automated material handling equipment is installed and makes sorting cost-effective. Research on the design of such standardized loading units and their implementation into a distribution network is done by academics and industry practitioners working collaboratively on the Physical Internet. Already in the initial manifesto of one of the Physical Internet's founding fathers – Benoit Montreuil – there is mention of modular containers (Montreuil, 2011). Later, several research groups have worked on actually designing a prototype container (Landschützer et al., 2015) and analysed the extent to which smart information technology should be added to its design (Sallez et al., 2016). The modularity these containers is one of its key characteristics and is scaled so that it is compatible with both Euro pallets and 20- or 40-foot maritime containers, as shown in Figure 4.3. While the prototype developments did not lead to a design that is used at scale, the idea about standardization and the operational implications of using pre-sorted loading units persevered.

Figure 4.3 Dimensions of modularly sized containers (Landschützer et al., 2014)



4.2 State-of-the-art

The state-of-the-art is divided across the two types of vehicles introduced above, namely non-autonomous and autonomous vehicles, and includes practices related to standardized loading units and containers.

4.2.1 Non-autonomous road-based vehicles (zero-emission)

4.2.1.1 URB-E

Introduction	
Name	URB-E

Figure	
Short description	URB-E focuses on grocery deliveries, using electric bike with trailer combinations, carrying foldable containers. The bikes can tow 800 pounds of goods, but the company does not restrict itself to bikes – in the future they might use electric (possibly autonomous) vehicles too.
Start date	2013
End date	On-going
Status	URB-E is currently operational in New York City and Pasadena, USA, and plans to expand its operations into more cities soon. At the moment, 1800 containers circulate in New York. In 2021, the start-up firm raised 5 million USD in a first venture capital funding (series A funding) round.
Websites/reference	https://www.grocerydive.com/news/urb-e-looks-to-electric-bicycles-to-make-grocery-delivery-more-efficient/598048/ https://www.socaltech.com/urb_e_gets___m_for_urban_delivery_network/s-0080987.html https://cleantechnica.com/2017/01/15/urb-e-last-mile-solution-new-urb-e-sport/
Type of vehicle (light electric van)	
OEM	URB-E
Vehicle	URB-E
Dimensions	1,39 (W) x 3,59 (L) x 2,5 (H) meter
Loading capacity (weight)	800 pounds (362 kg)
Loading capacity (volume)	Unknown
Speed	Max 20 km/u
Range	Unknown
Operating model	
Operational implications	URB-E leases its vehicles to retailers that home deliver groceries. The retailers integrate the use of these cargo bikes into and alongside their normal delivery vans.
Distribution network implications	URB-E is developing a containerized delivery network in urban areas, focused on small container systems which are rolled on and off into parking spaces, and where the last mile is delivered via bicycle. URB-E currently operates a yard to store its containers and bikes in mid-Manhattan, and plans to open other depots elsewhere in Manhattan as well as in Brooklyn, New York.

4.2.1.2 Albert Heijn light electric vehicles

Introduction	
Name	Albert Heijn light electric vehicles

Figure	
Short description	To comply with the regulations for zero-emission zone that will be implemented from 2025 in the Netherlands, Albert Heijn will start delivering its groceries by means of light electric vehicles. It tests two types of vehicles and aims to have a working solution in every zero-emission zone within the next two years.
Start date	2021
End date	On-going
Status	It concerns a test with these vehicles in two cities. The light electric van will be used in Amersfoort (Netherlands) and the electric cargo bike in Breda (Netherlands).
Websites/reference	https://nieuws.ah.nl/albert-heijn-gaat-boodschappen-bezorgen-met-elektrische-minibusjes/ https://www.addaxmotors.com/en/model-mt15/# https://rytle.com/movr/
Type of vehicle (light electric van)	
OEM	Addax Motors NV (Belgium)
Vehicle	Addax MT15 LEV
Dimensions	1,39 (W) x 3,59 (L) x 2,5 (H) meter
Loading capacity (weight)	1000 kg
Loading capacity (volume)	5 m3 36 Albert Heijn crates
Speed	Max 65 km/u
Range	Max 130 km
Type of vehicle (e-cargobike)	
OEM	Rytle
Vehicle	Rytl Movr 25
Dimensions	1,2 (W) x 2,7 (L) x 2 (H) meter
Loading capacity (weight)	180 kg
Loading capacity (volume)	2 m3 20 Albert Heijn crates
Speed	Max 25 km/u
Electric support	Yes: 2 wheel hub motors (250W)
Range	Max 75 km
Operating model	
Operational implications	The larger diesel delivery vans have more capacity than the 36 or 20 crates of the vehicles described above. Accordingly, less customers can be visited in a single tour. Hence, the vehicles are to be applied in situations with high customer density and efficiently using the vehicles may require multiple tours per vehicle per shift.

Distribution network implications	The use of smaller electric vehicles, instead of diesel delivery vans, requires changes to the distribution network of Albert Heijn's e-commerce deliveries. Currently, Albert Heijn is in the process of opening its eight distribution centres dedicated for e-commerce, and to enable efficient routes for the delivery vehicles they make use of 23 local hub locations.

4.2.2 Autonomous vehicles

Given the regulatory and societal context in the European Union, and the context of the ULaaDS projects, we pay special attention to smaller-scale applications of autonomous road-based vehicles. For types of autonomous vehicles, local authorities have some regulatory discretion to test applications at some scale. Permits for unmanned aerial vehicles fall under the often more stringent federal or (inter)national jurisdiction. Perhaps more importantly, there are serious concerns about noise pollution when applying drones at scale. While potentially useful technology for the much-needed material handling efficiency gains inside hub facilities, autonomous vehicles used indoors are associated with a relatively high investment cost and need for standardisation, which are expected to hinder broad scale application in the urban freight transport context in the following years.

4.2.2.1 Co-Op convenience store robot deliveries

Introduction	
Name	Co-Op convenience store robot deliveries (UK)
Figure	
Short description	The Co-Op convenience stores robot deliveries were first deployed in the United Kingdom in eight stores in the Monkston neighborhood (Milton Keynes, UK).
Start date	2020
End date	On-going
Status	While ramping up its same-day grocery delivery service, Co-Op is expanded its side-walk robot deliveries from Milton Keynes to Northampton in November 2020 and plans to use around 300 of them by the end of 2021.
Websites/reference	https://starshipgroceries.com/monkston/ https://www.nytimes.com/2020/05/20/technology/delivery-robots-coronavirus-milton-keynes.html https://www.co-operative.coop/media/news-releases/rise-of-the-robots-as-co-op-and-starship-roll-out-autonomous-delivery
Type of delivery service	

Urban freight flow	Convenience store goods
Scale	Local-to-local
Delivery services	Instant delivery (within one hour).
Type of vehicles	A sidewalk robot from Starship Technologies
Vehicle characteristics	Starship robots are small (125cm heigh with flagpole, 57 cm wide, and 68 cm long) and light vehicles (23 kg) that travel autonomously on the sidewalk. The robot can carry a few items per trip (weighing up to 10 kg) within a 6-km range. It has an electric engine with a maximum movement speed of 6 km/h. (Source: https://www.dimensions.com)
Order process	Consumers can order via a Starship Technologies app (Starship Food Delivery), which includes a range of about 1000 convenience store goods from a nearby Co-Op store. When ordering, the consumer pins a location where it wants to meet the robot (e.g., in front of their house), after which they can track its movements.
Delivery and hand over of goods	Order is picked in the nearest Co-Op and placed into the sidewalk robot. Robot departs from the store and moves to the pinned location. Once the robot arrives, the consumer receives an alert. It must then meet the robot, which can be unlocked through the app.

4.2.2.2 Kroger grocery delivery

Introduction	
Name	Kroger grocery delivery (USA)
Figure	
Short description	Kroger first tested the delivery robot in December 2018, in a pilot program that lasted several months and saw over 2000 deliveries from a single store in Scottsdale (Arizona, USA). Subsequently, the delivery robots were deployed at larger scale in Houston (Texas, Arizona), where they delivered from two stores to four postcode areas. The pilot program and subsequent deployment both first relied on Nuro's self-driving Toyota Prius fleet, before introducing Nuro's own custom vehicle.
Start date	2018
End date	On-going
Status	Kroger delivers groceries in selected postcodes in Houston Texas.
Websites/reference	https://www.kroger.com/f/delivery-by-nuro https://www.nuro.ai/ https://www.wired.com/story/nuro-grocery-delivery-robot/

	https://eu.usatoday.com/story/money/2019/03/17/kroger-ends-unmanned-vehicle-grocery-delivery-pilot-program-arizona/3194604002/ https://medium.com/nuro/introducing-r2-nuros-next-generation-self-driving-vehicle-a9974ff6c2e0
Type of delivery service	
Urban freight flow	Groceries (supermarket)
Scale	Local-to-local
Delivery services	Same day and next day delivery
Type of vehicles	Nuro R1. In April 2020, Nuro announced its follow-up vehicle, the R2.
Vehicle characteristics	The Nuro R2 is a small road-based vehicle that can travel on the road autonomously. The vehicle is 186 cm high, 110 cm wide, and 274 cm long and weighs 1150 kg. It can handle a payload up to 190 kg and travel at a maximum speed of 40 km/h. (Source: https://www.dimensions.com)
Order process	Consumers order online at Kroger's website or via the mobile application. During the first pilot program, customers could choose for same day or next day delivery at a fee of 5,95 USD.
Delivery and hand over of goods	Order is picked from a Kroger store and loaded into the Nuro R1, which has space for 12 bags of groceriess. The robot drives autonomously, on the road, to the customer's address. Customers can track the vehicle's location and get a notification upon its arrival. The vehicle has a touch display through which it can be unlocked (also via app). Customer picks the bags of groceries from the vehicle, which then returns to the store autonomously.

4.2.2.3 ALEES demonstrator Mechelen

Introduction	
Name	ALEES demonstrator Mechelen (Belgium)
Figure	
Short description	Under the supervision of VIL, project partners in the ALEES project (the city of Mechelen and ACP) demonstrated the use of an autonomous road-based vehicle in the city centre of Mechelen (Belgium). The vehicle autonomously traveled a pre-determined – and closely monitored – route to test a few scenarios.
Start date	May 25, 2018
End date	May 25, 2018
Status	The project included a single day of demonstration
Websites/reference	https://vil.be/project/alees/

	https://vil.be/2018/primeur-vil-laat-zelfrijdend-voertuig-pakjes-leveren-in-centrum-mechelen/#.YJVTZmaA6-Y
Type of delivery service	
Urban freight flow	B2B shipments to 5 local shopkeepers (standard boxes, passive temperature-controlled boxes, and a roll container) and B2C shipments (parcels).
Scale	Local-to-local
Delivery services	At the moment, no delivery service is offered.
Type of vehicles	Easymile EZ10 shuttle.
Vehicle characteristics	The Easymile EZ10 is designed as a passenger shuttle that can carry up to 12 passengers (max 900 kg). The vehicle is 287 cm high, 189 cm wide and 405 cm long, and weighs 2130 kg. It can travel autonomously on a fixed route. The maximum speed of the vehicle is 40 km/h, but can be capped if necessary – in Mechelen it traveled at a maximum speed of 10 km/h.
Order process	The demonstrator simulated several use cases, including supplying local shops and delivery parcels to consumers. At this stage there is no formal ordering process in place for customers and receivers of goods – due to the demonstrating nature of the project.
Delivery and hand over of goods	Receivers of goods retrieve the goods from the vehicle. At this stage, there is no formal process in place for the notification upon arrival of the vehicle.

4.2.3 Containerization

Currently, containerization is mostly used in cargo bike logistics.

4.2.3.1 DHL Cubicycles

Introduction	
Name	DHL Cubicycles
Figure	
Short description	DHL has started to roll out Cityhubs with the use of Velove Armadillo's, or Cubicycles as DHL calls them. The cubicycles are larger type of e-cargobike, with a modular cargo trailer.
Start date	2017
End date	On-going
Status	In 2017, DHL started with this combination in Utrecht. It has been experimenting for some time and has been demonstrated to work well in the last mile configuration of DHL. Especially, the modular trailer allows for a quick transhipment between delivery truck and Cubicycle. In 2021, DHL

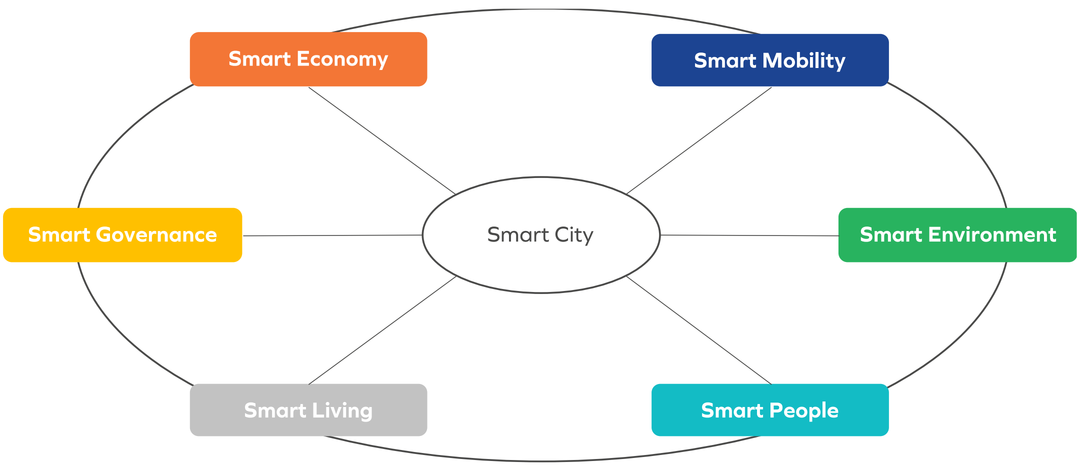
	announced its own cargobike design (Chariot) co-designed by its cycle couriers. Although not explicitly introduced as the Cubicycle replacement model, that does seem to be the case.
Websites/reference	https://www.velove.se/last-mile-solutions https://www.fietsdiensten.nl/dhl-lanceert-nieuwe-vervoerscombinatie-cubicycle-stadsdistributie/ https://www.dhl.com/nl-nl/home/pers/persarchief/2021/dhl-express-introduceert-nieuwe-cargofiets-de-chariot.html
Type of vehicle (light electric van)	
OEM	Velove Bikes AB (Sweden)
Vehicle	Armadillo
Dimensions	0,6 (W) x 3,1 (L) x 1,6 (H) meter
Loading capacity (weight)	150 kg
Loading capacity (volume)	1 m3
Speed	25 km/h
Range	Max 50 km
Operating model	
Operational implications	The containers that are mounted on top of the cargobikes are preloaded in a DHL depot and transported to a city by a van or on a trailer where they are mounted onto the cargobike. A trailer has the capacity of 4 containers.
Distribution network implications	A parking space is needed where the containers can be transhipped from the trailer or van onto the cargobike. Other than that, little network implications exist.

5. Platforms for urban freight transport

Smart city initiatives are booming. Until 2019, over a thousand of such initiatives took place around the world (Deloitte, 2018), and more than seven thousand academic journal and conference papers were written about it (Zheng et al., 2020). Broadly, a smart city can be defined as "a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership" (European Parliament, 2014). A smart city is built on three foundational elements: 1) it leverages data sources from the physical and digital world, 2) it interconnects and integrates data from various city services and companies, and 3) it uses the data for intelligent decision making (Harrison et al., 2010 and Pan et al., 2021).

Smart city solutions contain a very broad scope of, mostly information technology applications. As shown in Figure 5.1 below, these solutions can be categorized under six dimensions of a smart city: smart people, smart environment, smart living, smart governance, smart economy, and smart mobility. The vision for a truly smart city is that all these solutions are integrated into a system "connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city" (Harrison et al., 2010). Currently, there are few, if any, examples where this vision already became reality. Rather, cities are currently mostly pilot testing with individual applications. At a broader implementation level, local authorities are struggling to come up with a detailed and financially viable business case for a smart city platform (Timeus et al., 2020).

Figure 5.1 The six dimensions of a smart city (adopted from Zheng et al., 2020)



5.1 Types of smart city platforms relevant to ULaaDS

In the context of ULaaDS, the focus is on the issues stemming from trends in urban freight transport because of the on-demand economy. In that context, an important objective is to reduce the negative societal and environmental impact from freight transport the shippers, carriers, and receivers of goods in the urban space. This includes business-to-business, business-to-consumer, consumer-to-business, and consumer-to-consumer shipments into, out of or within the city boundaries. A comprehensive overview of the challenges involved is provided in Pan et al. (2021):

- Megacities and urban planning: The number of very large cities is expected to increase – and with it the demand for urban freight transport. This will render efficiently organizing urban freight transport increasingly difficult and the corresponding issues require attention in urban planning and design.
- The rise of the on-demand economy and the war of speed and flexibility in omni-channel retail: As a result of the on-demand economy, delivery leads time expectations become more and more stringent. We have seen a trend from multiple day delivery, to next day, to same day, to a few hours, to even delivery within 10 minutes (e.g., Gorillas). This too challenges efficient planning of the corresponding urban freight operations as it becomes both more important and difficult to precisely forecast the arrival of orders and to consolidate multiple orders into efficient routes.
- Stricter regulations and stakeholder objectives: In an attempt to curb the negative externalities from increased urban freight transport, cities around the world are imposing increasingly stringent regulations, for example in terms of access restrictions, road pricing, etc. These regulations follow changing objectives from stakeholders. Stakeholders expect the urban space to be attractive for leisurely activity, and consumers come to expect more sustainable deliveries.

Platforms to address these issues are developed, owned and operated by different stakeholders, which has implications on the scope of the initiative as well as the operating and business model. Below, a distinction is made between platforms that are initiated, owned and operated by a city, a commercial party or by the community.

5.1.1 City driven platforms

Platforms for the management of urban freight fall in the dimension of smart mobility and may consist of many types of applications, such as smart traffic lights, smart parking support, smart road-user charging/toll systems, GPS systems for public transport information, automatic traffic recording, traffic visualisation systems, road safety and accident prevention systems, electronic control of restricted access zones, and many more. These applications are often installed by a (local) government and platforms built on them in the context of a city are therefore commonly also initiated by the city.

One particularly successful type of smart mobility platform initiated by cities around the world is the bicycle sharing system. Bicycle sharing systems are not a novel concept. Indeed, the concept saw its inception in the 1960s in Amsterdam, the Netherlands, with the so-called "white bicycles" (De-Maio, 2009): bicycles that anyone could use free of charge to make trips in the city – they were painted white to be easily recognized. A few innovation cycles further, the notion behind bike sharing systems has not changed: provide users with access to bicycles when needed (Parkes et al., 2013). The most recent systems make use of smartphone technology for real-time availability, power assisted bikes, solar-powered docking stations, and integration into mobility as a service platforms (Shaheen et al., 2010). Some bike sharing platforms rely on docking stations where users can access the bicycles, whereas other platforms are dockless, relying on GPS data and smartphone technology to enable user access (Gao & Li, 2021).

During the coronavirus pandemic, many local shops and boutiques were confronted with lock down measures and/or customers that did not come to their shop. Many of those shops either had no webshop at all, or one that was not often visited/easily found by consumers. In response, many cities experimented with the setup of online shopping malls, where local shops can present themselves to consumers under a single brand. The online shopping malls often also provide same-day home deliveries.

5.1.2 Commercially driven platforms

In the context of sustainable urban freight transport, most commercially driven platforms are crowd logistics platforms. Crowd logistics is an emerging form of logistics and is part of the broader trend towards a sharing economy. The rationale behind crowd logistics is that it is possible to use idle or underutilized logistics resources by tapping into the crowd – that is, by outsourcing specific logistics tasks to independent, often individual, operators (Castillo et al. 2017, Carbone et al., 2017). Supply and demand for logistics resources often meet online, moderated by a crowd logistics platform using advanced information technology, such as tracking and tracing, matching algorithms, mobile applications, payment systems (Frehe et al., 2017).

Logistics platforms exist for a range of (urban) freight flows. First, when considering general cargo, there are differences in the scale of the freight flow on which the platforms target. Broadly, one can distinguish between platforms focusing on maritime container logistics (e.g., uturn, flexport, TEUbooker), for full-truckload transportation (e.g., Uberfreight, instafreight, cargonexx, teleroute), less-then-full-truckload (saoodo, carrypicker, quicargo) and last-mile logistics (e.g., dropper, annanow, stuart, paack, glovo). In larger-scale transportation, logistics service providers often consolidate different types of goods. Particularly in the last mile however, different platforms focus on different freight flows. The most notable difference can be seen in platforms that focus on meal delivery and those focusing on general parcel delivery.

5.1.3 Community driven platforms

Lastly, there are also mobility platforms that are developed, owned, and operated by the (local) community. The development of these platforms mostly follows a bottom-up approach, where citizens are acting themselves to reduce the kilometres driven by polluting vehicles and/or the number of vehicles traveling in their neighbourhood. To this end, the platforms focus on the sharing of vehicles so that ownership of a vehicle is not needed to be able to use it. A good example is the development of a network consisting of dozens of individual free cargo-bike sharing operators in Germany and Austria (Becker, & Rudolf, 2018). Each operator provides cargo-bikes to citizens in their local area. The cargo-bikes are managed as common goods: users pay no membership fee (although voluntary contributions are welcomed), but are involved in keeping the cargo-bike system up and running. Collectively, the operators often meet to discuss lessons-learned and further develop their network.

5.2 State-of-the-art

The state-of-the-art is organized according to the discussion above and thus presents different practices across three categories: city driven, commercially driven, and community driven platforms.

5.2.1 City driven platform initiatives

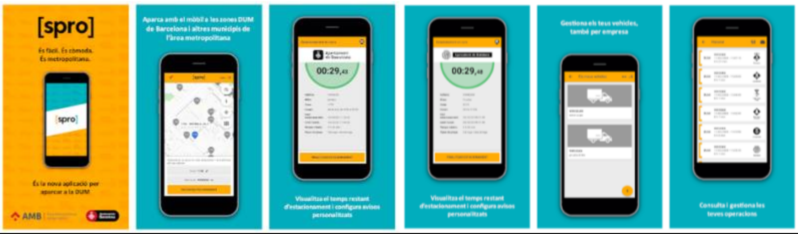
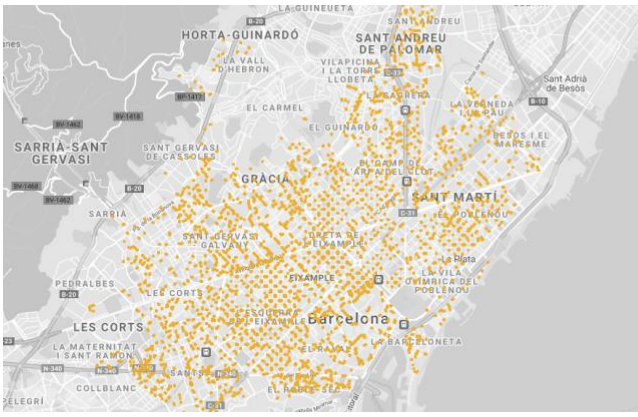
Many cities experiment with individual technologies – or combinations of a few technologies – to enable smart urban freight transport solutions. Below, three of such examples are included in the state-of-the-art.

5.2.1.1 UFL real-time curb visibility app (Seattle, USA)

Introduction	
Name	Real-time curb visibility app
Figure	
Short description	Researchers from the Urban Freight Lab (Supply Chain Transportation & Logistics Center, University of Washington) developed an app to help delivery couriers find a parking spot without cruising. Real-time and historical usage data is analysed using machine learning to predict the likelihood of parking being available when the driver arrives at its destination. These predictions will improve over time as more data is used and analysed. The goal is to reduce parking seeking behaviour by parcel delivery vehicles by 20% in the pilot, which now is a large problem in Seattle (Dalla Chiara & Goodchild 2020; Dalla Chiara et al., 2021).
Start date	2021
End date	On-going
Status	The first sensors were installed September 2020, a first version of the app was launched in April 2021. Currently, commercial vehicle drivers are invited to use the app and provide feedback.
Websites/reference	https://depts.washington.edu/sctlctr/research-projects/technology-integration-gain-commercial-efficiency-urban-goods-delivery-system-meet https://www.fybr.com/ https://lacuna.ai/index.html

Type of initiative	
Solution type	Smart parking support for commercial vehicles
Ownership / initiative	Public-private partnership, project funded from the U.S. Department of Energy
Data	
Data providers	Fybr and Lacuna Technologies App users
Data provision	Seattle privacy rules don't allow for video cameras, so researchers and IoT providers Fybr and Lacuna Technologies installed 274 sensors under the pavement of commercial vehicle load zones in the Belltown area of Seattle. The in-ground sensors use magnets and light to detect vehicle presence and measure the time vehicle remains parked. Researchers from the UFL and developers from project partner Pacific Northwest National Laboratory integrate data from these sensor technologies, develop data platforms to process large data streams, and launched a prototype app to let delivery drivers know when a parking space is open – and when it's predicted to be open so they can plan to arrive when another truck is leaving.
Functionality for users	
Functionality	See which parking spaces are, or will soon become, available / in use.

5.2.1.2 SRPO (Barcelona)

Introduction	
Name	SPRO
Figure	
Short description	In June 2020, the Barcelona metropolitan area and City Council launched SRPO, a mobile app supporting commercial vehicle users in finding a parking place in Barcelona, Badalona, Castelldefels, Esplugues, L'Hospitalet, Sant Joan Despí and Sant Just Desvern. SPRO is the successor of AreaDUM which had 170,000 registered users. The app enables its users to identify a parking place and quickly reserve it.  The city of Barcelona defined an Urban Freight Transport area – Distribució Urbana de Mercaderies, in Catalan – where on weekdays, between 8 am and

	8 pm, commercial vehicles can park close to their destination for loading and unloading for a maximum of 30 minutes. The intension is to provide maximum rotation and serve as many vehicles as possible with the limited parking space available – the area has about 9000 parking spaces for commercial vehicles.
Start date	2020
End date	On-going
Status	The SRPO app is in use by its users.
Websites/reference	https://www.areaverda.cat/en/spro https://beteve.cat/mobilitat/spro-aplicacio-metropolitana-carrega-descarrega/
Type of initiative	
Solution type	Smart parking support for commercial vehicles
Ownership / initiative	The predecessor of SRPO, AreaDUM, was developed with funding for the SUMP (2013-2019) of the city of Barcelona. It is developed by the public service company B.SM, who also manages and monitors the parking spaces, for the City Council of Barcelona.
Data	
Data providers	Parking meters of B.SM App users
Data provision	Data from the parking meters and app users is combined to provide an updated view of available parking spaces. In the city of Barcelona, the app uses geolocation technology and a predictive system to present the availability of regulated parking spaces.
Functionality for users	
Functionality	Users of the app can use the parking spot for free for 30 minutes when loading and/or unloading. If the vehicle is registered as a zero-emission vehicle, an additional 30 minutes of free parking is available. Drivers can set personalized alarms to warn for example when the 30 minutes free parking are nearly up.

5.2.1.3 Smart city Groningen

Introduction	
Name	Flowcubes
Figure	

Short description	With the help of smart sensors, the number of cyclists and pedestrians are measured at 20 locations in the city centre. The municipality of Groningen wants to use the collected data to explore how a Smart City approach can strengthen the city centre of Groningen. This could include the dynamic management of traffic flows through the city centre based on real time data. Also, during events a better view can be obtained of the freight and passenger flows through the city centre. For entrepreneurs in the city centre, the data can provide a much better picture of the passer-by or visitor in their street.
Start date	2019
End date	Under construction
Status	Municipality of Groningen is currently exploring the use of existing automatic sensors to also capture freight vehicles.
Websites/reference	https://ruimtevoorjou.groningen.nl/project/41-aanpak-slimme-binnenstad-smart-city-verkenning-2017/ https://www.technolution.com/move/nl/flowcube/
Type of initiative	
Solution type	Automatic traffic recording and dynamic planning
Ownership / initiative	The project is an initiative of the municipality of Groningen under the broad inner city improvement plan called "ruimte voor jou" (room for you).
Data	
Data providers	20 automatic traffic recording units throughout the inner city
Data provision	Currently, the units are used to measure pedestrian and bike movements, but they can be adjusted to also include other traffic (anonymized).
Functionality for users	
Functionality	Users – mostly transportation companies – can use the data from the system to plan their trips such that they avoid traffic as much as they can within the current time window restrictions. When using zero-emission vehicles, there are broader time windows, which makes up-to-date insight into how busy it is in the city even more valuable.

5.2.1.4 Warenhuis Groningen

Introduction	
Name	Warenhuis Groningen
Figure	
Short description	The coronavirus pandemic outbreak early 2020 accelerated the development and roll out of this platform where local shops and boutiques can present their store and inventory under one brand "Warenhuis

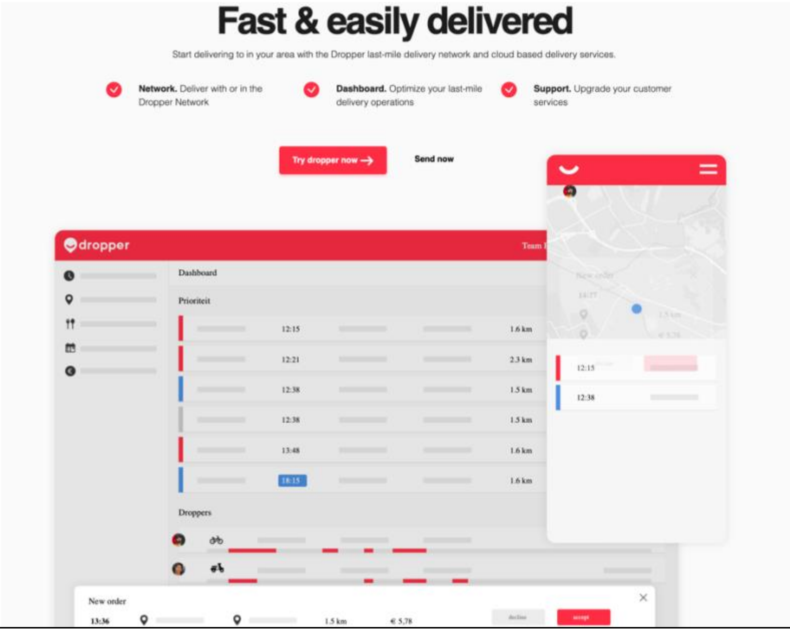
	Groningen". Consumers can either get inspired before going shopping physically, or for many shops order their goods online and receive them at home. A customer can order from multiple stores. Delivery of the goods is executed by a third-party – in this case first Dropper and now Go Fast.
Start date	2020
End date	On-going
Status	The platform has been fully operational for over a year and is constantly further developed to meet the needs of local shops and boutiques. During lock down measures, those needs were mostly related to selling goods online. With – what hopefully is – the tail-end of the pandemic, those needs will shift towards adapting to the on-demand economy and sustainable urban freight policy of the city of Groningen. Adding functionalities to support for example sustainable supply of goods are considered.
Websites/reference	https://warenhuis.groningen.nl/
Type of initiative	
Solution type	Online shopping mall
Ownership / initiative	The project is an initiative of the Groningen City Club (an association of local shop keepers in Groningen) and partially supported by the municipality of Groningen. Start-up company Zupr is the technology provider and rolled out this type of platform in 83 Dutch cities after Groningen.
Data	
Data providers	Mostly shop keepers and a few brands (suppliers)
Data provision	Shopkeepers provide a list of their inventory – and some developed API connections to their cash register and inventory systems.
Functionality for users	
Functionality	Shopkeepers can present their shop and goods online. Consumers can see the stories behind the shops and order online. Courier companies receive multiple orders at once for local home delivery.

5.2.2 Commercially driven platforms

Commercial platforms offering logistics services are popping up in large numbers. By and large, these are private company initiatives through start-ups, most of which are absorbed by larger parcel delivery services soon after their start. Below, a wide range of different examples is provided.

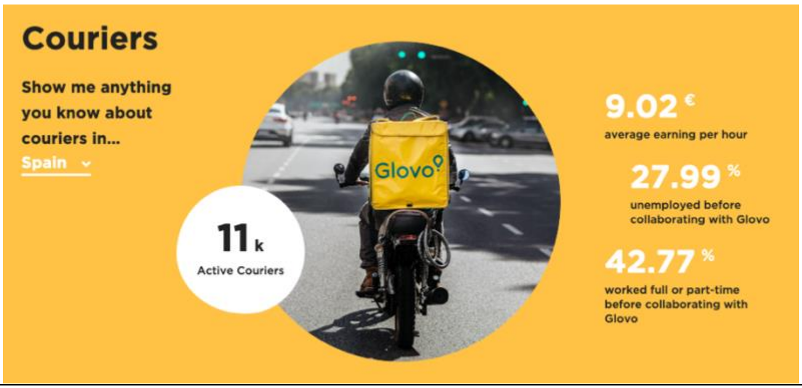
5.2.2.1 Dropper

Introduction	
Name	Dropper

Figure	
Short description	Dropper offered cloud-based solutions for last-mile senders, couriers and teams. They focused on connecting local senders to local couriers for instant, same day or next-day deliveries in the local area. Based on smart routing and planning tools, users of the platform could optimize their last-mile operations.
Start date	2019
End date	2021
Status	March 2021 Dropper filed for insolvency and seized all operations.
Websites/reference	https://admin.dropper.nl/en/ https://www.rtvnoord.nl/nieuws/205397/Dropper-wil-pakketjes-van-stadswinkels-meteen-bij-je-thuisbrengen
Type of platform	
Urban freight flow	Parcel delivery
Scale	Local-to-local and last-mile deliveries
Delivery services	Next day, same day, and instant delivery.
Consignees	Senders and receivers of goods can order.
Type of vehicles	Mostly (cargo) bikes, a few delivery vehicles from professional courier services.
Couriers	A mix of professional courier services (e.g., Cycloon, GoFast) and individual freelancers under the Dropper name.
Planning of couriers	Hybrid and centralized scheduling.

5.2.2.2 Glovo

Introduction	
Name	Glovo

Figure	
Short description	Glovo was founded in Barcelona in 2015 as a food delivery service. Food delivery is still its biggest service, but it promises to deliver anything within 30 minutes – now branding itself as a lifestyle app for "quick commerce".
Start date	2015
End date	On-going
Status	In March 2021, the Spanish government announced new legislation that classifies freelance couriers as employees, not self-employed workers. Despite potentially being affected negatively by the new law, it raised €450 million in a series F round for its expansion into Eastern Europe and Africa and to develop a new division for quick commerce.
Websites/reference	https://about.glovoapp.com/en/inside-glovo https://www.forbes.com/sites/iainmartin/2021/04/01/spanish-delivery-startup-glovo-raises-530-million-round/?sh=792038b926d0 https://www.washingtontimes.com/news/2021/mar/11/gig-economy-shifts-spain-delivery-riders-are-now-e/
Type of platform	
Urban freight flow	Convenience goods (groceries, food, drinks, tobacco, pharmaceuticals)
Scale	Local-to-local
Delivery services	Instant delivery
Consignees	Receivers (consumers) order online and generate a transport request with their order.
Type of vehicles	Mostly bikes
Couriers	Couriers are independent professionals.
Planning of couriers	Pure self-scheduling

5.2.2.3 MixMove Smart City Logistics

Introduction	
Name	MixMove
Figure	
Short description	MixMove grew out of an EU FP7 project iCargo and is closely related to the Physical Internet community. MixMove provides several cloud-based software solutions that facilitate the use of transportation networks and city hubs.

Start date	2015 (by the end of the iCargo project)
End date	On-going
Status	MixMove is designed for and aims to facilitate the transition to a physical internet. Until then, it mainly supports individual companies, where it helps integrating the logistics of several product types and sales channels into one optimized transportation network planning.
Websites/reference	https://www.mixmove.io/
Type of platform	
Urban freight flow	General cargo
Scale	Long-haul transport and last-mile deliveries
Delivery services	Next day or longer
Consignees	Suppliers and carriers
Type of vehicles	Using vehicles of MixMove software user, mostly large trucks on long-haul; smaller delivery vans in last-mile.
Carriers	Carriers that use the MixMove software themselves, or the carriers of suppliers that use the MixMove software.
Planning of couriers	Centralized planning.

5.2.2.4 Peddler

Introduction	
Name	Peddler
Figure	
Short description	Peddler connects local supply with local demand. Consumers can browse through an online shopping mall (mostly boutiques and small local shops), order products online and get it home delivered the same day. Peddler delivers via its own bicycle couriers, 7 days per week, two rounds per day (14:00-16:00 and 18:00-20:00).
Start date	2020
End date	On-going
Status	Peddler started its operation in Amsterdam and expanded into Utrecht. They plan to open their platform in more cities in 2021.
Websites/reference	https://www.peddler.com/nl/
Type of platform	
Urban freight flow	E-commerce and goods from local shops
Scale	Last-mile delivery
Delivery services	Same day or next day
Consignees	Consumers
Type of vehicles	Cargo bikes
Carriers	Peddler operates its own delivery service

Planning of couriers	Centralized planning

5.2.3 Community driven platforms

Community driven platforms are often small in scale and information about them in publicly available sources is scarce. One particularly interesting example includes the free cargobike sharing system including many individual free cargobike sharing operators in Germany and Austria.

5.2.3.1 Forum for free cargobike sharing

Introduction	
Name	Forum Frei Lastenräder
Figure	
Short description	Forum Freie Lastenräder is a collaborative platform for the various Free Cargo-Bikesharing initiatives in German-speaking countries. Its members (e.g., Lastenräder Stuttgart) offer cargo-bikes to anyone who is a registered for free. The cargo bikes are common goods between the registered users – that is, there are no membership fees, but the initiatives do ask for donations and/or voluntary engagement (e.g., repairs). The bikes are mostly used by residents that either have no access to a car or replace a car trip with a bike trip.
Start date	Unknown
End date	On-going
Status	As of 2021, the Forum Freie Lastenräder includes 129 active members.
Websites/reference	https://www.lastenrad-stuttgart.de/wieesfunkioniert https://dein-lastenrad.de/wiki/Willkommen_beim_Forum_Freie_Lastenr%C3%A4der
Type of platform	
Urban freight flow	Groceries and other convenience goods
Scale	Last-mile
Delivery services	N/a
Consignees	Residents
Type of vehicles	Different types of (e-)cargobikes
Carriers	N/a
Planning of couriers	N/a

5.2.3.2 Cargonomia

Introduction	
Name	Cargonomia
Figure	
Short description	Cargonomia is a multipurpose initiative, connecting zero-emission transport solutions (by cargo bikes) with sustainable food production (delivering organic food produced in the proximity of Budapest), bike manufacturing and competency advocacy (organizing workshops and training sessions). In addition to the direct marketing of local food products, Cargonomia is also a logistics center for sustainable urban transport solutions, where community members can borrow, rent, and buy locally manufactured cargobikes. According to the cooperative, Cargonomia supports a system which supplies more than 3,000 food boxes per year, its bicycle couriers cover nearly 18,000 km every year, delivering goods throughout a territory of 27 km² of the city.
Start date	2015, cargobike-sharing system launched in March 2018
End date	On-going
Status	The cooperative is composed of three social enterprises, is partnering with other local initiatives and small businesses, and is involved in the international Degrowth network
Websites/reference	http://cargonomia.hu/ https://kozteherbringa.hu/
Type of platform	
Urban freight flow	Groceries and other convenience goods
Scale	Last-mile
Delivery services	Next day or longer
Consignees	Residents and local businesses
Type of vehicles	Different types of cargo bikes
Carriers	N/a
Planning of couriers	N/a

6. Benchmarking operating and business models

This section provides benchmarks for the operating and business models of the ULaaDS solutions and logistics schemes. The discussion of the different operating and business models is structured according to the structure of the ULaaDS project, which considers two main solutions: 1) collaborative delivery models – aimed at enhancing logistics efficiency and enabling multi-modal urban freight transport; and the 2) integration of urban freight and passenger transportation networks. Solution 1 includes three logistics schemes: i) containerised urban last-mile delivery; ii) crowdsourcing platform for city logistics; and iii) city-wide platform for integrated management of urban freight transport. Solution 2 includes two logistics schemes: i) location and infrastructure capacity sharing; and ii) vehicle capacity sharing.

The ULaaDS solutions and logistics schemes could consist of a combination of different innovative practices discussed in the previous chapters introducing the state-of-the-art for hub location and infrastructure sharing, emerging vehicle technology, and platforms. The inclusion of different practices in each of the schemes may have significant implications for the operating and business model of the scheme. Below, these are discussed for each of the ULaaDS schemes. The discussion for each of them follows a similar structure. First, the scheme is introduced, followed by a discussion of the different innovative practices that can be included in it and the implications for the operating model. Lastly, the business model implications are discussed, following the extended business model canvas approach introduced in Section 2 of this deliverable.

6.1 Collaborative delivery models

Collaborative delivery models offer a solution for the on-demand delivery of goods to customers and businesses in a city. In order to ensure these delivery models are flexible, cost-effective and sustainable, the integration of cargo bikes and/or (zero-emission) light commercial vehicles is an important prerequisite. The ULaaDS schemes to be trialled in the lighthouse cities thus focus on ways to integrate those zero-emission vehicles efficiently and effectively into existing delivery networks.

6.1.1 Containerised urban last-mile delivery

The first ULaaDS logistics scheme discussed within the context of solution 1 pertains to the use of standardised and modular loading units for last-mile deliveries. Instead of loading a delivery vehicle at a sorting terminal outside the city, which is the standard way of working, parcels are loaded into these containers, transported to a hub nearby or within the city and transhipped onto a last-mile delivery vehicle. A key benefit is that the containers can be transported to the city on large vehicles, leading to economies of scale, while the last-mile delivery is done with small vehicles. If managed well, these smaller vehicles can operate more efficiently and cost-effectively while at the same time minimize the negative externalities involved with larger last-mile delivery vehicles (e.g., greenhouse gas emissions, noise pollution, congestion, safety). In the standard way of working, the use of smaller vehicles often results in many trips from and to the terminal. Add to that the lower maximum travel speed of small (electric) vehicles and the high facility costs for terminals near a city centre, and the challenge of using those type of vehicles in the last mile without standardised containers becomes apparent. If the container design is standardized and modular, further benefits to a containerised urban last-mile include the possibility to mix goods from different carriers onto the same larger vehicle feeding the last-mile vehicles, secure storage of goods inside the containers, and compatibility among different transport systems and vehicle types.

6.1.1.1 Integrating cargo bikes and light commercial vehicles in the last mile

Integrating cargo bikes and other light commercial vehicles into an existing urban last-mile delivery network requires careful consideration. Cargo bikes yield several potential operational benefits, mainly stemming from their relative agility, compared to conventional delivery vehicles. For example, cargo bikes require considerably less parking space, which opens more parking options, which in turn reduces both the time needed to find a parking space when driving and enables parking closer to the consumer (reducing the time needed between the delivery vehicle and consumer doorstep). Also, cargo bikes can access some areas that conventional delivery vans cannot, for example, narrow bicycle lanes as well as emission and access restricted zones.

Cargo bikes can have considerable sustainability advantages in the urban space, although there are also concerns related to how these – often larger bicycles – should be integrated into existing traffic (e.g., bike lanes, pedestrian zones, roads). An early case study in central London revealed that greenhouse gas emissions dropped by 20% (CO2 equivalent) after introducing an urban consolidation centre coupled with electrically assisted cargo tricycles and electric vans (Browne et al., 2011). When considering the impact of cargo bikes more broadly, traffic simulation results suggest even larger CO2 reductions are possible (Melo & Baptista, 2017). Generally, the use of cargo bikes also has a positive impact on the financial bottom line, albeit this does depend on the types of cargo bikes used and on the context in which they are implemented (Giglio et al., 2021). These contingencies relate, for example, to the location of the urban transhipment point (Assmann et al., 2020) or consolidation centre from which the cargo bikes tours depart, which requires substantial effort from local authorities (Ørving et al., 2019). Also, the use of cargo bikes has implications for the operational planning of the routes – cycle couriers have particular views on what constitutes a good route (Liu et al., 2020).

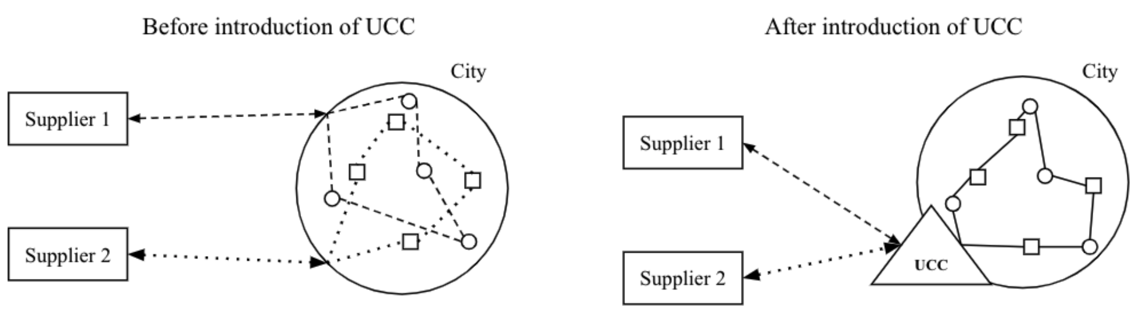
Important operational disadvantages of cargo bikes pertain to their limited loading capacity – both in volume and weight – and their limited driving speed and range. Those disadvantages can be overcome by redesigning the distribution network, to include local transhipment points, and putting cargo bikes to use in areas with characteristics that suit cargo bike delivery well. In terms of operational benefits, the total time travelled can be reduced in a system with cargo bikes and (mobile) depots with 15-40 percent, and the travel distance with 0-80 percent, depending on the delivery density (Dalla Chiara et al., 2020). These operational improvements depend mostly on the delivery density (i.e., delivery addresses per km2), which needs to be sufficiently large, and the weight and volume capacity of the cargo bike. Using a combination of cargo bikes and larger vehicles (e.g., bikes for small-sized parcels in specific areas and vans for the rest) can increase distribution network efficiency even more (Perboli & Rosana, 2019).

At the moment of writing, the use of small electric commercial vehicles is already cost-competitive without subsidy (yet some countries, such as France, are considering incentives to support cyclologistics[9]). That is, when compared on a per kilometre use basis – without considering network investments and other changes to accommodate the use of such vehicles – more than €2500 can be saved over a 5-year depreciation period (Tsakalidis et al., 2020). Nevertheless, due to the shorter range and limited loading capacity of these smaller vehicles, major changes to the distribution network design are usually required, which increases capital and operational expenditures. Larger electric vehicles may require far less distribution network changes. Often, the instalment of a (fast) charging infrastructure suffices, and diesel vans can be replaced one-to-one for electric counterparts. However, for these larger electric vehicles, the break-even point in the total cost of ownership compared to internal combustion engine vehicles is not yet reached without subsidy.

6.1.1.2 Urban consolidation centres

One of the practices that may mitigate the investments needed to efficiently integrate cargo bikes or small electric vehicles in the last-mile distribution network is the use of urban consolidation centres (UCCs). These UCCs can be used to transfer the of goods from one vehicle to another as well as the pooling of resources. The logic behind using this type of hub is appealing: all suppliers that would enter the city (centre) for only one or a few goods, can instead deliver those goods at the urban consolidation centre, where those goods can be combined with those of many other suppliers that face a similar challenge. As per this logic, many trucks of different suppliers – each making a few stops – are replaced by a few trucks making many stops. A simplified representation of this logic is displayed in Figure 6.1.

Figure 6.1. The benefits of using an urban consolidation centre (adopted from Dreischerf and Buijs, 2021).



To be economically viable without long-term government funding, urban consolidation centres require considerable freight volumes (Janjevic & Ndiaye, 2017a; 2017b). It is important to note here that there are only a few examples of urban consolidation centres that meet these criteria, and most initiatives were terminated after government subsidies where stopped (e.g., Kin et al., 2016). As previously seen, this was the case of the Goederenhub Groningen Eelde (section 3.3.2.1), too. A lack of volume is often cited as an important reason for the lack of success with urban consolidation centres (e.g., Allen at al., 2014, Björklund & Johansson, 2018). Simply put, the fixed costs associated with establishing an urban consolidation centre as well as the variable costs involved with material handling need to be offset by efficiency gains that are obtained in the last mile.

[9] https://www.ecologie.gouv.fr/plan-national-developpement-cyclologistique

In a parcel delivery context, prior studies have estimated that this requires at least 350 parcels per day (Janjevic and Ndiaye, 2017b; Kin et al., 2016; Lin et al., 2016), but depending on the context-specific factors, it seems that this is a low estimate. One important factor is that many suppliers already make use of some form of hubs in their distribution network, and/or do not use the urban consolidation centre for all their customers in the city, which limits the routing efficiencies that can be gained (Dreisscherf and Buijs, 2021). At the same time, there are many logistics service providers that operate hub facilities around the city that are economically viable without government funding. Usually, these are seen as private label hubs, and not called urban consolidation centres.

Urban consolidation centres involve many different stakeholders, most notably the operator of the hub, the sender of goods (i.e., suppliers), the parties transporting the goods (i.e., carriers), and the ones receiving the goods (i.e., receivers). Also, several interest groups, NGOs and local government bodies are often involved. Each of these stakeholder groups is important in making an urban consolidation centre a success (Österle et al., 2015, Van Duin et al., 2018), and projects can be initiated from each of these stakeholders. Usually, these projects are either initiated by the receivers (e.g., Holguín-Veras & Sánchez-Díaz, 2016) or by the carriers and/or their interest groups (e.g., Estrada & Roca-Riu, 2017).

6.1.1.3 Mobile depots

One of the practices that may mitigate the investments needed to efficiently integrate cargo bikes or small electric vehicles in the last-mile distribution network is the use of mobile depots. As discussed in the state-of-the-art, these mobile depots can be trailers that attach directly to a tractor unit or containers that are moved to a delivery area by a truck. Typically, mobile depots are the size of a single – or a few – parking spot(s). Therefore, they offer significant advantages as they can be located on specific local characteristics and even depending on the daily demand. Academic models are developed to support the daily location decisions, when the mobile depot is not to be located in the same place each day, but moved from delivery area to delivery area (Arvidsson and Pazirandeh, 2017). Mobile depots are thus more flexible than a fixed hub facility and a location is potentially easier to find. Yet, the use of mobile depots requires several changes to the standard way of working. In an early experiment by TNT Express, for example, the mobile depot used in Brussels not only required a considerable investment up front, but also increased operational costs (Verlinde et al.,2014). In part, this was due to the one-off design and construction of the mobile depot – in this case a trailer – and the small-scale application. The use of standardised mobile depots, together with standardised and modular loading units, at larger scale may help overcome these barriers. In Rio de Janeiro by contrast, a trial proved successful in both operational and environmental impact, although in 4 out of 15 neighbourhoods the use of mobile depots resulted in an increase in delivery costs (Marujo et al., 2018).

6.1.1.4 Business models for containerised urban last-mile delivery

A containerised urban last-mile delivery scheme can be designed and implemented in different ways. This benchmark considers two options. First, containerised urban last-mile delivery can be implemented by a single carrier or by an alliance of multiple carriers. Second, containerised urban last-mile delivery can make use of different type of transhipment points where the containers are loaded onto the last-mile delivery vehicles.

Table 6.1 **presents the business model canvas for containerised urban last-mile delivery when implemented into a single carrier network**. In this situation, the business model is described from the perspective of that carrier (e.g., a parcel delivery company). To benefit from the containerisation, the carrier network needs to consist of a combination between a larger terminal further outside a city and one or multiple transhipment points closer to, or within, a city centre. The state-of-the-art discussed in Section 3 presented several logistics practices to facilitate such a transhipment point. That is, transhipment of standardised loading units from a large truck to the smaller delivery vehicles can be organised at an urban consolidation centre (i.e., a hub facility in a building at a fixed location). Alternatively, the standardised loading units can be transhipped on an open space or a dedicated one, such as a parking lot or a micro-depot, or the loading units can be transported inside a mobile depot and located in one or different places in the city throughout the day. These network design choices influence the business model for containerised urban last-mile delivery, as shown in Table 6.1. The business model implications of using an urban consolidation centre or simple transhipment point are represented in turquoise (and with an a.) while the implications of using a container or mobile depot are represented in orange (and with a b.).

Table 6.1 Business model canvas for containerised urban last-mile delivery in a single carrier network with different types of transhipment points

<table>
<tr><td colspan="5">Mission statement: To facilitate a quick uptake of small-sized, zero-emission vehicles in the last mile</td></tr>
<tr>
<td rowspan="2">Key partnerships:
1. Manufacturer of standardized loading units and/or containers
2. Manufacturer of cargo bikes and/or light commercial vehicles
3a. Municipality and/or private company for location of hub/transhipment point
3b. Municipality for location of container/mobile depot</td>
<td>Key activities:
1. Load goods into standardized loading units in terminal
2a. Load loading units on (semi-)truck
2b. Load loading units into container
3. Transport loading units/container(s) towards city
4a. Tranship loading units from truck onto smaller last-mile vehicles
4b. Position mobile depot in city
5. Operate last-mile delivery routes</td>
<td rowspan="5">Value proposition:
1. To enable the integration of smaller zero-emission vehicles into urban last-mile delivery network
2. To provide transhipment for last-mile delivery.
3. To enable sustainable last-mile transportation with (zero-emission) vehicles of the best size.
4. To optimise and homogenize loads and vehicle capacities</td>
<td>Buy-in & support:
1. Local authority for finding appropriate location and providing permits for transhipment points, as well as appropriate road infrastructure for cargo-bikes
2. Courier willingness to operate cargo-bikes and/or light commercial vehicles.</td>
<td rowspan="2">Beneficiaries:
1. Carrier by enabling more cost-effective transport.
2. City visitors and residents by more sustainable last-mile delivery process.
3. Local authorities and all stakeholders due to reduced environmental, safety- and health-related costs.</td>
</tr>
<tr>
<td>Key infrastructure and resources:
1. Standardized loading units
2a. Larger trucks and other vehicles carrying goods towards the city centre
2b. Containers/mobile depots
3. Cargo bikes and/or light commercial vehicles for last-mile deliveries</td>
<td>Deployment:
1a. Changes to operational processes to enable integration of loading units and transhipment
1b. Changes to operational processes to enable integration of loading units and containers
2. Planning of feeder routes towards city and last-mile routes</td>
</tr>
<tr>
<td colspan="2">Budget costs:
1. Rent or depreciation of standardized loading units and/or containers
2a. Rent for building in which hub is established
2b. Rent or depreciation of container/mobile depot
3. Total cost of ownership (acquisition, operational, maintenance, etc.) costs involved with cargo bikes and/or light commercial vehicles.</td>
<td colspan="2">Revenue streams:
1. Cost reduction in last-mile delivery routes
2. End-receiver of goods willing to pay more for sustainable last-mile delivery, and/or willing to wait so that last-mile delivery efficiency can be improved</td>
</tr>
<tr>
<td colspan="2">Environmental costs:
1a. Energy use involved with the building in which the hub is operated
1b. Energy use involved with the manufacturing of the container/mobile depot
2. Energy use of cargo bikes and/or other light commercial vehicles</td>
<td colspan="2">Environmental benefits:
1. Reduced total greenhouse emissions involved with last-mile delivery due to consolidation on-route to transhipment point
2. Reduced greenhouse gas emissions and noise pollution in last-mile delivery route by enabling the use of smaller zero-emission vehicles.</td>
</tr>
<tr>
<td colspan="2">Social risks:
1. Attracting additional freight flows and/or larger vehicles because of transhipment operation
2. Low paid work for material handlers
3a. Use of building that could otherwise be used for housing or retail, negative impact on street scene
3b. Use of parking space for container/mobile depot that could otherwise be used for car, café terraces, etc.</td>
<td colspan="2">Social benefits:
1. Smaller (zero-emission) vehicles in city centre and streets
2. (Low skilled) jobs for citizens in the area
3. Safer streets due to reduced number of large freight vehicles.</td>
</tr>
</table>

Table 6.2 presents the business model canvas for a containerised urban last-mile where the infrastructure is used by multiple carriers. It considers the situation where the carriers involved make use of standardized loading units and containers that serve as mobile depot. That is, the loading units

and/or containers from different carriers are located in parking spaces in the city centre. The zero-emission last-mile mile vehicles depart their routes from these mobile depots. To enable a system in which multiple carriers can operate together, the business model presented in **Table** 6.2 **takes the perspective of a third-party company that operates a pool of containers** (i.e., mobile depots) and possibly also the standardised loading units. While the mission statement is the same in Table 6.1 and Table 6.2, and the environmental and social costs and benefits are similar too, the other elements of the business model canvas differ markedly. This is mainly due to the involvement of multiple carriers and the introduction of a new type of stakeholder, namely the third-party company operating the pool of resources required to achieving the mission statement.

Table 6.2 Business model canvas for containerised urban last-mile delivery in a network with multiple carriers using a mobile depot transhipment practice

<table>
<tr><td colspan="5">Mission statement: To facilitate a quick uptake of small-sized, zero-emission vehicles in the last mile</td></tr>
<tr><td rowspan="2">Key partnerships:
1. Carriers involved in the network
2. Manufacturer of containers, loading units and/or cargo bikes</td><td>Key activities:
1. Provide containers, loading units and/or cargo bikes
2. Web-based/mobile app for track and trace of containers, loading units and goods</td><td rowspan="5">Value proposition:
1. To provide a pool of containers (and possibly standardized loading units) for urban last-mile delivery.
2. To enable a shared network of transhipment points for multiple carriers</td><td>Buy-in & support:
1. Carriers involved in the network
2. Local authority for finding appropriate location and providing permits for containers</td><td rowspan="2">Beneficiaries:
1. Carriers involved in the network by enabling more cost-effective transport.
2. City visitors and its residents by more sustainable transportation.
3. Local authorities by reduced environmental-, safety- and health-related costs.</td></tr>
<tr><td>Key infrastructure and resources:
1. Containers
2. Loading units
3. App developers</td><td>Deployment:
1. Determining the number of containers and loading units in the pool
2. Maintenance of containers and loading units</td></tr>
<tr><td colspan="2">Budget costs:
1. Manufacturing/purchasing costs of the containers and/or loading units
2. Development cost of web-based mobile app for track and trace</td><td colspan="2">Revenue streams:
1. Rental fee for using or revenue from acquisition of containers and/or loading units by carriers
2. Fee for using app for track and trace</td></tr>
<tr><td colspan="2">Environmental costs:
1. Energy use manufacturing the containers and/or loading units</td><td colspan="2">Environmental benefits:
1. Reduced total greenhouse emissions involved with last-mile delivery due to consolidation on-route to transhipment point
2. Reduced greenhouse gas emissions in last-mile delivery route by enabling the use of smaller zero-emission vehicles.</td></tr>
<tr><td colspan="2">Social risks:
1. Attracting additional freight flows and/or larger vehicles because of transhipment operation
2. Use of parking space for container/mobile depot that could otherwise be used for car, café terraces, etc.</td><td colspan="2">Social benefits:
1. Smaller (zero-emission) vehicles in city centre and streets
2. Safer streets due to reduced number of large freight vehicles</td></tr>
</table>

6.1.2 Crowdsourcing platform for city logistics

The second ULaaDS logistics scheme discussed within the context of solution 1 pertains to the introduction of a crowdsourcing platform to manage city logistics. Many start-ups, scale-ups, and established companies offer web-based and mobile applications aimed at using crowd-sourced couriers for the last-mile delivery of goods within a short time span (e.g., same day, 2-hour, or even 30-minute delivery). The typical process involves customers ordering one or multiple goods from a local retail store – either on the website of the store itself or via the application of the crowdsourcing platform. After the order is received by the platform, the platform matches a crowd-sourced courier to the delivery task. The courier picks up the good(s) at the store(s), possibly combines it with goods from other customers – using a hub facility or not – and delivers the goods to the customer(s). All the while, the customer is informed in real-time about the different steps of the delivery process.

6.1.2.1 Crowdsourcing platform operating models

Crowdsourcing platforms for city logistics come in a wide variety, both in terms of the types of logistics services and resources offered as well as in the way they match supply and demand. In terms of logistics services, there are crowdsourcing platforms that offer local delivery (e.g., food, local shops), freight shipping (e.g., oddly sized parcels, general cargo) and storage (Carbone et al., 2017). One critical element of a crowd logistics platform is the technique used for matching the supply of logistics resources with the demand. Alnaggar et al. (2021) provide a useful overview in this regard:

- **Pure self-scheduling:** Crowd members do not need to indicate their working hours prior to a shift. Rather, the crowd member simply reports itself when available for performing logistics. When those tasks arrive, the platform shows them to the crowd member using some rule-based policy and the member may choose to accept or decline the task.

- **Hybrid and centralized scheduling:** Crowd members provide their availability in advance – usually days or even weeks – and the platform assigns the member to a shift. Vice versa, the platform schedules shifts and tasks within the shifts, and the crowd members can sign up for a shift in advance. This way of matching supply and demand is closely related to traditional logistics services, with the exception that crowd members have some flexibility in posting their availability and/or choose for a particular shift.

- **En-route matching:** A crowd member is making a trip that is irrespective of any potential logistics task. He/she reports this trip to the platform, which analyses if a logistics task can be conveniently assigned to the crowd member (e.g., minimizing the detour required to perform the task). The crowd member accepts or rejects the proposed task.

- **Bulletin-board matching:** The platform simply posts all available logistics tasks on a bulletin board and crowd members can browse the board for tasks that match their availability. No algorithms are used to automatically assign tasks to crowd members.

While many believe crowd logistics may yield large potential benefits in terms of operational cost (Buldeo Rai et al., 2017 & 2018), environmental and societal impact, typical crowd logistics models do not scale easily, compared to conventional parcel delivery vehicle routes (Qi et al., 2018). Rather, the crowd can be used to respond to sudden fluctuations in demand, thereby reducing the fleet size needed to serve demand and gaining operational flexibility. A large portion of the academic literature on crowd logistics therefore has been devoted to developing smart algorithms to integrate outsourcing of logistics tasks to crowd members into overall vehicle routing processes (e.g., Arslan et al. 2019, Kafle et al., 2017, Wang et al. 2016).

6.1.2.2 Crowdsourcing platform business models

Whereas the academic literature abounds with research on the operating models for crowd logistics (Castillo et al., 2017, Pourrahmani & Janner, 2021), research on value creation and business models for crowd logistics is scarce. Rougès & Montreuil (2014) explored the first aspects of the underlying business model, which was further advanced into a framework for analysing crowd logistics business models in Frehe et al. (2017). Buldeo Rai et al. (2017) identify the characteristics that describe different crowd logistics operational and business models that exist, including the different actors (i.e., receiver, commissioner, service provider, platform, and crowd) and how those actors interact with each other. Carbone et al. (2017) provide a framework explaining how crowd logistics can create value, which they attribute mainly to the availability of idle resources and the difficulty of the logistics tasks, and to the ability of the platform to smartly support the operations and (financial) transactions. Ciobotaru, & Chankov (2021) provide the most comprehensive insight into crowd logistics platforms to date. In a review of the business models of over 100 crowd logistics initiatives they develop a business model framework with 74 features, which they then use to define six distinct crowd logistics business models. These clusters are based on who is seen as the main customer (e.g., the buyer of goods, the sender, local retailers), what makes up the crowd (e.g., commuters, travellers, non-professional drivers, or professional drivers), how the goods are ordered and delivered, and how the price is set (e.g., by the customer, by the crowd member, in negotiation, or set by the platform itself. **Table** 6.3 **summarizes the main insights from these studies into a comprehensive business model canvas for a crowdsourcing platform in the context of urban freight transport, showing the option with a hub facility in orange.** It considers the perspective of the company developing and operating the platform. Some of these companies offer a hub facility, where the couriers start and end their tours, can change into their work outfit, and bring goods for temporary storage.

Table 6.3 Business model canvas for crowdsourcing platform in the context of sustainable urban last-mile delivery (with hub facility in orange)

<table>
<tr><td colspan="5">Mission statement: To include crowd-resources into sustainable urban last-mile delivery</td></tr>
<tr><td rowspan="2">Key partnerships:
1. Local shops and other shippers requesting transportation
2. Crowd couriers
3. Owners/operators of zero-emission vehicles
4. Hub facility owners</td><td>Key activities:
1. Maintain web-based and mobile application for receiving transportation requests
2. Planning the availability of couriers and/or their routes
3. Track and trace
4. Material handling (unloading, temporary storage, sorting, and reloading) at hub facility</td><td rowspan="5">Value proposition:
1. To provide its users (e.g., shops and consumers) with on-demand last-mile delivery services
2. To offer temporary storage and bundling of orders at hub facility</td><td>Buy-in & support:
1. Local shops need to be willing to use the platform, instead of using existing parcel delivery companies or their own employees for home delivery</td><td rowspan="2">Beneficiaries:
1. Local shops gain access to a ship-from-store on-demand delivery service
2. Local customers can support local shops by ordering their products and receive them at home</td></tr>
<tr><td>Key infrastructure and resources:
1. Digital platform accessible to customers requesting last-mile delivery
2. Crowd-resources (both couriers and zero-emission vehicles)
3. Hub facility for couriers and freight consolidation</td><td>Deployment:
1. Onboarding of the many different actors that may request transportation
2. Recruitment, onboarding, and retainment of a crowd of couriers</td></tr>
<tr><td colspan="2">Budget costs:
1. Compensation (i.e., salary or fee per delivery) for couriers
2. Development of the digital platform and web services
3. Business development and onboarding of users
4. Rent and operating cost involved with hub facility</td><td colspan="2">Revenue streams:
1. Delivery fee paid by local shops or other actors requesting transportation
2. A membership fee for special services (e.g., guaranteeing courier availability, API connection with a store's inventory system, API connection with store's payment system)</td></tr>
<tr><td colspan="2">Environmental costs:
1. Energy for operating platform
2. Energy for operating hub</td><td colspan="2">Environmental benefits:
1. Low greenhouse gas emission in the last mile when using zero-emission vehicles</td></tr>
<tr><td colspan="2">Social risks:
1. Modern slavery by underpaying crowd couriers
2. A large number of cargo bikes and couriers occupying the inner city</td><td colspan="2">Social benefits:
1. (High-skilled) jobs for developers of the platform and (low-skilled jobs) for crowd couriers
2. Local stores gain access to an additional sales channel (shipping from store to local consumers)</td></tr>
</table>

6.1.3 City-wide platform for integrated management of urban freight transport

The third ULaaDS logistics scheme discussed within the context of solution 1 is the management of all urban delivery capacities on a single, neutral platform – one that is operated by the city or a city-owned company. The aim is to optimize last-mile deliveries by pooling resources and freight flows from many actors in the city while considering the real-time situation in the city as well as its regulatory framework (e.g., vehicle access restrictions, zero-emission zones). The pooled resources may include several (types of) hubs in a city, and the vehicles and freight flows from multiple actors,

thereby potentially balancing out peaks and throughs in the need for vehicles and workers of individual actors. If providing real-time data about for example busy parts of the city, routes can be dynamically re-optimised to avoid those parts or change to a vehicle type that better accommodates the level of other activities in the city.
A city-wide platform can digitally pool the resources and freight flows of multiple actors in the city. The actual transfer of goods from one actor to another as well as the pooling of resources may require several hub facilities (e.g., decentralised warehouses in the city that could serve as shared facilities). As previously discussed, in the context of city logistics, these facilities are often referred to as Urban Consolidation Centres (UCC) and the simplified representation of this logic is displayed in **Error! Reference source not found.**.

6.1.3.1 Real-time open data

Cities increasingly install various sensors for the measurement of all sorts of processes in the city. These sensors may, for example, track flows of vehicles on the ring-road to inform a smart traffic light system, count the number of pedestrians in a part of the city to manage crowds, measure air quality levels, automatically recognize number plates to enforce access restrictions, etc. Cities also have ample information about, for example, the location of schools and other spaces with vulnerable citizens, (dynamic) access restriction policies and road prices, and planned or on-going construction work. Potentially, both the static geographical data and the real-time data collected by various sensors can be extremely valuable for logistics companies operating in the city. This data can be used to dynamically re-route a vehicle already on its way, or as input to the routing of vehicles in advance (e.g., avoiding schools around their opening and closing times). With the help of advanced data analytics techniques these data can even be used to incorporate learned trends into the vehicle routing. For example, given the current crowds in the city, the day of the week, and the weather forecast, estimations can be made about the crowds later in the afternoon. The anticipation of a large crowd may compel a logistics service provider to postpone a planned trip in the afternoon for tomorrow morning – which could be beneficial for the city (i.e., one vehicle less in a crowded city) and the company (i.e., it would be much more efficient to travel outside crowded hours).

Making these data available does pose a few considerable challenges for cities, however. Firstly, there are technological issues pertaining to, for example, the format in which the data should be offered and the digital platform or website through which it should be made accessible. Secondly, there can be important privacy concerns. The raw data collected by many sensors are sometimes directly traceable to individuals, for example, in the case of the data captured by automatic number plate recognition cameras and software. For other sensors, the data may not be directly related to specific individuals, but only after combining data from that sensor with other (publicly available) databases. The EU's General Data Protection Regulation (GDPR), which came into existence in 2016, protects individuals against abuse of their personal data. At the same time though, the GDPR leads to broad concerns about making potentially valuable data available, even when anonymized. A third concern is the business case for the city. Given the first two challenges, it is costly to make sensory data openly available for local businesses to use. It is often unclear for cities how to justify the required investments as the revenues and other benefits from providing open data are not easily quantified (Timeus et al., 2020).

6.1.3.2 Business models for city-wide platforms

One of the aims of a city-wide platform for managing urban freight transport would be to pool resources and freight flows from multiple parties active in the city. These resources could involve both hub facilities and zero-emission vehicles from different local shops, suppliers, and logistics service providers. When considering using shared hub facilities, an important decision involves the choice for a certain type of hub. This could be one or more micro-hubs or urban consolidation centres – a choice that primarily boils down to the freight volumes that are to be expected. It is also crucial to determine whether that hub will be operated by a corporate entity – and potentially shared with others – or a publicly owned hub. This choice has important implications on the business model of the city-wide platform too, as discussed in Table 6.4, where aspects specific to a corporate hub are shown in turquoise and those for a publicly owned hub in orange.

Table 6.4 Business model canvas for city-wide platform for integrated management of urban freight transport, privately or publicly owned

<table>
<tr><td colspan="5">Mission statement: To pool resources and freight flows of multiple providers for sustainable urban freight transport</td></tr>
<tr><td rowspan="2">Key partnerships:
1. Local shops and suppliers involved with urban freight flows
2. Logistics providers with potential resources to be shared
3. Company operating the hub</td><td>Key activities:
1. Unlocking information about the current rules and regulations to logistics providers
2. Offer insight into available shared warehouse and vehicle space</td><td rowspan="5">Value proposition:
1. To provide a platform with up-to-date information about rules and regulations in the urban space
2. To enable the use of shared warehouse space
3. To enable the use of shared vehicles</td><td>Buy-in & support:
1. Existing companies with potential shared hub facilities
2. Logistics providers to share their resources</td><td rowspan="2">Beneficiaries:
1. Logistics service providers gain from insight into current state of rules and regulations
2. Citizens and other people staying in the city benefit from improved efficiency (e.g., less vehicles, fewer buildings for logistics)</td></tr>
<tr><td>Key infrastructure and resources:
1. Digital platform accessible to logistics providers
2. Logistics spaces for hub facilities
3. Logistics providers with resources to be shared</td><td>Deployment:
1. Develop tender to purchase platform or capabilities developing the platform
2. Integrate up-to-date regulations (e.g., access restrictions, tolls) into platform
3. Identify locations for hubs and logistics providers for resources</td></tr>
<tr><td colspan="2">Budget costs:
1. Cost involved with developing the platform
2. Subsidy to establish (and operate) hub facility or to help an existing hub to share its facility with others</td><td colspan="2">Revenue streams:
1. Fee for using shared warehouse (e.g., per unit handled) or using a delivery service
2. Membership fee for access to the platform for logistics providers</td></tr>
<tr><td colspan="2">Environmental costs:
1. Energy for operating platform
2. Energy for running hub facilities and logistics resources</td><td colspan="2">Environmental benefits:
1. Reduced greenhouse gas emissions from better utilization of existing logistics resources</td></tr>
<tr><td colspan="2">Social risks:
1. Weaker market position for logistics providers that are not active on the platform</td><td colspan="2">Social benefits:
1. A reduced number of vehicles operating in the city
2. More compliance with rules and regulations due to unlocking of up-to-date information directly to logistics providers</td></tr>
</table>

Prior experience with platforms that aim to make better use of existing resources indicates they may find themselves in a situation where those resources are insufficiently available to meet demand for urban freight transportation. In part, those situations are due to difficulties of attracting and retaining logistics providers (Hong et al., 2020). Logistics providers, as well as potential platforms that unlock the use of those providers, operate on thin or no margins. The financial compensation to the logistics providers is one of the main cost components – together with the development and maintenance of the digital platform. As a result, logistics providers are typically offered minimum compensation. The logistics providers thus may seek other work, or at least accept other – better paying – work when it is offered to them. As demand for different urban freight transport flows is highly correlated, this creates difficulties when the platform is in high need for logistics resources. That is, when the demand for one type of freight flow is high (e.g., parcels shipped from store during bad weather around the Holiday season), so is the demand for another type of freight flow (e.g., meal delivery). Instead of relying on a generic pool of resources, these platforms may feel inclined to hire their own couriers and buy their own vehicles. This makes them de facto competitors with the other logistics providers that are or could be active on the platform. The resulting tension has frequently led to those logistics providers withdrawing from being available to the platform.

6.2 Integration of urban freight and passenger transportation networks

From the perspective of a liveable and sustainable city, urban freight and passenger transportation have several challenges in common. Key amongst those is to avoid each passenger or shipment coming into the city in its own (polluting) vehicle. In recent decades, many European cities have focused on developing various sorts of infrastructure to enable multi-modal transportation of passengers, where cars are either not needed at all, or left at the edge of the city. Passengers then continue their journey into the city by public transport, on a bike, and/or by foot. A similar structure is sought for urban freight transport. It hence makes sense to consider where an overlap exists between available infrastructure for passenger and urban freight transportation and to combine that infrastructure where possible. ULaaDS solution 2 is thus aimed at designing and testing operating and business models that focus on sharing passenger and freight infrastructure, locations, as well as vehicles.

6.2.1 Location and infrastructure capacity sharing

The first ULaaDS logistics scheme discussed within the context of solution 2 builds upon the existing mobihub concept. This concept is aiming for a seamless integration of the public transportation infrastructure with other transportation modes, such as parking personal cars, shared cars, electric vehicle charging stations, etc. Within the ULaaDS project, these services will be extended with urban freight transport features, such as (mobile) micro hubs or parcel lockers for instance. The rationale is that public transit hubs are particularly well suited for these hub facilities as there is typically sufficient space available at relatively low cost (compared to other urban spaces). Besides, the location is easily accessible for smaller zero-emission vehicles. What is more, the use of some of the logistics additions, like parcel lockers, allows customers to pick up or return parcels on their way from work or a trip to the city, avoiding unnecessary vehicle trips within the city.

6.2.1.1 Placing parcel lockers at public transit hubs

As discussed in the state-of-the-art, parcel lockers are a specific form of collection and delivery points. For parcel delivery companies, the use of collection and delivery points is often more efficient than attended home delivery. This has to do with two factors. First, customers that opt for delivery via this option do not have to be at home when the delivery takes place. This will reduce the need for re-delivery of a parcel whose delivery failed during the first attempt (Deutsch, Golany, 2018). Second, the number of stops that needs to be made by the courier is reduced when several customers in its route opt for delivery via a collection and delivery point. Both result in a reduction of the length and duration of the route travelled by the courier and hence reduce transportation costs (Zurel, 2018).
The academic literature on this subject is largely devoted to developing algorithms that support efficient vehicle routes in situations where collection and delivery points are present (e.g., Grabenschweiger et al., 2021, Orenstein, 2019, Redi et al., 2020). Of course, the potential cost savings must outweigh the investment and operating cost involved with the collection and delivery point itself (van Amstel, 2018). Another important decision that influences the cost structure of using collection and delivery points is related to network design (e.g., Lin et al., 2020, Morganti et al., 2014, Pan et al., 2021, Yang et al., 2020). Mostly, these studies are focused on developing mathematical

models that are powerful enough to solve this complex problem. A few other studies take an approach that is more closely linked to spatial planning, such as Lachappelle et al (2018).

It is important to note instead of the parcel delivery company traveling to the customer's home, it is the customer traveling to the collection and delivery point to pick up or drop off its parcel. While this does not change the cost structure of the parcel delivery network (i.e., the customer doesn't actually pay a cost for its trip to the collection and delivery point), it is a critical factor when considering the societal and environmental impact. If customers mostly use their car to pick up or drop off parcels, this will lead to considerable congestion and greenhouse gas emissions – indeed, potentially much more than would have been the case in a setting with attended home delivery. Although empirical research on this subject is scarce, it seems that often a high percentage of customers use their car to collect a package from - or return it to – a parcel locker. The reported percentages of customers using their car ranges from 45% (Hofer et al., 2020) to more than 50% (Moroz and Polkowski, 2016) or even 70% (Liu et al., 2019). Generally, it is understood that this percentage becomes higher as the parcel locker or collection point is located farther from the customer. The use of a car to visit a collection and delivery point is particularly problematic when this visit is the sole purpose of the customer's trip. If the customer would be traveling anyway, and the visit to the parcel locker can be combined with some other purpose without much extra mileage, this would mitigate the effect of car usage. This phenomenon is called "trip chaining" and plays an important role in the environmental effects associated with using parcel lockers (Liu et al., 2019; Prandtstetter et al., 2021; Buldeo Rai et al., 2019).

Each type of collection and delivery point can be private (i.e., owned and operated by a single operator) or white label (i.e., operated by an operator that makes lockers accessible for multiple parties). Private label solutions are closed-loop systems, often owned and operated by a parcel delivery company. They offer their customers the possibility to deliver their package at a collection and delivery point and receive notification when the package is ready for pickup. The customer uses a code, or app to pick up or drop off a parcel (e.g., by opening the specific box of a parcel locker in which its package is stored). White label solutions rely on others to supply the goods. Those partners can be parcel delivery companies, but also other commercial and non-commercial parties, such as webshops, local retail stores, libraries, pharmacies and many more. The collection and delivery point operator often owns and runs the data platform via which all partners can interact with the customer. Sometimes the operator also owns a facility, such as a parcel locker, but the ownership can also be transferred to a private or public entity.

6.2.1.2 Mobile micro depots at public transit hubs

Besides parcel lockers, public transit hubs can also reserve space for temporarily placing (mobile) micro depots, from where small (zero-emission) vehicles can start their delivery tours. It is important to consider the location of the public transit hub when offering these types of hub facilities. Larger public transit hubs are often located at the edge of the city. Its distance to the city centre or other neighbourhoods where the parcels are to be delivered may then be too large for transport by cargo bike. These types of facilities thus better fit at – often smaller – public transport hub in the urban area, from where the distance to the delivery locations is much shorter. This enables a cost-effective cargo bike delivery.

6.2.1.3 Offering shared (cargo) bikes at public transit hubs

Insights from academic studies on (cargo) bike sharing systems can be divided in four categories (1) the sustainability of bike sharing; (2) factors that impact bike usage; (3) operating models for managing bike sharing platforms; and (4) business models for bike sharing platforms. The debate about the environmental and societal impact of bike sharing is on-going. On the one hand, there are clear signs that bike sharing reduces the use of other – often more polluting – forms of mobility (e.g., Qin et al., 2018, Fishman et al., 2014), especially on shorter-distance rides. On the other hand, there are growing concerns about over-supply in specific cities (e.g., Beijing) and user misbehaviour (Ma et al., 2018) leading to challenges with parking, maintenance and right of way (Hauf & Douma, 2019). Research on the factors that impact the use of bike sharing systems highlight the importance of the design of the system – such as the user interface (e.g., Jia et al., 2018) – but also of the environment in which the system is implemented – such as the built environment, socio-demographic attributes, and safety (e.g., Eren & Uz, 2020). In addition, the business and operational models play an important factor, as different configurations (free floating, station-based, etc.) can have very different results.
In the context of ULaaDS, the primary focus is on the operating and business model aspects of cargo bike sharing platforms. The operating models for bike sharing systems include important decisions about network design. In the case of a system with docking stations, the question is how many and where to locate them so that usage is maximized. The study of Xu and Chow (2020) stresses the importance of this point: in their longitudinal data analysis they show that adding one additional station in New York is associated with 102 additional trips per day on average, but ranging from 135 in Manhattan to only 13 outside of Manhattan. When users need not bring back their bicycle to the initial docking station, or in a free-floating system, fleet management becomes a real challenge. One of the most studied operational aspect is related to the repositioning of the bicycles (e.g., He et al., 2020), but also the detection of bicycles that need repair is an important operational challenge (Kaspi et al., 2016).

The business model of (cargo) bike sharing platforms also received considerable attention. The value proposition of these platforms usually involves meeting some need for short distance urban trips in a sustainable manner and/or to alleviate urban congestion. Value is created via the development and maintenance of a supply chain for the bikes (including the bikes, potential docking stations, operational management, etc.), which are also the major cost components (i.e., bicycles acquisition, website/app development, maintenance costs, repositioning costs) on top of the promotion and overhead cost. Value is captured mostly via rental fees and/or subscriptions (Gao & Li, 2021) – often complemented with advertisement income, income from providing data, or public investments (Parkes et al., 2013). Increasingly, there are concerns about the sustainability of (regular) bike sharing platforms (e.g., bikes lying around everywhere), which affect their business models – for example, by reducing the number of bikes available in the city, imposing fines for wrong parking, a need to share usage data, (e.g., Gao & Li, 2021, Long and van Waes, 2021). In ULaaDS the focus is on cargo bike sharing, where most of the issues from general bike sharing platforms may not emerge as the sheer number of cargo bikes required will be much lower than the typical bike sharing platforms. Still, it will be important to carefully consider the number of cargo bikes, their parking locations, maintenance policies etc. – taking the lessons learned from general bike sharing into consideration. However, this problem is yet to be encountered for shared cargo bikes.

6.2.1.4 Business models implications for location and infrastructure capacity sharing

Public transport hub locations and infrastructure are well suited for shared use with important practices for sustainable urban freight transport, such as the use of parcel lockers, micro-hubs and cargo bike services. **Table** 6.5 **presents the business model implications for the use of parcel lockers on public transit hubs from the perspective of the actor operating the locker**. The table makes a distinction between white label and private label lockers. The main differences are in the fact that a white label parcel locker system introduces one new key actor (i.e., the parcel locker operator) and the interaction between multiple potential users. This has an effect on many aspects of the business model, and particularly in the revenue streams. In the case of a white label parcel locker, its users do not have to pay the initial investments. But, the profit margin of the company operating the parcel locker has to come from the fee per parcel and potential membership fees of its users. Because of the white label nature of the system, the services can be used by anyone who is willing to pay these fees, be it parcel delivery companies, the sellers of goods, receivers, and/or the couriers. For a private label system, the "revenue" comes from reduced route length of delivery vehicles and a smaller fleet size needed as a result. All cost and revenue streams are internal to the parcel delivery company deploying the system.Table 6.5 Business model canvas for parcel lockers at public transit hubs.

Table 6.5 Business model canvas for parcel lockers at public transit hubs with aspect specific to white label lockers in turquoise and private label ones in orange

<table>
<tr><td colspan="5">Mission statement: To enable a sustainable parcel delivery service on top of traditional home delivery</td></tr>
<tr><td rowspan="2">Key partnerships:
1. Public transport authority
2. Logistics service provider(s) and other suppliers</td><td>Key activities:
1. Accept parcels from logistics service provider(s) and other suppliers
2. Accept return parcels from customers
3. Enable pick up and drop off by customers</td><td rowspan="5">Value proposition:
1. To provide pick up and drop off services for parcels
2. To provide an additional delivery method to local shops</td><td>Buy-in & support:
1. Local authority for finding appropriate location and providing permit for locker placement
2. Logistics service providers and other suppliers for using the locker system</td><td rowspan="2">Beneficiaries:
1. Customers gain access to another delivery option with high on-demand aspect
2. Local shopkeepers gain access to an open delivery service
3. Logistic service providers can save route distance</td></tr>
<tr><td>Key infrastructure and resources:
1. Parcel locker
2. Public space with access to power
3. Digital infrastructure to alert customer when parcel is available and for accessing locker box</td><td>Deployment:
1. Install parcel locker
2. Integrate it into existing delivery processes
3. Offer easy integration into delivery processes of third-party logistics providers and suppliers</td></tr>
<tr><td colspan="2">Budget costs:
1. Investment cost of installing locker system
2. Operational cost (power) and maintenance</td><td colspan="2">Revenue streams:
1. Cost saving from shorter delivery routes
2. Fee per parcel
3. Membership fee for third-party users
4. Revenue from advertisement on locker system</td></tr>
<tr><td colspan="2">Environmental costs:
1. Energy use of manufacturing and operating the locker system
2. Greenhouse gas emission from customers traveling to parcel locker in polluting vehicle</td><td colspan="2">Environmental benefits:
1. Reduced greenhouse emissions involved with transport by logistics service provider</td></tr>
<tr><td colspan="2">Social risks:
1. Reduced service for attended home delivery because easy alternative exists (e.g., logistics service provider not willing to make second attempt at home delivery)
2. Increased number of trips (in polluting vehicles due to heavy parcels) to the public transport hubs for pick-up or drop-off matters only</td><td colspan="2">Social benefits:
1. Alternative for attended home delivery for customers
2. Less vehicles in the city
3. Possibility to trip chain</td></tr>
</table>

Table 6.6 **shows the business model canvas for the placement of micro depots at public transportation hubs**. These can be either mobile depots or fixed facilities. The business model implications for these choices are reflected in the table. Table 6.6 assumes private label micro depots: the company installing and operating the micro depot is the same one that makes use of it in the last-mile delivery. The main difference is in the way the micro depot is supplied with parcels. In the case of a mobile depot, the depot itself is loaded at a larger scale hub upstream in the distribution network and then transported to the public transport hub. When the micro depot is a fixed facility, the parcels are pre-sorted and loaded onto a truck at the larger scale hub and transported to the micro depot.

Table 6.6 Business model canvas for micro depots at public transit hubs with aspect specific to fixed depot facilities in turquoise and mobile depots in orange

Mission statement: To enable the use of smaller, zero-emission vehicle in the last-mile delivery process

<table>
<tr><td rowspan="2">Key partnerships:
1. Public transport authority</td><td>Key activities:
1. Loading mobile depot at larger hub facility upstream in the distribution network
2. Transport the mobile depot to/from the public transport hub
3. Load parcels onto truck at larger depot and transport to the micro depot
4. Enable access to couriers delivering parcels</td><td rowspan="5">Value proposition:
1. To provide a hub facility from where small, zero-emission vehicles can start their routes</td><td>Buy-in & support:
1. Local authority for finding appropriate location and providing permit for locker placement</td><td rowspan="2">Beneficiaries:
1. Logistics service provider gets access to a location that is easy to access and close to the city
2. Citizens benefit from the use of smaller, zero-emission vehicles</td></tr>
<tr><td>Key infrastructure and resources:
1. Depot building or mobile container
2. Public space (with access to power)</td><td>Deployment:
1. Make public transport hub ready for instalment of micro depot
2. Integrate smaller, zero-emission vehicles into last-mile delivery process</td></tr>
<tr><td colspan="2">Budget costs:
1. Investment cost of establishing depot and/or mobile container
2. Operational cost involved with supplying micro depot or picking up/dropping off mobile depot
3. Maintenance cost</td><td colspan="2">Revenue streams:
1. Cost saving from shorter delivery routes with zero-emission vehicles</td></tr>
<tr><td colspan="2">Environmental costs:
1. Energy use of manufacturing and operating the micro depot</td><td colspan="2">Environmental benefits:
1. Reduced greenhouse emissions involved with transport by logistics service provider</td></tr>
<tr><td colspan="2">Social risks:
1. Increased traffic (with resulting safety issue) involved with supplying micro depot, or picking up/dropping off mobile depot</td><td colspan="2">Social benefits:
1. Smaller, zero-emission vehicles in the city</td></tr>
</table>

Table 6.7 **shows the business model implications for enabling cargo bike services at a public transportation hub**. The business model canvas is developed from the perspective of a third-party company operating the fleet of cargo bikes and its accompanying services and operations. A key aspect will be gaining the buy-in and support of the potential users, who are used to simply driving with their own vehicle into the city. Vehicle access restrictions in the city centre may therefore be critical (e.g., low or zero emissions zones). At the same time, it is important to make the cargo bikes a good, cost-effective alternative so that its users' access to the city centre is maintained. Otherwise, the small and medium sized companies will lose access to the city in favour of the larger companies that can bear the investment involved with zero-emission vehicles themselves – leaving the cargo bike service at the public transportation hub unused.

Table 6.7 Business model canvas for cargo bike services at a public transportation hub

<table>
<tr><td colspan="5">Mission statement: To provide a sustainable delivery method for users that would otherwise use their polluting vehicle</td></tr>
<tr><td rowspan="2">Key partnerships:
1. Public transport authority</td><td>Key activities:
1. Provide a parking place for cargo bikes
2. Design, implement and operate app or other solution for access to cargo bikes
3. Maintain cargo bikes</td><td rowspan="5">Value proposition:
1. To provide easy access to cargo bikes at convenient location</td><td>Buy-in & support:
1. Local authority for finding appropriate location and providing permits</td><td rowspan="2">Beneficiaries:
1. City visitors and its residents by less unsustainable vehicles in the city
2. Local shops and repairmen maintain their access to the city that is closed off for polluting vehicles
3. Citizens can rent cargo bike for own needs (weight and load issues) with no need to possess a car or similar</td></tr>
<tr><td>Key infrastructure and resources:
1. Space on public transport hub
2. Cargo bikes
3. App and/or webservices for managing the fleet of cargo-bikes</td><td>Deployment:
1. Making public space ready for parking of cargo bikes
2. Integrate cargo bikes in existing app for renting, or develop the app
3. Notify potential users about the existence of the cargo bike rental system</td></tr>
<tr><td colspan="2">Budget costs:
1. Investment in cargo bikes
2. Maintenance costs for keeping cargo bikes operational
3. Development of platform to access cargo bikes</td><td colspan="2">Revenue streams:
1. Rental fee for use of cargo bikes or;
2. Membership fee for use of cargo bikes
3. Advertisement fee for display at cargo bike station and/or on the cargo bikes themselves</td></tr>
<tr><td colspan="2">Environmental costs:
1. Energy use for manufacturing the cargo bikes.</td><td colspan="2">Environmental benefits:
1. Reduced greenhouse emissions involved with transport due to use of cargo bikes instead of delivery vans</td></tr>
<tr><td colspan="2">Social risks:
1. Lack of use, because small and medium companies cannot afford the rental system.
2. Disappearance of small and medium sized repairmen and other services in the city centre</td><td colspan="2">Social benefits:
1. Smaller (zero-emission) vehicles in city centre and streets</td></tr>
</table>

6.2.2 Transport vehicle capacity sharing

The second ULaaDS logistics scheme discussed within the context of solution 2 explores the integration of small goods transport with passenger transport, using potential spare capacity of passenger transport vehicles (e.g., taxi services, small shuttle services, and bus lines). In busy parts of the city, such a combination of freight and passenger transport in a single vehicle could help avoid congestion. Reversely, in less busy parts of the city, combining freight and passenger transportation may enable more cost-effective services, which in turn may result in **more** services (e.g., more frequent bus lines, shorter parcel delivery times) in those areas.

6.2.2.1 Operating model implications for integrating passenger and urban freight transport

The common approach to integrating passenger and urban freight transport is to consider passenger transport vehicles for potential freight transport (Trentini & Mahléné, 2010). This is logical, given that passengers have higher expectations and legal requirements to the vehicle – and hence cannot reasonably be transported in existing freight vehicles. From this viewpoint, a next step is to determine which type of passenger vehicle to open for freight transport and how to organize the operational aspects. The academic literature generally considers two types of passenger vehicles: small, unscheduled vehicles (e.g., taxis) and larger, scheduled vehicles (e.g., busses and trams).

When considering smaller, unscheduled vehicles – where passengers announce themselves at the last minute – there are little opportunities to structurally incorporate freight transport. Rather, the drivers could spend a part of their shift transporting passengers (i.e., serve as taxi) and another part – for example, during times when there are few passengers – as de facto ad-hoc driver in a crowdsourcing system (see Sections 5.1.2 and 6.1.2). When considering the actual integration of parcel deliveries into passenger transport, it is more common to consider more stable passenger transport services related to, for example, transporting elderly or other persons with reduced mobility. These types of taxi services are often (largely) known before the taxi shift starts. In those settings, parcel delivery and passenger transport requests can be merged into a single delivery plan. One option is to consider all requests together and construct a single plan in which trips visit all passenger pick-ups and drop-offs as well as all parcel pick-ups and drop-offs; alternatively, the plan first considers all passenger trips and then tries to insert the parcel deliveries. In any case, the transport of passengers often has preference over the transport of parcels. That is, parcel deliveries are postponed when the planning of passenger trips can otherwise not be fulfilled in time. Operational planning algorithms are proposed for both a deterministic setting, where all information about a single shift is assumed to be known in advance (e.g., Li et al., 2014), and for a stochastic setting, where new information is revealed throughout the shift (e.g., Li et al., 2016).

In the case of using bus or tram lines for urban freight transport, it is important to consider the predetermined routes and schedules for those passenger transport services. What is more, the vehicles often have a limited space available for transporting freight – in many cases separated from the spaces allocated to potential passengers. Attempts to implement such services so far have been generally unsuccessful. Between 1196 and 1999, three German municipalities North of Aachen ran a demonstration project with busses that were especially designed to carry both passengers and parcels (Trentini & Malhéné 2010). In 2007, the city of Amsterdam pilot tested a cargo tram to transport parcels into the city centre[10]. A decade later, the French city of La Rochelle studied the integration of urban freight and passenger transport (Masson et al., 2017). None of these examples is still operational, mainly due to practical challenges related to difficulties in information sharing between the different stakeholders involved, limited funding for repurposing the existing public transport vehicles, low passenger acceptance, and the lack of mathematical decision support to efficiently plan the operations (Ghilas et al., 2018). One of the main concerns for the operating model is that the schedule public transport lines can only be used as a feeder line for the transportation of freight, while the first and last mile must be executed by another mode of transport. Bus and tram lines are not going from door-to-door and cannot stay much longer at a stop than they currently do, which only allows to quickly load or unload a roll container or large bag with parcels. The remainder of the parcel delivery needs to be organized from there. This could be done in combination with the other practices reviewed in the state-of-the-art (e.g., collection and delivery points, crowd-sourced deliveries). In fact, Berlin is currently testing a scheme through which containers are loaded on trams in two depots located outside the city. When reaching the city centre, the containers are loaded onto cargo bikes for the last-mile delivery[11].

6.2.2.2 Legal aspects of integrating passenger and urban freight transport

It is important to consider legal aspects when setting up a logistics service that uses public transport vehicles for the transportation of urban freight. In the Cargo Hitching project, a feasibility study was conducted for moving urban freight via bus lines. It identified four general ways in which this can be done in practice, namely 1) in the bus in a separate space, 2) in the bus under supervision, 3) outside the bus in a trailer, 4) a purpose-built hybrid vehicle (i.e., a parcels and passenger transport vehicle). For the bus company that worked in the project, only transport in the bus under supervision was feasible. The other ways required considerable investment in repurposing the vehicle or designing an entirely new trailer, or even vehicle. Within the context of transportation in the bus under supervision, the parcel can be moved inside a large bag or in a roll container. Both are, however, not allowed under Dutch law because of safety considerations for the passengers traveling on the bus. The advice was to request a statutory exemption to enable a demonstrator project.

Other legal aspects to consider here are related to insurance. Instead of a single parcel delivery company, working with well-defined operational and standardized processes, the case of Cargo Hitching involved many more actors in the delivery process (e.g., an urban consolidation centre to accept the parcels, another company provider the workers supervising the bus trip, the local shop acting as pick up point). The addition of multiple actors and the fact that part of the transport is exposed to many people on the bus has at the very least consequences for insurance costs, and more likely affects the willingness of insurance companies to insure these processes at all.

[10] Delivering goods by cargo tram in Amsterdam (Netherlands). http://www.eltis.org/index.php?id13&study_id1547

[11] https://www.berliner-zeitung.de/mensch-metropole/jetzt-kommt-die-cargo-tram-bvg-testet-guetertransport-in-der-strassenbahn-li.158243

6.2.2.3 Autonomous vehicles

One way to mitigate some of the potential operational and legal challenges mentioned above is to make use of autonomous vehicles that are purposefully built to transport passengers and freight. While academic research on that specific topic is still lacking, one can draw from related, recent research about the operational and business model implications of autonomous vehicles. Academic studies have constructed models predicting the adoption and potential sustainability impacts of such developments (e.g., Fritschy & Spinler, 2019, Sen et al., 2020, Simpson et al., 2019). Long-haul trucking seems to be a particularly potent direction for the application of autonomous vehicle technology. When considering the total cost of ownership – including an array of cost factors beyond the acquisition cost, such as the driving distance and time, maintenance, insurance, taxes, remote operations – estimates reveal a potential total cost reduction of 15 to up to 60 percent, depending on the type of truck and operating scenario considered (Engholm et al., 2020, Wadud, 2017). A particularly valuable application of this technology seems to be to operate autonomous trucks between two logistics hubs. For the first and last mile, a truck with driver must take over. In such a scenario, many of the severe challenges involved with driving around without a driver in busy urban environments are absent (Deloitte, 2021). Still, the potential cost savings could be about 30% per kilometre travelled – considering a small increase in capital expenditure needed to invest in autonomous vehicle technology, some fuel efficiency savings, small insurance premium savings, and a large driver cost saving (Wishart et al., 2020).

Perhaps more interesting to ULaaDS are recent developments in smaller-scale applications of autonomous road-based vehicles. These types of vehicles can be further categorized into sidewalk robots and small road-based autonomous vehicles (i.e., with a gross maximum weight of 3,5 tonnes). Sidewalk robots are very small delivery vehicles that either move autonomously or follow a delivery person (i.e., semi-autonomously) on the sidewalk. There are several manufacturers and models (Touami, 2020), but a typical version weights about 20 kilograms, travels at a speed of about 2 kilometre per hour on average, has a range of about 10 kilometre and can carry around 6 parcels (Jennings & Figliozzi, 2019). As a result of the relatively short range, sidewalk robots are often accompanied with a larger delivery van – also known as mothership – that can bring the robots from a depot to the start of their local delivery route. The use of sidewalk robots together with a mothership to transport them to their delivery area seems to be an economically viable operating and business model, especially in settings where it takes considerable time to hand over a parcel to its receiver (Jennings & Figliozzi, 2019). These positive effects on the operating and business model mainly stem from reduced working hours of the delivery person, but there is also some mileage savings. The model of Jennings & Figliozzi (2019) does point to an increased mileage of autonomous vehicles on the sidewalk. Because the robots are propelled by electric engines, considerable greenhouse gas emission reductions are to be expected though (Figliozzi, 2020). There are many different designs (Touami, 2020), but a typical model will be able to carry around 30-100 parcels, travel at 10 kilometre per hour on average, and has a range between 20-100 kilometre. Vehicles with those characteristics may even yield larger cost and greenhouse gas emission reductions than sidewalk robots, particularly when the number of customers in a delivery area is low and distances between customers is thus larger (Figliozzi, 2020).

6.2.2.4 Business model implications for integrating passenger and urban freight transport

Integrating urban freight flows into existing or new passenger transportation services has important business model implications. An overview of those implications is shown in Table 6.8, where a distinction is made between the use of smaller, unscheduled passenger vehicles (e.g., taxis) and larger, scheduled passenger vehicles (e.g., busses and trams). The business model is developed from the perspective of a company that operates these vehicles and opens them up for freight transport. A clear issue emerges from this table, namely the large investments required to get an integrated passenger and urban freight transport system running at scale – an observation also made by Ghilas et al. (2018) – and the relatively limited revenue streams available. This holds particularly for systems with larger, scheduled passenger vehicles, which are also the systems with the largest possible environmental and societal benefits. If local governments expect large environmental and societal benefits, they may thus need to subsidize this form of urban freight transport, as they do for the transport of passengers. Systems with smaller, unscheduled vehicles may suffer from the same issues as crowd-sourced ride-hailing and delivery services, such as an overcrowding of vehicles in the city, unlawful parking, etc.

Table 6.8 Business model canvas for integrating passenger and urban freight transport with aspect specific to smaller, unscheduled vehicles in turquoise and larger, scheduled vehicles in orange

<table>
<tr><td colspan="5">Mission statement: To reduce congestion and emission in busy areas and offer cost-effective transport of passengers and urban freight in less busy areas of a city</td></tr>
<tr><td rowspan="2">Key partnerships:
1. Passenger transport authority or company
2. Logistics providers involved with first and last mile</td><td>Key activities:
1. Schedule the integrated passenger and urban freight transportation services
2. Pick up, transport, and drop off parcels
3. Load, transport, and unload roll carriers or bags with parcels</td><td rowspan="6">Value proposition:
1. To provide a service for urban freight transport using passenger vehicles
2. Optimize load and vehicle usage</td><td>Buy-in & support:
1. Legislators writing rules and regulations or consider statutory exemptions for integrating urban freight transport in passenger vehicles
2. Passengers need to accept goods in vehicle</td><td rowspan="2">Beneficiaries:
1. Logistics service providers gain from cost-effective transportation of parcels to less busy areas of the city or its surroundings
2. Citizens and other people staying in the city benefit from improved efficiency (e.g., less vehicles) in busy areas of the city</td></tr>
<tr><td>Key infrastructure and resources:
1. Decision support for planning the operations
2. Mobile app to guide drivers to passenger and parcel pick-up and drop-off locations
3. Passenger vehicles that enable transport of multiple parcels at once
4. Roll containers or bags for parcels</td><td>Deployment:
1. Form an alliance of actors (e.g., logistics service provider, public transport authority, collection point operator) to initiate the service
2. Identify areas where service will run
3. Identify public transport lines on which goods will be transported</td></tr>
<tr><td colspan="2">Budget costs:
1. Developing decision support and app that helps drivers pick up and drop off passengers and parcels
2. Transportation costs, or costs for detours needed to pick up and drop off parcels.
3. Designing or retrofitting vehicles that can carry both parcels and passengers
(4. Lost-sales due to reduced capacity for passengers)</td><td colspan="2">Revenue streams:
1. Fee per parcel transported
2. Cost saving from optimised routes and optimisation of vehicle capacity</td></tr>
<tr><td colspan="2">Environmental costs:
1. Greenhouse gas emissions involved with detours to pick up and drop off parcels
2. Greenhouse gas involved with first and last mile, depending on the vehicle used</td><td colspan="2">Environmental benefits:
1. Reduced greenhouse gas emissions from better utilization of existing vehicles</td></tr>
<tr><td colspan="2">Social risks:
1. Passengers are exposed to potential dangers with parcels, such as dangerous goods (low probability).
2. Increased traffic due to inefficient transport of individual parcels by individual vehicles</td><td colspan="2">Social benefits:
1. Additional income or work for drivers
2. A reduced number of vehicles operating in the city
3. More public transport services in less busy areas of the city due to increased cost-effectiveness</td></tr>
</table>

When the scheme includes **autonomous vehicles**, this changes the business model canvas on a few important aspects, as shown in Table 6.9, which is developed from the perspective of a company operating the vehicle. Much like the situation described in Table 6.8, the revenue streams are limited, while the investment and operating costs are considerable. In addition, the potential social and environmental are somewhat more limited, especially when operated at relatively low scale. It is not to be expected that autonomous vehicles will traverse public roads in large numbers soon. Therefore, it is more likely that applications with autonomous vehicles are first deployed on private property or in restricted areas under strict operating rules. These can form excellent environments for further testing the business case and scalability of autonomous last-mile delivery at larger scale.

Table 6.9 Business model canvas for integrating passenger and urban freight transport using autonomous vehicles

<table>
<tr><td colspan="5">Mission statement: To enable a better use of an autonomous vehicle capacity by combining passenger and urban freight transport</td></tr>
<tr><td rowspan="2">Key partnerships:
1. Company or campus that wants to adopt an autonomous vehicle on-site
2. Logistics service provider
3. Parties doing first and last mile transportation</td><td>Key activities:
1. Schedule route and service of autonomous vehicle
2. Organize loading and unloading of the goods from the vehicle</td><td rowspan="5">Value proposition:
1. To provide a service for urban freight transport using an autonomous passenger vehicle</td><td>Buy-in & support:
1. Legislators writing rules and regulations or consider statutory exemptions for autonomous vehicles
2. Passengers need to accept goods in vehicle</td><td rowspan="2">Beneficiaries:
1. Company using the autonomous vehicle for passenger transport
2. Receivers of goods
3. Cities with increased safety and liveability</td></tr>
<tr><td>Key infrastructure and resources:
1. Autonomous vehicle designed for combined passenger and urban freight transport
2. Restricted area on which autonomous vehicle is allowed to drive without driver</td><td>Deployment:
1. Form an alliance of actors (e.g., logistics service provider, autonomous vehicle manufacturer/operator) to deploy the service
2. Identify tractor on which autonomous vehicle will operate (to reduce need for a level 4 autonomous vehicle and enhance chance at regulatory exemption).</td></tr>
<tr><td colspan="2">Budget costs:
1. Acquisition of autonomous vehicle and cost for preparing its trajectory
2. Operational costs involved with loading and unloading vehicle</td><td colspan="2">Revenue streams:
1. Fee per parcel
2. Passenger transport services fee</td></tr>
<tr><td colspan="2">Environmental costs:
1. Energy use for manufacturing the vehicle (when using a zero-emission vehicle)</td><td colspan="2">Environmental benefits:
1. Zero-emission last-mile transport of passengers and goods (when using a zero-emission vehicle)</td></tr>
<tr><td colspan="2">Social risks:
1. Safety of other road users where autonomous vehicle operates
2. Loss of jobs due to no need of drivers</td><td colspan="2">Social benefits:
1. More flexible parcel delivery by additional service option.</td></tr>
</table>

7. Conclusions

In this deliverable, we present a state-of-the-art and benchmark of the business and operating models for sustainable on-demand urban logistics solutions. The state-of-the-art covers a wide range of current logistics practices, including hub facilities at different scales, hub location and infrastructure sharing, containerisation, zero-emission vehicle usage, autonomous vehicle usage, and logistics platforms. The operating and business model implications from these types of practices are studied in the light of the ULaaDS logistics schemes. This has resulted in a benchmark for the operating and business models of the ULaaDS logistics schemes.

ULaaDS focuses on two categories of on-demand logistics solutions for sustainable urban freight transport. The first solution category is aimed at enhancing logistics efficiency via collaborative, multi-model urban freight transport. As part of this category, ULaaDS considers three logistics schemes: the use of standardised and modular containers, the integration of crowd-sourced delivery services, and the use of city-wide platforms for integrated management of urban freight transport. The second solution category focuses on the integration of urban freight and passenger transportation networks. As part of this category ULaaDS considers two logistics schemes: location and infrastructure sharing, and transport vehicle capacity sharing.

As input to the design and implementation of the ULaaDS solutions – and in particular to their operating and business models – this deliverable presents an overview of the state-of-the-art of sustainable logistics practices that could be a part of the ULaaDS solutions. In total, the deliverable presents a structured review including about 30 current logistics practices with relevance to the ULaaDS solutions. Information about these practices is derived from academic articles, consultancy reports, news items, and web pages of the companies involved in the practices. The resulting state-of-the-art provides a strong foundation for a discussion about the operating and business model choices that are to be made for the ULaaDS solutions. For each ULaaDS logistics scheme, the implications of including certain logistics practices are discussed. This discussion is structured around 9 business model canvasses that serve as benchmark for the operating and business models of the ULaaDS logistics schemes.

References and further readings

7.1 Reference projects

Table 7.1 below presents a list of relevant projects and initiatives that have a relationship to ULaaDS in some ways, which is also presented accompanied by a brief description of each one of them.

Table 7.1 Relevant projects and initiatives for ULaaDS

Name	Brief description	Relationship to ULaaDS (partners involved)
City Changer Cargo Bike	CCCB will take the very best cargo bike implementation examples, contexts and expertise in Europe and profit and learn from them in order to transfer these on a large scale and in the best way possible to new cities and contexts - in CCCB's forerunner cities, in the follower cities and beyond. CCCB is based on the huge potential of cargo bikes to replace: - 23 - 25% of the commercial deliveries in cities - 50% of the commercial service and maintenance trips - 77% of private logistics trips (shopping, leisure, child transport)	Assessment of cargo bike implementation examples, contexts and expertise in EU to transfer these on a larger scale. ULaaDS will use the raise of awareness among the relevant stakeholders (public, private and commercial sectors) to create a collaborative and cooperative framework. (MEC, FGM)
ALEES	"Self-driving logistical electric units for urban environments": determine the requirements for the use of self-driving vehicles in logistics operations in urban environments, for instance for parcel delivery	ULaaDS will build upon the first practical test performed with an AV shuttle in the city of Mechelen using the results of ALEES about the requirements and possibilities for autonomous delivery vehicle in inner cities. (IML, MEC, VIL)
CityLab	CityLab will i) improve basic knowledge and understanding on areas of freight distribution and service trips in urban areas that have received too little attention; ii) test and implement 7 innovative solutions that are promising in terms of impact on traffic, externalities and business profitability and have a high potential for future growth; and iii) provide a platform for replication and spreading supported solutions. Focused on four axes for intervention: 1) Highly fragmented last-mile deliveries in city centres; 2) Large freight attractors and public administrations; 3) Urban waste, return trips and recycling; 4) Logistics facilities and warehouses.	Elaborating the Living Lab methodology and practice project supporting seven implementation actions, data collection and evaluation and transfer to 9 cities. ULaaDS will use experiences from the Living Lab methodology elaborated for implementation, data collection and evaluation of use cases; and experiences from transfer to satellite cities and follower cities. (TOI)
PIONEER	3 WP: 1. Local resident serving as package delivery person (street hubs as micro hubs); 2. Multichannel logistics (integration of chain management, transport, inventory management and warehouse management); 3. Logistical network integration of bicycle couriers	Focuses on the development of Physical Internet based concepts around micro-hubs for e-commerce, whereby a balance is sought between service orientation, efficiency, sustainability and quality of life. The Physical Internet (PI) is a future vision for fully open and connected logistics networks, in which physical, digital, operational and financial interconnectivity are central. ULaaDS will build on and extend the work in PIONEER focusing on on-demand urban freight transport. (RUG, DROP)
SURFLOGH	The focus of the project is the optimization of the interaction between the existing and new hubs and the urban logistics	ULaaDS will use experiences from stakeholder cooperation platforms created

	system, promoting both efficient and sustainable logistics in urban areas in smaller and medium-sized cities The novelty of the project is the combination of a system and supply chain approach in developing these hubs as to make them really 'smart'. This means that it goes beyond past experiments and pilot projects that focus foremost on location.	within city labs when setting up the local fora. The concept of the smart urban hub developed will be leveraged for the development of the dual MobiHub concept and enhance the intereaciton between hubs and the urban logistics system. (GRO, MEC, EDI, DRO)
Cargo Hitching	Cargo hitching means the combination of people and cargo flows: cargo that hitches a ride on a vehicle transporting persons or persons hitching a ride on a vehicle transporting cargo. This creates attractive business opportunities because the same transportation needs can be met with fewer vehicles and drivers.	First exploration of the possibilities to combine people and goods transport, focusing on decision support via mathematical modelling. ULaaDS will leverage the derived requirements for pilot tests with combined people and goods transport. (RUG, GRO)
SENSE	Accelerating the Path Towards Physical Internet -SENSE- project strategic objective is to accelerate the path towards the Physical Internet (PI), so advanced pilot implementations of the PI concept are well functioning and extended in industry practice by 2030, and hence contributing to at least 30 % reduction in congestion, emissions and energy consumption.	Further understanding of PI concept and its opportunities for transport and logistics. ULaaDS will use the results to ensure the integration of our solutions with the roadmap for the deployment of PI (VIL, IML)
Share North	Develop, implement, promote and assess car sharing, bike sharing, ride sharing and other forms of shared mobility in urban and rural areas and employment clusters. Living labs will integrate modern technology with activities to support changes in mobility behaviour.	Creation of living labs for the development, implementation, promotion and assessment of shared mobility in urban areas, replicating the concept of Mobihubs. ULaaDS will leverage the novel cooperative business models for shared mobility and MaaS to be applied in the integration of shared solutions for logistics delivery while developing the concept of Dual Mobihubs (BRE, BER)
eHUBS	eHUBS are on-street locations that bring together e-bikes, e-cargo bikes, e-scooters and/or e-cars, offering users a wide range of options to experiment and use in various situations. The idea is to give a high-quality and diverse offer of shared electric mobility services to dissuade citizens from owning private cars, resulting in cleaner, more liveable and pleasant cities. They can be minimalistic, light, medium, large, depending on demand & supply.	Clear link to passenger and freight combination at different levels and serving as entry point for potential new logistics services for infrastructure sharing. Knowledge about eHUBS implementation and promotion is useful for ULaaDS as a whole as well as new business model framework.
LEAD	LEAD will build a ready-to-use Digital Twin capability, using dynamic data-driven simulation to understand market change needs, work out best response strategies and monitor the impact of new polices and solutions. Also including consumer preferences	**ULaaDS' SISTER PROJECT** Part of CIVITAS Might be useful to combine efforts on understanding and representing digital twins for a best toolbox from ULaaDS. Keeping up to date with potential options for UL and how to assess them and tackle the associated **decission-making** process where the toolbox wants to take part too
SENATOR	The project will develop a smart network operator, as a control tower supported on an ICT Platform that will work as a **support tool for decision making, integration and planning of all logistics operations.** In consequence, it will minimize the negative impacts that this distribution causes in the cities and will constitute an effective mean of collaboration between agents (citizens, operators, transporters and administrations). This will be done through 2 living labs. **The main objective of SENATOR is to provide 4 governance schemes for urban planning policies**: User demand planning, Transport planning, Freight & Logistics planning and City infrastructure focused	**ULaaDS' SISTER PROJECT** Part of CIVITAS The project will help city councils to manage, under a 360-vision approach, sustainable transport policies in an optimal way connecting freight flows into urban planning. This will enable understanding and help in urban planning which is related to the ULaaDS toolkit mostly. Within the objectives, citizen centered approach is considerably relevant, so is replicability

Additionally, there are many other projects and interesting reads that are worth having a look. Many of these are included in the ULaaDS 360º Observatory, which can be accessed via the ULaaDS website (www.ulaads.eu). The website also includes much more interesting content and will be updated throughout the project with further readings for any interested party.

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