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ICT and Innovative solutions to support the greening urban freight

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GRETA Project

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More information about GRETA can be found on https://www.interreg-central.eu/greta/

1. The GRETA project

GRETA project aims to decarbonize the last mile delivery in Functional Urban Areas (FUAs) in Central Europe (CE) and create liveable and accessible cities for all by 2030. The project seeks to implement joint sustainable solutions in CE FUAs using zero-emission vehicles and cargo bikes and reorganize urban spaces with curb management. The pilot actions in the cities of Maribor, Reggio Emilia, Verona, Poznan, and Budapest (with Berlin FUA as an observer) have the potential to quickly deploy as pop-up measures in combination with existing measures. GRETA provides capacity-building activities, strategies, action plans, and tools for public authorities, enterprises, and relevant organizations to ensure financial, environmental, and social sustainability beyond the project's lifetime.

Last-mile delivery generates negative impacts, including emissions, noise, and congestion. Due to the Covid-19 crisis, global parcel distribution volume almost doubled, further adding inefficiencies in the peripheral areas. GRETA's FUAs recognize the problems that generate pollution, nuisance, noise, and congestion and jointed recognized three main problems: the lack of use of green zero-emission last-mile vehicles, conflicts between freight and public vehicles, and the lack of knowledge and strategies for a flexible and shared use of the curb and public space. Despite having SUMPs/SULPs, FUAs struggle to activate fitting measures while keeping their centres attractive and alive for residents and tourists.

GRETA addresses the common challenges of all CE FUAs by creating the conditions to promote ZE logistics through the use of microhubs, cargo bikes, light e-vehicles, and curb management strategies. Additionally, the project also focuses on paving the way to innovative concepts such as regional collaborative logistics, physical internet, and freight curb management. GRETA facilitates the dialogue towards the acceptance of a business and governance as a service model, where cities must equip themselves with a network of innovative services to guarantee seamless experiences for their users and a mobility plan considering different functions and priorities of the services.

GRETA's objective is to support the urban mobility transition in CE FUAs by jointly developing solutions and strategies with a huge potential for decarbonization of the last mile in line with the Green Deal and the Urban Mobility Package, abating congestion, pollution, and nuisance. The project's success relies on capitalizing on previous experiences, exploiting synergies with ongoing initiatives, testing innovative pilots, improving competences and knowledge among PPs and stakeholders.

2. Executive summary

Deliverable 1.3.4 consists of a thorough literature review to examine the breadth of innovative strategies and technologies proposed to optimize last-mile logistics and to minimize its externalities while improving the liveability of city centres and FUAs.

Leveraging a systematic approach via Google Scholar, this study consolidates insights from a diverse array of peer-reviewed articles, conference proceedings, and academic reports. By synthesizing existing research, this review aims to provide a holistic understanding of current advancements, in order to identify useful information for the advancement of the GRETA project.

The technologies examined in this deliverable have been classified under the following categories:

- Policy and planning solutions;
- Infrastructural and organizational solutions;
- Information and Communications Technology (ICT) driven solutions;
- Vehicle-based solutions.

3. Introduction

Globalization, rapid urbanization, and significant growth in e-commerce have collectively led to an unprecedented increase in transportation demand over recent years. According to Eurostat (2024), in 2023, 92% of surveyed individuals used the internet, with 70% purchasing or ordering products or services online in the 12 months preceding the survey. This boom in online shopping has revolutionized consumer habits, setting new expectations for fast and convenient delivery. Consequently, logistics networks have had to adapt rapidly to meet these demands, placing intense pressure on transportation systems and leading to notable logistical, environmental, and urban planning challenges.

A particularly critical component of the logistics chain, known as the "last mile", involves the final step in the delivery process: transporting goods from a distribution hub to the customer's doorstep. This stage is not only essential for achieving high customer satisfaction but also presents one of the most complex, costly, and resource-intensive aspects of the supply chain. Last-mile delivery alone can account for up to 28% of a shipment's total cost (Ranieri et al., 2018), due to factors such as low load factors, frequent stops, and congestion in urban areas. Moreover, the density and frequency of last-mile trips in city centres contribute to high economic costs and negative externalities, including air and noise pollution, increased traffic congestion, and a reduction in urban liveability.

The high environmental impact of last-mile deliveries has prompted cities and companies to rethink traditional delivery models, focusing on innovative strategies to alleviate these issues. Re-designing last-mile logistics has become a critical area of research, aiming to reduce both economic costs and environmental footprints. Solutions under exploration include the use of electric and autonomous vehicles, drone deliveries, micro-distribution hubs, and bike couriers. Some companies are even experimenting with delivery by foot or robotic carriers to avoid traffic and reduce emissions further. As the urgency to make urban logistics more sustainable grows, so does the interest in this topic within the academic and business communities. Between January and October 2024 alone, approximately 12,800 research articles with last-mile logistics as keyword have been published on Google Scholar, one of the primary sources for academic literature.

The search for sustainable and efficient last-mile delivery solutions is more than just a trend; it reflects a broader commitment to transforming the logistics sector in a way that benefits cities, companies, and the environment. This movement is shaping the future of urban transportation and city planning, making last-mile logistics one of the most vibrant areas of study and innovation today. The studied solutions can be divided into different categories, here follows the categorization that has been used in this report:

- Policy and Planning Solutions
- Infrastructural and Organizational Solutions
- Information and Communications Technology (ICT) driven Solutions
- Vehicle-Based Solutions

4. Policy and planning solutions

4.1. Integrating freight considerations into urban mobility planning

Urban freight transportation planning is a complex process. Public authorities typically have less expertise and capacity in addressing specific issues related to freight compared to passenger mobility, while private companies involved in organizing and implementing urban freight distribution possess in-depth knowledge of the technical aspects of the field.

The European Union has established specific policies and guidelines and initiated the promotion of dedicated tools and platforms to tackle the challenges of urban freight transportation. In the 2011 White Paper, the EU outlined a clear strategy for achieving 'near zero emission urban logistics by 2030,' which was followed by several supportive initiatives, including the Urban Mobility Package (UMP), the Low Emission Strategy of 2016, and the three Mobility Packages of 2017 and 2018.

The efficient integration of long-distance and last-mile transportation, through the establishment of urban nodes (serving as either the starting point or destination for passengers and freight on the trans-European transport network), is also a key priority for the EU. Additionally, the implementation of measures such as 'off-peak hour deliveries' and the adoption of clean freight vehicles have been recommended to support these objectives (European Commission [1]).

SUMPs are regulated by the European Commission, that described concepts and guidelines for the integration of the plans. These should refer to the entire FUAs, taking into account real traffic flow conditions. A SUMP should foster collaboration and synergies across all levels of government—local, regional, and national—while integrating various policy areas and its development should involve active partnership with local residents and stakeholders.

The concept of Sustainable Urban Mobility Planning, as outlined in the Urban Mobility Package, is grounded in eight widely recognized guiding principles (European Commission [2]):

- Planning for sustainable mobility in the “functional urban area”
- Cooperation across institutional boundaries
- Involvement of citizens and stakeholders
- Assessment of current and future performance
- Definition of a long-term vision and a clear implementation plan
- Development of all transport modes in an integrated manner
- Monitoring and evaluation of the implementation of measures
- Quality assurance

The complexity of a sustainable planning process is further heightened by the need to:

a) engage a range of private actors from a fragmented environment with diverse and often conflicting needs and goals, and

b) strike a balance between the industrial demand for high efficiency and low-cost operations, and societal requirements for reduced CO_2 emissions, enhanced safety, and greater sustainability (European Commission [1]).

4.1.1. Sustainable Urban Logistics Plans (SULPs)

The Sustainable Urban Logistics Plan (SULP) is a medium-to-long-term strategic framework aimed at meeting the transportation needs of individuals and businesses in urban areas and their surroundings to enhance quality of life. It defines actions aimed at promoting efficient mobility while achieving objectives related to safeguarding the quality of life of citizens and preserving the historical, cultural, and environmental heritage of the region. It builds upon established planning practices and emphasizes the principles of integration, participation, and evaluation.

Moreover, it's fundamental to ensure that SULP measures are impact-driven, data-backed, and adapted to city-specific needs, enhancing urban freight efficiency and sustainability. This is guaranteed by a structured approach for identifying targets and evaluating the efficiency of implemented measures. Concrete and achievable targets and indicators are first defined by involving different stakeholders, basing the decision process on the evaluation of past experiences and city typology. Key Performance Indicators (KPIs) are defined as well. The package of measures is finalized into the SULP and will be monitored through the defined KPIs, while its efficiency will be evaluated. The assessment will be done ex-ante (before) the implementation of measures and ex-post (after). These evaluations can be performed also with the help of logistic observatories, which evolved from databases and information centres, driven by the need for relevant information in transport and logistics. They analyse trends like logistics sprawl and e-commerce, which impact urban areas through increased logistics facilities, diverse traffic flows, and new types of jobs.

The European Commission in July 2024 designated 431 European cities as promotors of seamless traffic flows, by adopting their plan. Each city is also supposed to regularly collect and share with the commission data on mobility indicators.

4.2. Curbside Management

Among the many transportation infrastructures increasingly overused and congested is the curbside, meaning the edges of streets or roads where vehicles typically stop or park temporarily, often used for specific purposes such as loading and unloading passengers or goods. It encompasses areas adjacent to sidewalks and streets, serving as a key interface for various activities, including ridesharing, deliveries, and public transportation.

Recent research on curbside management techniques highlights the growing challenges and potential solutions for urban curbside spaces. Managing curbside space is challenging due to a lack of clear and complete understanding within local administrations. Although data to address mobility needs often exists, it remains inaccessible due to technical challenges, inconsistent formats, and isolated systems. Effective curbside management requires standardized processes for collecting, storing, and sharing curbside data, along with user-friendly tools to help non-technical decision-makers analyse and manage curbside use.

Logistics providers, in particular, face challenges finding safe, legal loading zones with tight schedules, congestion, and limited delivery spaces. This often leads to parking on sidewalks or double parking, creating safety risks, increasing congestion, and contributing to higher emissions.

Cities are exploring various strategies to address increased demand from diverse users. Key concerns for public officials include enforcement, data management, and interagency coordination (Diehl et al., 2021). Some cities are adopting comprehensive planning approaches or performance-pricing models to improve curbside management (Zalewski et al., 2012).

4.2.1. Dynamic curbside management for loading/unloading

Effective management of curbside space can enhance traffic flow, reduce congestion, and improve urban liveability. Therefore, dynamic curbside management - meaning allocating the curbside space for various uses throughout the day/week - is a critical aspect of urban transportation systems, especially with the increasing demand from new mobility operators and goods delivery services. For instance, these flexible zones could be adjusted to expand, contract, or serve different purposes based on changing demands for various uses (Yu and Bayram, 2021). This solution relies on comprehensive data collection and analysis, including understanding peak usage times, user behaviours, and the types of services required at different times.

In GRETA project, Budapest pilot is developing a curbside management framework, containing curbside function assessment methodology and real-life testing, that will contribute to the development of a multifunctional public space.

4.2.2. Sensors for parking slots

Dynamic curbside management is often associated with the implementation of sensors and analytics tools that enable real-time monitoring. In fact, innovative technologies, such as smart parking systems and occupancy sensors, are being developed to enhance curbside space efficiency (Diehl et al., 2021). IoT-based systems using ultrasonic sensors and microcontrollers have achieved high accuracy and cost-efficiency (Yong Choong Hong et al., 2023). These systems typically involve sensors detecting vehicle presence, data transmission to a central server, and information display on mobile applications for users to locate available parking spaces (Mutiara et al., 2015; Jindaprakai & Nuchitprasitchai, 2019). These studies emphasize the need for data-driven, adaptable approaches to curbside management in response to evolving urban mobility needs. Researchers have proposed advanced methods like graph-based deep learning to predict curbside use patterns (Hao et al., 2023). Computer vision techniques for monitoring curbside lane occupancy are also studied as a tool to assess illegal parking (Gao et al., 2022).

In order to face this problem, the European Institute of Innovation and Technology (EIT) in 2022 has launched the FlexCurb project, that aims at studying a two-parts digital solution for curbside management (EIT, 2022). The first part of the project consists in applying and evaluating the performance of a planning platform to check real-time parking activity to reveal curbside use patterns, while the second part consists of an application for drivers to help them find available loading zones (Astegiano, 2022).

In GRETA project, Verona will implement a remote booking system for loading bays enabling operators to schedule deliveries in advance. This system will show the loading bays status, indicating whether they are free, reserved, or occupied. Additionally, IoT devices and sensors will be installed to detect vehicle presence in the bays, offering real-time updates on availability. This will be complemented by flashing lights to allow drivers to have a prompt visual indication of the bay status. Moreover, a mobile app will show efficient delivery routes, real-time updates on traffic conditions, and notifications on available loading bays. Electric cargo bikes will be introduced as sustainable delivery vehicles, reducing environmental impact and congestions.

4.3. Regulatory measures

To address the challenges emerging in urban areas due to the growth of freight transportation, governments and local authorities have implemented a range of regulatory measures aimed at balancing the efficiency of freight operations with broader urban development goals. These measures, including emission regulations, delivery time restrictions, low-emission zones (LEZ), and smart logistics technologies, are transforming freight operations in urban environments. Additionally, they serve as incentives for couriers to invest in new technologies, conduct research, and upgrade to more sustainable fleets.

4.3.1. Establishing limited traffic zones (LTZ), low-emission zones (LEZ) and zero emission zones (ZEZ)

Limited Traffic Zones (LTZ) are regulatory measures designed to restrict or limit access for certain types of vehicles in specific urban areas. Typically established to reduce air pollution, alleviate congestion, and improve the liveability of city centres, these zones can vary in structure. LTZs can be categorized based on the time window and the types of vehicles allowed.

Time-based differentiation:

- Permanent
- Daily (e.g., active only a few days each week, such as on weekends or specific weekdays)
- Hourly (e.g., active during the daytime with unrestricted access at night)

Vehicles restriction differentiation:

- No vehicle permitted – pedestrian zones
- Only zero-emission vehicles allowed – Zero Emission Zones (ZEZ) (e.g., bicycles, electric vehicles). These areas aim at completely eliminating pollutant emissions contributing to a healthier environment.
- Only vehicles with a certain emission class are allowed – Low Emission Zones (LEZ) (e.g., restricted access for vehicles with EURO 5 class or lower if diesel-powered, EURO 3 or lower if gasoline-powered). These zones are designed to reduce air pollution and improve air quality.

4.3.2. Multi use lanes and dedicated/preferential freight vehicles lanes

Dedicated or preferential freight vehicle lanes are specific traffic lanes designated for the use of freight vehicles, such as trucks and other large commercial vehicles. These lanes are designed to optimize the movement of freight, enhance road safety, and improve the efficiency of goods transportation. Dedicated lanes are exclusively used by freight vehicles, while on preferential lanes freight vehicles are given priority, but regular vehicles may be allowed too at certain time.

Multi use lanes are road segments dedicated to different types of vehicles or users, depending on certain conditions, such as time or purpose. For example, the same lane might serve freight vehicles during delivery peak hours and general traffic during the commuting travels peak hours.

Dedicated truck lanes (DTLs) can address increased truck traffic, reduce pavement damage, and improve operational efficiency (Bucklew, 2011). Microsimulation modelling indicates that restricting trucks from the leftmost two lanes or designating the left lane exclusively for trucks can also help reduce lane-changing conflicts, though it may lead to an increase in merging conflicts (Tantawi et al., 2009). Dedicated bus lanes can increase car capacity by eliminating conflicting bus manoeuvres and reducing lane changes, potentially reducing passenger delay at signalized intersections when bus occupancy is high or car demand is low (Arnet et al., 2015). It also ensures that public transport reaches stops on schedule, even during peak hours when the city is congested. Moreover, for autonomous and connected trucks, dedicated platoon lanes can improve fuel efficiency, traffic throughput, and safety.

Multi-use lane strategies on urban arterials can benefit urban freight activities while maintaining overall network performance. An example of multi-use lane is if a bus lane also accommodates taxis and cyclists, or shared-use paths such as pedestrian and cyclists promiscuous paths.

5. Infrastructural and organizational solutions

5.1. Consolidation and deconsolidation

Freight consolidation is a logistics strategy that aggregates customer orders over space and/or time to enhance transportation efficiency, reduce costs, and improve overall supply chain performance (Luan, 2010; Rahman, 2024). By consolidating smaller shipments from various sources—across different products, routes, or vendors—into a single, larger shipment, companies can streamline their operations and make more effective use of transportation resources (Min & Cooper, 1990). This practice is especially advantageous in last-mile delivery scenarios, where the rise of e-commerce and consumer expectations for rapid, reliable delivery have led to a surge in freight demand within urban centres.

In addition to cost savings, freight consolidation helps increase vehicle load factors by reducing the number of partially filled vehicles on the road, thus improving load efficiency and lowering per-unit transportation costs (Higginson & Bookbinder, 1994). By centralizing orders from various suppliers or locations into fewer, larger deliveries, consolidation reduces the frequency of trips and the need for multiple delivery vehicles—factors that translate into direct cost reductions.

Beyond cost and operational efficiency, freight consolidation can yield significant environmental and social benefits, particularly in congested urban areas. By consolidating shipments, companies can decrease the number of vehicles on the road (Monsreal et al., 2024), reduce greenhouse gas emissions (Pan et al., 2013), and mitigate the impacts of traffic congestion and air pollution in densely populated areas. This practice aligns well with broader sustainability initiatives, as fewer trips and fuller loads directly correlate with lower fuel consumption and carbon emissions.

Furthermore, the practice of freight consolidation is closely aligned with the concept of the physical internet, an innovative framework that aims to interconnect different networks. Inspired by the digital internet—which operates using standardized protocols and smart interfaces to exchange data—the physical internet applies similar principles by utilizing modular containers to optimize freight movement across multimodal transport networks through standardized processes, procedures, and systems. These modular containers, designed for seamless transfer between different transport modes, facilitate the consolidation of shipments from multiple origins (Kupriyanovsky et al., 2020). In Europe, the ALICE (Alliance for Logistics Innovation through Collaboration in Europe) initiative is actively working on implementing physical internet solutions, demonstrating how interconnected logistics networks can enhance global supply chain efficiency (ALICE, 2020).

This approach is closely linked to collaborative logistics (Zhou et al., 2011), where multiple businesses share transportation resources and coordinate to optimize routes and schedules. Enabled by digital platforms and real-time data sharing (discussed later in this paper), this collaborative model enhances last-mile delivery efficiency by pooling demand across various companies and sectors. Ultimately, it reduces both economic and environmental costs associated with fragmented, small-scale deliveries.

However, while freight consolidation improves efficiency at earlier stages of transportation, **freight deconsolidation** plays a critical role in ensuring timely and effective last-mile delivery. Deconsolidation refers to the process of breaking down larger, consolidated shipments into smaller loads at distribution hubs or urban consolidation centres before final delivery. This step is particularly relevant in **hub-and-spoke logistics models**, where goods are first transported in bulk to regional or urban hubs and then distributed to their final destinations.

Deconsolidation is essential in **e-commerce-driven supply chains**, where retailers and third-party logistics providers (3PLs) need to swiftly separate consolidated shipments into smaller parcels tailored to individual customers. This process enhances flexibility, improves delivery responsiveness, and helps meet the increasing demand for same-day or next-day delivery services.

Both consolidation and deconsolidation work in tandem to create a **balanced, resilient, and sustainable logistics network**, ensuring cost efficiency, environmental benefits, and improved customer service. Nowadays, many types of structure exist to perform freight consolidations, differing in size, location in relation to city centres, type of management and many other factors.

5.1.1. Urban Consolidation Centres

Urban Consolidation Centres (UCCs) are city hubs aimed at improving urban freight delivery efficiency while reducing negative environmental and social impacts (Johansson, 2020; Johansson, 2018) and have the potential to decrease the number of delivery vehicles entering city centres by up to 75%. Typically situated on the outskirts of urban areas, UCCs function as warehouses that consolidate deliveries from multiple vendors destined for urban locations (Carvalho, 2023). This arrangement improves the coordination of complex logistics and enables delivery scheduling during off-peak hours. Furthermore, by consolidating deliveries near end customers, UCCs enable the use of electric vehicles that only need a short driving range for last-mile delivery.

Urban Consolidation Centres offer a promising solution for improving urban freight logistics while supporting sustainability goals. However, their success depends on careful planning, stakeholder cooperation, and consideration of local urban contexts. Despite their popularity, UCCs often fail in practice, indicating a knowledge gap (Johansson & Björklund, 2018). Research on UCCs has been most active from 2006 to 2010, with 114 schemes identified in 17 countries (Allen et al., 2012). Key themes in UCC research include stakeholder roles, distribution structure design, environmental and social considerations, and economic factors, and their savings increase as more companies participate in the project (Su & Roorda, 2014).

The UCCs potential for reducing vehicle-kilometres travelled in city centres has been demonstrated, but the optimal consolidation period may vary, with 3-day consolidation potentially being more cost-effective than daily or 2-day shipping in some cases (Rahman, 2024).

Locating consolidation centres strategically within cities is crucial for their effectiveness. Approaches using multi-criteria analysis, considering factors such as demand, land use, and road types, have been developed to identify suitable locations (Rudolph et al., 2021). Optimization models for zoning urban areas into delivery clusters served by MCCs have been proposed, aiming to minimize delivery distance, time, and cost (L. Savchenko & V. Davydenko, 2020) because shorter routes reduce fuel consumption, delivery time, and CO_2 emissions.

While many studies focus on finding optimal solutions and designs, there is limited research on financial viability and UCC initiative management. Additionally, although environmental and social arguments are often used to justify UCC implementation, few studies measure or evaluate their impact yet (Johansson and Björklund, 2018).

5.1.2. Microhubs

Microhubs, also known as "micro-distribution" facilities, “micro consolidation centres” (MCCs) or "micro-depots”, are much smaller facilities compared to UCCs and are usually located near city centres or in specific neighbourhoods they aim to serve. Providers utilize microhubs for storage, transshipment, and last-mile distribution of goods for both business-to-business and home delivery (Schodl et al., 2019). They are designed for micro-consolidation, which involves grouping goods at a location close to their final delivery point, typically within 1 to 5 kilometres from their destination (Janjevic and Ndiaye, 2014). Locating hubs closer to end-users enables the utilization of environmentally friendly transportation modes such as light electric freight vehicles (LEFVs) (e.g., electric cargo bicycles and small-sized electric vehicles) and pedestrian transportation, which have shorter travel ranges than conventional diesel and petrol delivery vehicles.

These hubs can either use permanent buildings or mobile structures (e.g. containers), and they may operate on a long-term or temporary basis, often managed by one or more businesses simultaneously. Collaboration among courier, express, and parcel carriers can improve the efficiency of microhubs (Hribernik et al., 2020); in particular, research indicates that collaboration among carriers can reduce distance-related costs by up to 16% (Juan et al., 2014; Juan et al., 2016), decrease environmental externalities by 24% (Verdonck et al., 2013), and boost delivered volumes by 25% for cooperating partners (Quak et al., 2016; Quak, 2012). However, challenges related to trust and data sharing present major obstacles to this collaboration.

In GRETA project, 3 FUAs are developing and implementing microhubs or Micro Urban Consolidation Center (MUCC) solutions: Reggio Emilia, Maribor and Poznan. Reggio Emilia pilot is implementing a microhub for e-cargo bike where transport operators can transship their goods from vans to e-cargo bike and deliver them to the city center, where access for traditional freight vehicles is limited. In order to be compliant with transport operators and last miler policies, they decided to develop a microhub with few/no shared space where each operator has a dedicated, limited and reserved flexible space adaptable to different requests and standards.

Maribor is developing a mobile microhub located at the edge of the city centre pedestrian zone equipped with environmentally friendly delivery vehicles (bikes, trolleys) for sustainable and flexible last mile delivery. The potential users are shop owners, residents and LSPs.

Poznan is testing a microhub located at the outskirts of the city center serving as a backup facility for transshipment for one operator only (GLS) from delivery vehicles arriving from GLS distribution center, equipped with cargo bikes, and to provide temporary storage for parcels. Shipments delivered from the distribution center are unloaded, sorted and then partially loaded into the cargo boxes of the bicycles. The remainder of the shipments, once sorted, are temporarily stored in the hub until couriers from subsequent rounds of deliveries arrive. Once the deliveries are completed, the hub serves an additional function as a cargo bike garage space.

5.2. Pick-up points

Pick-up points (PPs) refer to designated locations where individuals can collect items and goods usually purchased online offering an alternative to home delivery in e-commerce. These points are spreading serving as exchange points between deliverers and consumers potentially reducing operational costs and environmental impacts (Xu et al., 2014; Masteguim & Cunha, 2022). Some studies have shown that PPs can decrease fleet size and vehicle mileage by over 50% in urban areas; however, the effectiveness of this implementation depends on factors such as urban density and customers' behaviour (Niemeijer & Buijs, 2023). Choosing a pick-up point also helps avoid failed deliveries since the package is delivered to a secure location where the customer can retrieve it at their convenience, eliminating the need for multiple delivery attempts.

A key factor influencing the effectiveness of pick-up points in reducing kilometers traveled is the number of customers opting for this delivery method over home delivery. When PPs receive only a few or even single deliveries frequently, it results in limited or no-load consolidation, which ultimately fails to significantly reduce the kilometers traveled (Masteguim & Cuhna, 2022). For this reason, retailers may employ incentive strategies to encourage customers to switch from home delivery to PPs.

5.2.1. Automated parcel lockers

Automated parcel lockers (APLs) are self-service technologies that facilitate parcel collection in urban areas, offering advantages over traditional home delivery methods. These lockers, when located outside buildings, are accessible 24/7, allowing customers to pick up their deliveries at their preferred time. Goods are typically accessed by scanning QR codes or barcodes to ensure safety and security.

Researchers have developed simulation-optimization models to analyse APL network performance and determine optimal locker locations (Sawik et al., 2022; Rabe et al., 2020). These models combine system dynamics simulation with facility location problem optimization to understand APL system behaviour and make informed decisions about locker placement, considering factors such as market size, potential e-customers, and demand evolution (Rabe et al., 2020).

Unlike pick-up points in shops, APLs can also serve as temporary storage for consolidating or deconsolidating small deliveries. A test conducted in the city of Bologna, funded by URBANE Horizon Europe project, demonstrated their use as sustainable micro-logistics hubs. In this model, a traditional vehicle delivers supplies to the APL, and a small electric vehicle then retrieves the goods to complete the last-mile delivery in the city center after accessing the goods via QR codes. The innovation of these micro-logistics hub is that 2 carriers, that can potentially be competitors, use the same collaborative microhubs to deliver their parcels in Bologna city centre Limited Traffic Zone. This is allowed by an IT management platform that acts as orchestrator managing the flows of all stakeholders involved in the delivery process and guaranteeing their data protection, also with the support of a blockchain technology (URBANE, 2024).

6. Information and Communications Technology (ICT) driven solutions

6.1. Internet of Things - IoT

The Internet of Things (IoT) is a developing paradigm in modern technology, that allows physical objects to communicate, gather and exchange data through the embedded sensors and software, via internet. IoT integrates various technologies, including sensors, microcontrollers, networking, and data mining, to create smart systems in areas such as cities, homes, and transportation (Vamsidhar et al., 2020). It bridges the physical world with the Internet, enabling devices to be remotely controlled and allowing hardware to interact with the external environment autonomously, without human intervention.

In logistics, IoT applications encompass areas such as fleet management, automated warehousing and performance monitoring (Gowri, 2022). The technology facilitates data collection and analysis, leading to enhanced productivity, safety, and service quality (Tran-Dang et al., 2020; Kolodyazhens'kyy et al., 2021). IoT solutions in transportation help coordinate traffic, distribute parking spaces, and improve infrastructure. In warehouses, IoT provides a comprehensive view of operations, from ambient temperature to equipment performance. Mobile device sensing systems can track and optimize goods distribution logistics using smartphone sensors and data mining (Ferreira et al., 2017). Advanced cloud-based routing and scheduling systems leverage cloud computing to provide efficient, adaptable solutions for complex logistics problems (Gayialis et al., 2018). They can handle both static and dynamic routing, incorporating real-time data to monitor fleets and perform rerouting when necessary (Gayialis et al., 2021). Some systems focus on reducing environmental emissions by optimizing distribution costs and minimizing environmental impact (Kechagias et al., 2020). These IoT applications address key issues in urban freight distribution, including route optimization, environmental impact reduction, and improved coordination between stakeholders, ultimately leading to more efficient and sustainable urban logistics operation.

6.2. Digital platforms

Digital logistics platforms are emerging as catalysts for the industry's digital transformation, facilitating information exchange among multiple players (Stölzle & Häberle, 2021). These platforms can be classified based on coverage, size, functionality, and design, with both advantages and disadvantages identified. The market for digital logistics platforms is dynamic and heterogeneous, offering various services and attracting new entrants, including startups. While B2C platform principles have transformed many markets, their full potential in B2B logistics remains underexplored (Culotta & Duparc, 2022). Furthermore, digital platforms play a crucial role in sustainable development of green logistics, integrating modern technologies to enhance supply chain efficiency and competitiveness (Dmitriev & Plastunyak, 2020). As the digital logistics landscape continues to evolve, these platforms are expected to significantly impact transport and logistics systems, fostering collaboration and cooperation among various stakeholders.

6.2.1. City-wide logistics management platforms

Information and Communication Technologies (ICTs) are spreading into the field of logistics in order to optimize the supply chain in general. These technologies are spreading in the urban environment too and are used both to optimize logistics operation of carriers and to integrate different platforms used by different actors of the urban freight transport system (Comi & Russo, 2022).

ICTs can be used to process a wide variety of real-time information, such as roadblocks, congestion, weather condition and free parking spaces, in order to plan an optimal route for delivering.

City-wide logistics management platforms facilitate the coordination of various delivery services within a city, enhancing efficiency and reducing congestion. They serve as neutral hubs for all physical and digital assets involved in city logistics and this may include the utilization of UCCs and warehouses throughout the city (i.e. ULaaDS platform). By embracing a collaborative approach that includes both public and private stakeholders, cities can more effectively address the complexities of urban logistics, resulting in better service delivery and an improved quality of life for residents.

6.2.2. Real-time delivery tracking and notifications

Real time delivery tracking has become an important part of logistic and deliveries, particularly in the context of e-commerce deliveries. Customers can receive real-time notifications about their delivery status, including the estimated time of arrival and updates. This technique allows a good reduction of failed deliveries, while increasing the customer's satisfaction.

From the companies' point of view, real-time tracking is crucial for reacting fast to unforeseen disruptions and for addressing issues like hubs congestion and delivery delays. This also helps improving efficiency and security of parcel management by reducing the likelihood of lost or misplaced items, that are usually marked by a barcode or a tracking number. In fact, real-time tracking is performed with various technologies such as barcodes, radio frequency identification (RFID), magnetic stripes, voice and vision systems, optical character recognition (Shamsuzzoha & Helo, 2011), GPS tracking and QR codes.

6.3. Optimization Software

Optimization software in logistics plays a crucial role in enhancing efficiency, reducing costs, and improving decision-making across supply chains. These advanced tools use algorithms, artificial intelligence, and real-time data to optimize key logistics processes such as route planning, warehouse management, inventory control, and freight scheduling. By minimizing delays, maximizing resource utilization, and adapting to dynamic market conditions, optimization software enables businesses to streamline operations, reduce environmental impact, and meet customer demands more effectively. As logistics networks become increasingly complex, the adoption of these technologies is essential for maintaining competitiveness and ensuring sustainable growth. In the next paragraphs the major optimization strategies will be analysed.

6.3.1. AI-powered route optimization

The use of modern technologies to optimize logistics distribution routes has become a key issue over the last years. The development of artificial intelligence is leading to their application into various fields, including logistics. In fact, AI - often combined with IoT - allows to process a vast amount of data in short time, including historical delivery records, road closures and real-time traffic information. This approach aims to address the limitations of traditional routing methods by incorporating advanced AI techniques to adapt to dynamic conditions and optimize performance.

AI-based systems utilize real-time traffic data and machine learning algorithms to study dynamic traffic conditions redistributing traffic flows and minimizing congestion (Dikshit et al., 2023). AI-powered adaptive routing intelligently distributes traffic flows by redirecting vehicles away from congested areas and onto underutilized routes. This approach reduces travel times and mitigates the negative impacts of congestion, including excess fuel consumption and emissions.

6.3.2. Automated scheduling and load management

The increase in supply deliveries has made it challenging to manage inventory, fulfil orders, and organize deliveries efficiently in a manual warehouse environment. Automated scheduling utilises algorithms to optimize the planning of logistic tasks including dock scheduling, while load management optimizes the arrangement of cargo within vehicles to ensure efficient space utilization and reduce transportation costs (Li 2023).

This also includes calculating the most efficient way to load and unload vehicles by considering different factors, such as cargo dimensions and weight and its destination, thereby reducing the number of trips needed while calculating the optimal routes.

As well as for the route optimization, AI tools and machine learning are fundamental for load and warehouse automatic management. The shift from manual to automated scheduling represents a significant advancement in logistics operations as the delivery landscapes continue to evolve, requiring more and more complex solutions.

7. Vehicle-based solutions

7.1. Electric and low emission vehicles

The introduction of Low-emission vehicles (LEVs) has become increasingly important in reducing air pollution from transportation. Among this, various electric vehicle types exist, including battery electric, plug-in hybrid, hybrid, and fuel cell vehicles, each with distinct powertrain configurations and enabling technologies (Nanaki, 2021). These vehicles are more and more used due to advancements in battery technology, supportive government policies, decreasing manufacturing costs, and potential integration with renewable energy sources.

Electric Vehicles (EVs) are expanding beyond personal transportation to include buses, trucks, and delivery vehicles (Soni & Kaur, 2023). As range and charging capacity improve, EVs are becoming increasingly attractive to a broader consumer base, so charging infrastructure and standards are developing to support widespread EV adoption too.

7.1.1. Electric vans

Electric vans are spreading to perform freight distribution; some studies show that these vehicles can reduce CO2 emissions by 67% compared to diesel vans (Acha et al., 2023). While the total cost of ownership for electric vans is currently slightly higher, factors such as extended ownership periods and smart charging can improve their economic viability. However, barriers to widespread adoption include range concerns, payload limitations, and high initial costs. For this reason, to accelerate the transition to electric fleets, policies such as purchase grants, congestion charging, and other financial and non-financial incentives are recommended. Among non-financial incentives there are free access to LTZs, access to preferential lanes and expanded time slots to enter into cities.

7.1.2. Electric cargo bikes

E-cargo bikes are emerging as a sustainable solution for urban last-mile logistics and private transportation, offering an alternative to fossil fuel-dependent vehicles. These electric-assisted bicycles can carry goods and children, potentially reducing car utilization in cities (Carracedo & Mostofi, 2022).

There are many different types of e-cargo bikes:

- Longtail cargo bikes: with an extended rear section that allows for additional cargo space, making them suitable for carrying children or larger loads. They typically have a capacity of around 60 kg and offer familiar handling, as they are similar to regular bicycles.

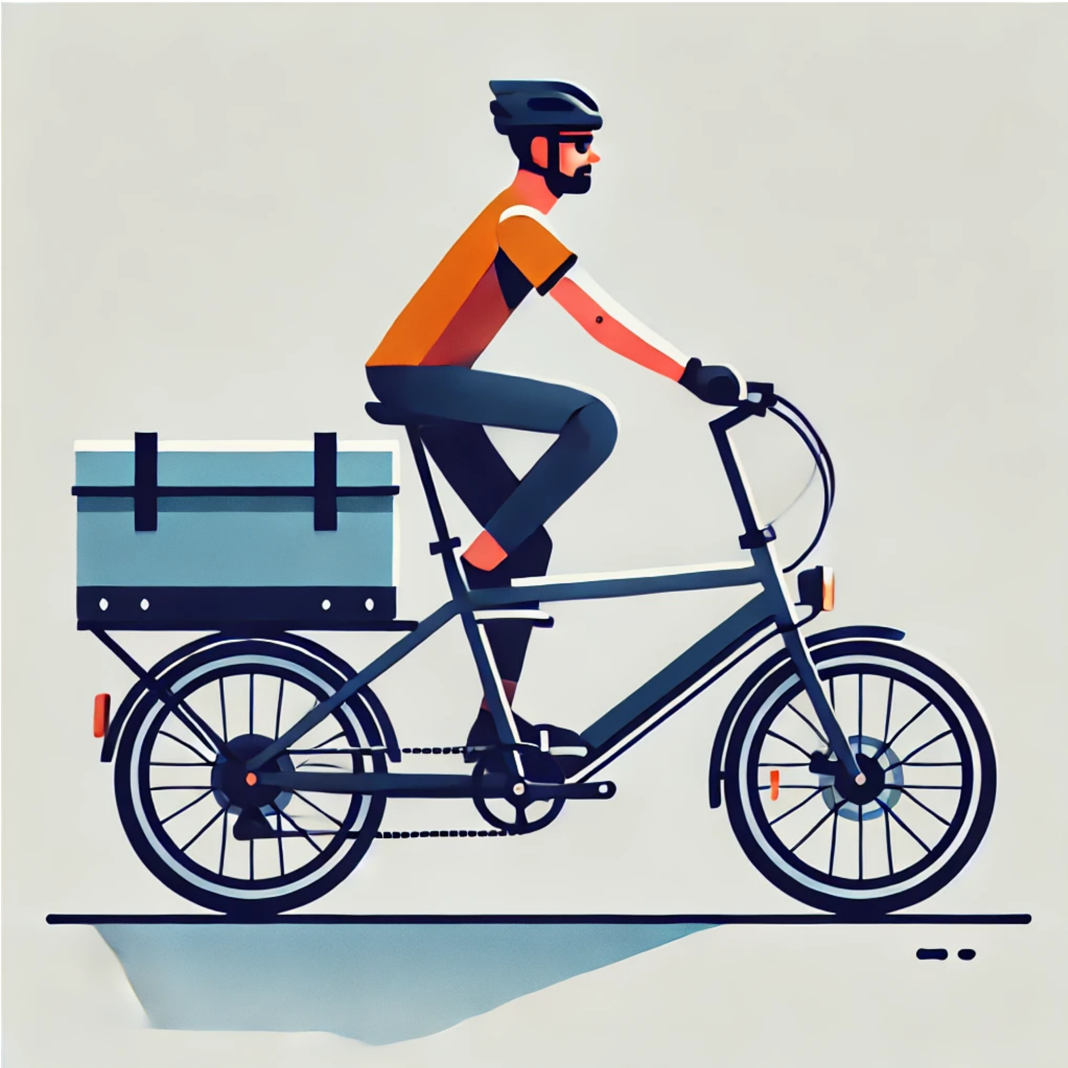

Figure 1: Longtail cargo bike

- Front loader bikes (Long John): the cargo area is located at the front of the driver. They offer great stability because the load is low, lowering also the gravity centre and allow the rider to see the cargo while driving. The capacity is around 100kg.

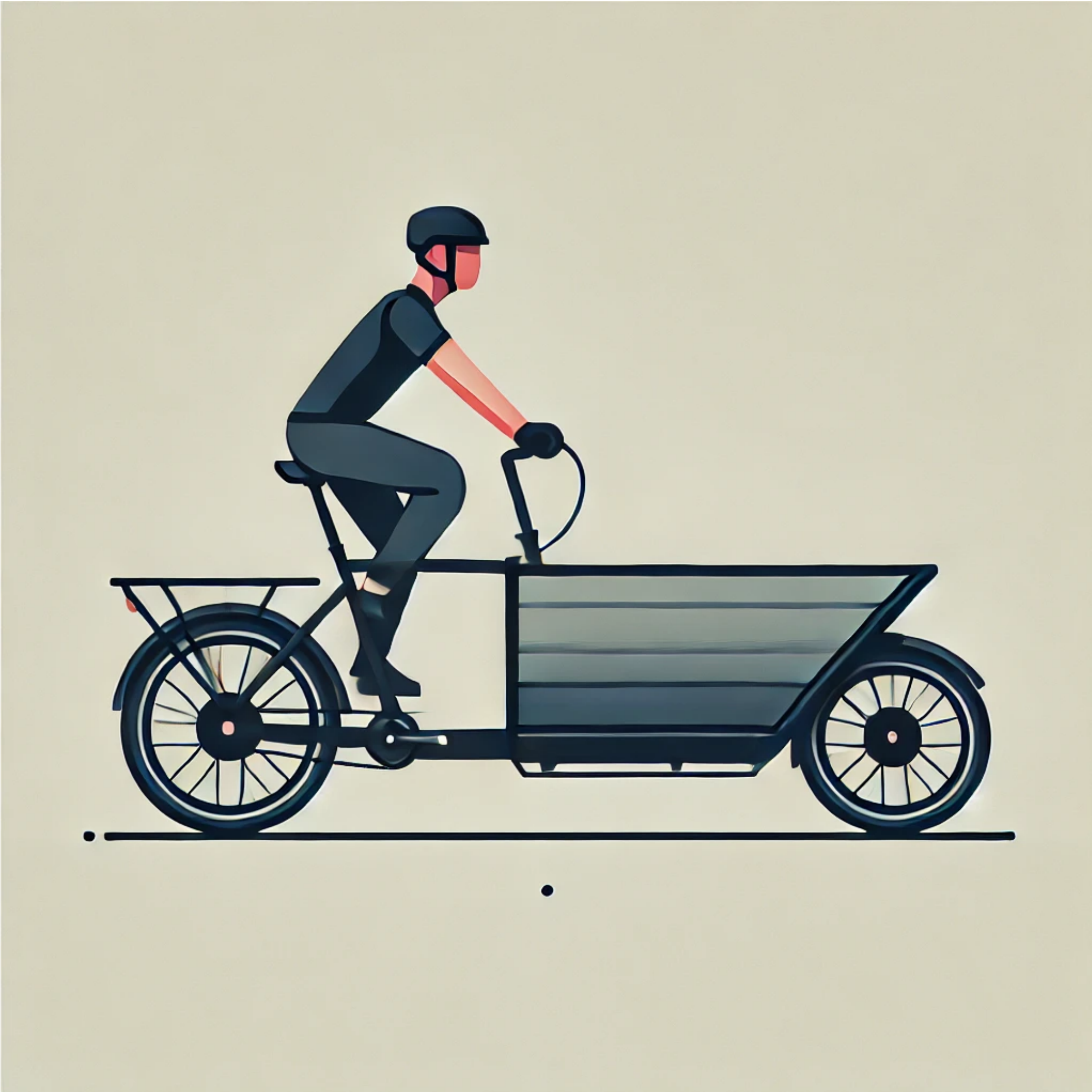

Figure 2: Long john cargo bike

- Cargo tricycles: these bikes typically offer the same weight capacity as long johns but provide greater stability while riding, allowing to move larger volumes. They can have the load positioned on the front or on the back.

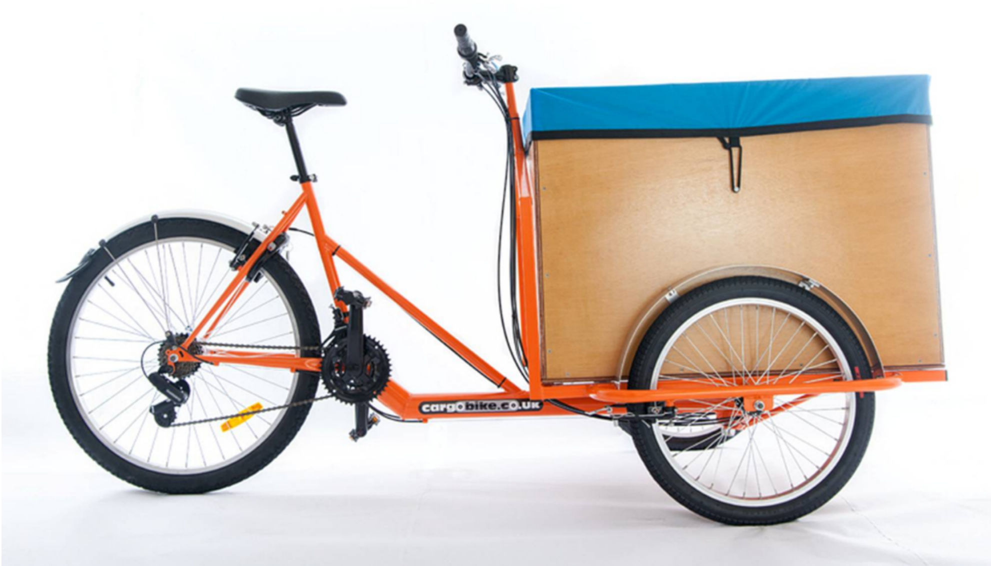

Figure 3: Tamar Cargo Trike | The Cargo Bike Company

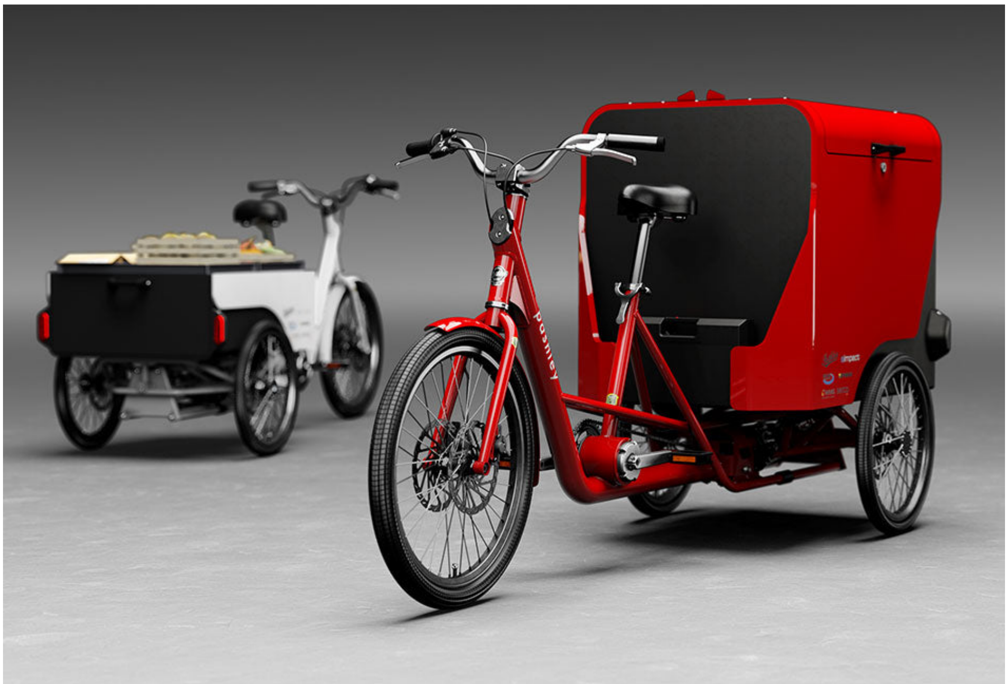

Figure 4: Pashley | ALECS cargo trike

- Cargo quadricycles: these vehicles have been developed in substitution of traditional VANS. They are typically larger than other bikes, offering up to 200kg of weight capacity and can be equipped with many optional such as rain covers for riders.

Figure 5: EAVcab | quadricycle

Using these vehicles for last-mile distribution can reduce CO2 emissions by up to 80% (EIT, 2024) and speed up delivery operations by as much as 60% (Sax, 2024). Additionally, they are exempt from restrictions in limited traffic zones and low-emission zones, allowing for deliveries at any time and on any day. In some urban settings, these vehicles are also permitted to operate on pedestrian roads.

The introduction of e-cargo bikes for urban freight deliveries can be a cost-effective solution, as these vehicles have lower operational costs compared to traditional delivery trucks and vans, particularly in city environments. Additionally, parking and navigating through traffic are easier for e-cargo bikes than for vans (Schrader et al., 2024).

However, there are some safety concerns to consider. The rider's safety is reduced compared to regular drivers, and they are more exposed to weather conditions and pollution. On the positive side, the safety of other road users is improved, as it helps prevent collisions between vulnerable street users and larger vehicles.

7.1.3. Trolleys

Trolleys play a significant role in last-mile delivery solutions, offering an efficient and ergonomic way to transport goods over short distances. Trolleys are commonly employed for the final leg of deliveries from trucks to businesses or residences in urban areas. They allow delivery personnel to efficiently transport packages over short distances in pedestrian-heavy environments. As urban areas continue to face challenges with congestion and sustainability, trolleys offer a simple yet effective tool in the last-mile delivery ecosystem.

Trolleys are often part of a broader urban freight strategy and may be used in conjunction with urban consolidation centres or microhubs to reduce truck traffic in city centres.

7.2. Autonomous vehicles

Autonomous vehicles (AVs) are self-driving cars that utilize advanced technologies like sensors, cameras, and artificial intelligence to navigate without human intervention. Although there are strict infrastructure requirements, ethical challenges and safety concerns, autonomous vehicles enhance overall street safety by eliminating driver errors and inattentiveness. Besides safety, they also enhance efficiency and accessibility in transportation, enabling individuals with physical disabilities who are unable to drive to travel independently.

Autonomous freight vehicles are increasingly being studied to enhance delivery efficiency, including sidewalk robots, autonomous delivery vans and trucks, as well as drones. These can operate around the clock without breaks and do not require constant human supervision. Despite these benefits, challenges remain, including technical, regulatory, and societal issues. The adoption of autonomous vehicles still faces significant challenges, including the need for more developed regulatory frameworks and the gradual building of public trust. This trust will depend on the technology demonstrating its safety and reliability across a variety of conditions and scenarios.

7.2.1. Autonomous trucks and vans

The implementation of self-driving trucks and vans has the potential to address numerous challenges in the logistics industry. For instance, in the United States alone, there is a shortage of over 80,000 truck drivers (AJOT, 2023), a figure projected to double by 2030. The situation in Europe is even more critical, with a deficit exceeding 200,000 drivers in 2023, coupled with a continuously growing demand, expected to reach around 750,000 by 2028 (IRU, 2023). Another significant issue is the rising cost of transportation, driven not only by increasing fuel prices and stricter vehicle standards but also by higher driver salaries. These challenges could be mitigated through the adoption of autonomous vehicles, which demonstrate particular potential in less complex traffic environments.

The planning process for autonomous vans can be challenging and involves route selection and task allocation, with performance indicators calculable for fixed routes without disturbances (Kassai et al., 2020). For this reason, autonomous vans haven't been deeply investigated yet in the literature. On the other hand, autonomous trucks may be easier to design than vans due to their more predictable and structured behaviour, following specific routes and schedules. The first use cases for autonomous trucks involve constrained autonomy: driverless trucks operate within the interstate highway system and certain geofenced areas. To complete the route outside of these preselected areas, a driver picks up the trailer at the distribution centre, manually guides it to a hub, and then couples it to an autonomous truck for further transport (Kelkar et al., 2024).

7.2.2. Sidewalk robots

Autonomous sidewalk robots are smaller compared to the autonomous vans and navigate sidewalks using advanced autonomous navigation systems. They're in fact able to determine an optimal trajectory that enables autonomous movement from their current position to a target location along a sidewalk. Additionally, these systems ensure efficient and reliable avoidance of both static and dynamic obstacles. By utilizing data from multiple sensors and a comprehensive environmental model, an autonomous navigation system allows robots to execute their motion tasks successfully while staying confined to the sidewalk (Gómez-Ayalde and Romero-Cano, 2022). These robots are used on smaller zones than autonomous trucks and vans, usually inside urban areas or big organized areas like campuses and deliver goods directly to final customers without human intervention.

7.2.3. Autonomous drones

Delivery drones are unmanned aerial vehicles (UAVs) specifically designed for transporting goods, ranging from packages and groceries to medical supplies. Their integration into logistic chain represents a significant shift in how products are delivered, offering numerous advantages over traditional methods.

Over environmental sustainability, the primary advantage of drones is their ability to bypass road traffic, significantly reducing delivery times, especially in congested urban areas. They can deliver items directly to customers within minutes, enhancing customer satisfaction. For this reason, many studies are carried out about using drones for delivering organs and hospital supplies, also in remote and underserved areas.

Amazon has been testing deliveries with drones since 2022 in America (Amazon, 2022) and is now planning to export this model in Europe too. Drones start their trips from Amazon Logistic hubs, carrying one package at a time with maximum weight of 2.3 kg and reach final customers within minutes (Amazon, 2023). This is possible because MK30 drones are equipped with artificial intelligence to help them avoid obstacles and are connected to the control station to monitor the flight and evaluate possible problems during the trip. This UAVs are full electric and equipped with an avionics technology known as VTOL (Vertical Take-Off and Landing). This feature enables vertical take-offs and landings during package collection and delivery phases, after which they will transition to horizontal flight mode, facilitating efficient transport between locations.

This approach is expected to streamline transportation and alleviate traffic-related issues in densely populated urban areas. However, considering the high delivery volumes to which Amazon has accustomed us in recent years, one could argue that the skies themselves may become congested, given that each drone is capable of delivering only a single package. This increased aerial traffic could potentially diminish the sustainability benefits of this new logistics model (De Maria, 2023).

7.3. Flexible vehicles design

Flexible vehicle design integrates modular architectures, adaptive technologies, and AI-driven systems to create vehicles that are customizable, efficient, and adaptable to diverse user needs and environments. It involves developing adaptable components and interfaces that can accommodate future modifications, balancing flexibility with static elements to optimize investments (Block et al., 2021).

7.3.1. Modular vehicles with adjustable capacity

Recent research explores the potential of modular vehicles for combined passenger and freight transportation in urban areas. These vehicles can adjust their capacity by adding or removing modules, allowing for flexible adaptation to fluctuating demands (Lin and Zhang, 2024).

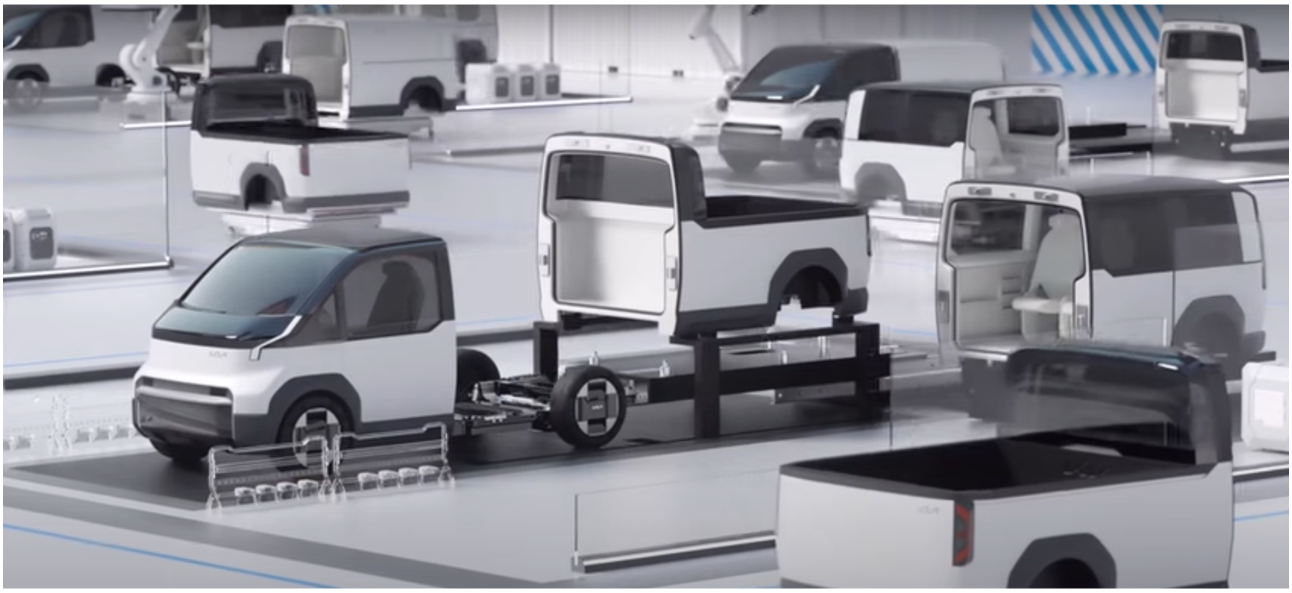

Figure 6: KIA new concept vehicle: PBV

Studies have shown that modular vehicle systems can lead to significant cost reductions, with one study reporting up to 48% savings due to modularity (Hatzenbühler et al., 2023). The concept extends to electric modular vehicles, which can be split into multiple units for charging or improved agility during deliveries (Aggoune-Mtalaa et al., 2015). For example, NExT is developing a small, modular vehicle that can link with other similar units when needed, reducing congestion and enabling freight exchange within the connected modular system.

Optimization models have been developed to address the complex scheduling and routing challenges associated with these systems, considering factors such as time-dependent demand, module availability, and rebalancing costs (Tian et al., 2023).

7.3.2. Modular swappable containers

Modular systems are studied not only for entire vehicles, but also for cargo units. The European project "Shift2zero" is studying a swappable cargo concept developed by PAX. It enhances logistics efficiency by enabling modular cargo units of standardized dimensions to be easily transferred between different vehicle types, from heavy-duty vehicles to smaller electric commercial vehicles. This system is based on the same concept of standard Unitized Transport Appliances (UTAs) used on ships, such as containers, and optimizes transshipment by improving resource distribution and reducing operational costs. It provides flexibility for end-users to manage fluctuating shipping demands while complying with urban access regulations. Additionally, it ensures the preservation of security standards during cargo transfers and promotes the standardization of modular swap boxes, allowing seamless integration with existing logistics frameworks. These containers can be easily assembled and disassembled, allowing for efficient storage and transportation of empty units (Gorbunov, 2013).

Unlike ship's UTAs, which are primarily designed for large-scale, long-distance freight transport, PAX's modular units are optimized for urban and last-mile logistics. While shipping containers provide efficiency and security in global trade, they lack the adaptability required for diverse vehicle types and urban environments. In contrast, PAX's swappable cargo units are more flexible, allowing for quick transshipment across various vehicle sizes, minimizing empty return trips and idle time, and ultimately increasing productivity while reducing carbon footprints. Furthermore, this system decreases transit times and delays, improving overall supply chain efficiency and customer satisfaction. This innovative approach supports collaborative logistics and helps businesses navigate increasingly restrictive transport environments.

7.4. Multimodal solutions

Multimodal solutions for last-mile logistics innovation integrate multiple transportation modes—such as trucks, bicycles, drones, and autonomous vehicles—to enhance the efficiency, sustainability, and cost-effectiveness of urban freight delivery. By combining different transport methods based on urban infrastructure, delivery urgency, and cost considerations, multimodal solutions optimize routing, reduce emissions, and improve service reliability. For instance, as we mentioned in the last paragraph, the implementation of UCCs usually implies the use of multi modal solutions, to maximise vehicle load.

7.4.1. Combining passengers and freight flows "Cargo Hitching"

Cargo hitching, also known as "crowdshipping" or "crowd logistics", is an innovative delivery model that leverages digital platforms to match shipment demand with excess transport capacity from the crowd (Ermagun and Stathopoulos, 2020). This may include public vehicles such as buses or trains but also rideshare vehicles or private cars. Cargo hitching combines transport modes dynamically, and for this reason it is considered a multimodal solution.

It offers potential benefits in urban goods deliveries, including cost advantages over traditional services for same-day and express deliveries (Shen and Lin, 2020). Cargo hitching can improve last-mile delivery efficiency and provide a tool for price discrimination between online and in-store channels. This practice is usually facilitated by the use of a dedicated digital platform that matches goods with the vehicle traveling in the direction needed. The performance of cargo hitching platforms is influenced by various factors, including shipping requests, built environment, and socioeconomic characteristics (Ermagun and Stathopoulos, 2020).

Utilizing existing public transit infrastructure for freight deliveries can significantly reduce emissions and congestion compared to dedicated delivery vehicles (Gatta et al., 2019). This solution is implemented on different public transit vehicles, such as trains, subways, buses or shared vehicles. This is performed by leveraging spare capacity on public transit systems, especially during off-peak hours (ITF, 2008). This requires a formal coordination between public transit authorities and shippers.

Thoughtful planning is essential to integrate freight deliveries smoothly with passenger services, also taking into account parcel size, weight limits, and handling procedures. Sometimes this solution requires some infrastructure adjustment, such as dedicated loading/unloading points at transit stops or secure cargo compartments, such as lockable compartments equipped with access tracking systems. The cargo compartments should be designed to avoid disrupting the normal movement of passengers. These compartments can not only be separated from passengers but can also optimize vehicle space by filling underutilized areas of the vehicles such as under seat storage, overhead racks and external cargo bays. For this reason a distinction can be done between shared vehicles – when cargo is carried among passengers - and shared infrastructure – where both passengers and cargo utilize the same infrastructure but freight is transported in separated, dedicated units (GRETA, 2024).

Cargo hitching can deliver goods to different destinations. They can be delivered to single points of unload – such as warehouses or UCCs – as in the case of busses and conventional public transport with fixed routes. On the other hand, a crowdshipping service can have multiple load and unload points along its route instead of a single destination. Freight can be picked up or dropped off for final delivery to individuals, businesses, or other logistics operators handling first and last-mile transport. This model may also include UCCs, microhubs, or lockers along the route, providing more flexible and accessible delivery options.

Advanced prediction methods, such as ConvLSTM, can effectively forecast short-term cargo hitching delivery trip production by capturing both spatial and temporal features (Shen and Lin, 2020). Additionally, cargo hitching has potential applications in reverse logistics, offering sustainable solutions that can reduce shipping costs, delivery times, and environmental impacts in urban areas (Upadhyay et al., 2020).

8. Conclusions

In conclusion, the exploration of urban logistics solutions reveals that a multi-faceted approach is essential to meet the challenges of growing urbanization. The implementation of diverse infrastructure solutions, such as UCCs and microhubs, plays a crucial role in optimizing the flow of goods within cities. These strategies help to reduce congestion while increasing the efficiency of deliveries, making them more adaptable to urban needs. Additionally, the integration of passenger and freight flows through multimodal solutions like "cargo hitching" allows for better utilization of existing transport networks, helping cities reduce dependency on dedicated freight infrastructure.

Technologies play a key role in the development of the new urban logistic context. The integration of IoT, digital platforms, and AI-powered optimization software is revolutionizing the logistics industry by enabling real-time tracking, more efficient route planning, and automated scheduling. These innovations help cities manage complex urban logistics systems with greater flexibility and transparency, contributing to smoother operations across the supply chain simplifying fast response to disruptions on the network.

Equally important is the integration of logistics considerations into urban mobility planning, with a strong focus on sustainability. Here, the European Union plays a pivotal role. Through strategic frameworks such as Sustainable Urban Logistics Plans (SULPs), the EU provides essential guidance and support for cities to adopt and implement these logistics measures. EU-funded programs like Horizon Europe and the European Green Deal incentivize and help fund innovative solutions, while also ensuring that policies, such as low-emission zones and dynamic curbside management, are effectively implemented. The EU's coordination ensures that cities across Europe are working towards common goals of reducing emissions and optimizing freight transport in urban environments.

In the context of improving logistics chains and prioritizing environmental sustainability, there is a growing interest in adopting electric and low-emission vehicles. This is especially crucial for the urban logistics sector, where electric cargo bikes, vans, and autonomous vehicles can significantly reduce congestion and emissions in city centres.

Despite significant advancements in urban logistics, several gaps remain that require further exploration. One major challenge is the lack of standardized frameworks for integrating urban freight solutions across different cities, leading to inconsistencies in policy implementation and infrastructure development. Additionally, while digital platforms and AI-driven optimization tools have improved logistics efficiency, concerns around data privacy, cybersecurity, and interoperability between different systems need further attention. Further studies on consumer behaviour and the social acceptance of novel delivery methods, including autonomous vehicles and drone deliveries, will also be essential for shaping policies that align with urban stakeholders' needs.

Looking ahead, the future of urban logistics will require continued collaboration between public and private sectors, with the European Union remaining a key player in facilitating innovation and supporting cross-border cooperation. The EU's commitment to sustainability, mobility, and economic growth, along with projects like GRETA, will ensure that urban logistics solutions remain adaptable and scalable across European cities.

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