URBANIZED

MODULAR AND FLEXIBLE SOLUTIONS FOR URBAN-SIZED ZERO-EMISSIONS LAST-MILE DELIVERY & SERVICES VEHICLES

URBANIZED D7.4: Knowledge transfer performed across missions and use cases replicability guidelines

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Executive summary

To be considered truly sustainable, logistics should be zero-emission, safe for everyone, and with a low impact on urban space, while fulfilling the demands of citizens and businesses. However, current urban logistics still require much development and innovation to reach a sustainable state. The URBANIZED consortium considers that modular vehicles are a key enabling technology in the transformation towards sustainable urban logistics. Modular vehicles can allow for a wider variety of innovative logistics models while increasing efficiency and reducing redundancy for fleet owners. Although the technology for modular vehicles and their logistics models is ready to be scaled up, large gaps still exist in terms of the market, policy, societal and organisational readiness.

To fully leverage the potential of modular vehicles, the following are needed:

1. Appropriate policy to facilitate:
    - long-term strategic clarity for logistics operators and companies
    - space to innovate new logistics models
    - acquisition of innovative delivery vehicles
    - public-private cooperation for knowledge sharing, collaboration, and partnerships
2. Research and trials to develop and validate the integration of modular vehicles and innovative logistics models, accessible to all logistics stakeholders.

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1. Introduction

URBANIZED stands for modUlaR and flexible solutions for urBAN-sIzed Zero-Emissions last-mile Delivery and services vehicles.

URBANIZED aims to prepare urban settings for the future by integrating flexibility and adaptability through modularity in the design of all-electric Light Commercial Vehicles (LCVs), to cover the rapid growth and the changing nature of deliveries and on-demand urban freight transportation (UFT) services while reducing the number of necessary vehicles and dramatically improving last-mile delivery operations.

URBANIZED worked and delivered innovations at 3 levels:

At the vehicle systems level: URBANIZED contributed to solving current automotive manufacturing challenges related to the trade-offs between standardisation and customisation when developing modular vehicle architectures that can serve various user needs by reducing the cost of modularity in each fit-for-purpose application, thus being able to radically reduce production costs for both mainstream and niche applications.

At the vehicle level: URBANIZED contributed to increasing the market offer and uptake of high-performance, urban-sized, zero-emission LCVs optimised for urban and suburban operations that will cover present and increasing future demand for these vehicles by offering superior solutions to the alternatives used today for equivalent missions.

At the fleet level: URBANIZED solved the trade-off between 'One size fit all' and 'Design for purpose' approaches when operating mixed fleets of small commercial vehicles thanks to modular vehicle architectures and adaptable energy management systems designed to increase the usability experience while reducing fleet investments and operational costs.
The overarching objective of URBANIZED was to develop and demonstrate a new flexible and modular vehicle platform for small commercial e-vehicles, satisfying design principles of right-sizing vehicles for specific missions in three dimensions: (i) high-performance e-powertrain components and control architectures, through the use of advanced hardware and software co-design approaches; (ii) interchangeable, plug & play cargo modules for different use cases scenarios and; (iii) integrated energy and fleet management strategies using data, connectivity and predictive control algorithms.

The URBANIZED project defined specific mission profiles within two main pre-selected use cases: last-mile post delivery (Use Case 1, led by partner BPO), and on-demand services and HoReCa (Use Case 2, led by partner COI). These missions will target specific end-user needs, presenting numerous opportunities for partners to learn from each other's experiences. This collaborative approach allowed ALKE, to explore and identify additional relevant applications for the project developments.

This comprehensive report compiles information from previous deliverables and workshops (see Figure 1) to enhance the transferability and replicability of the piloted URBANIZED use cases to other stakeholders, similar market applications, and end-users. It explores how URBANIZED partners can leverage opportunities for effective knowledge transfer within leading organisations and across all involved partners. Additionally, it identifies synergies with other partners and external stakeholders to maximise project results.

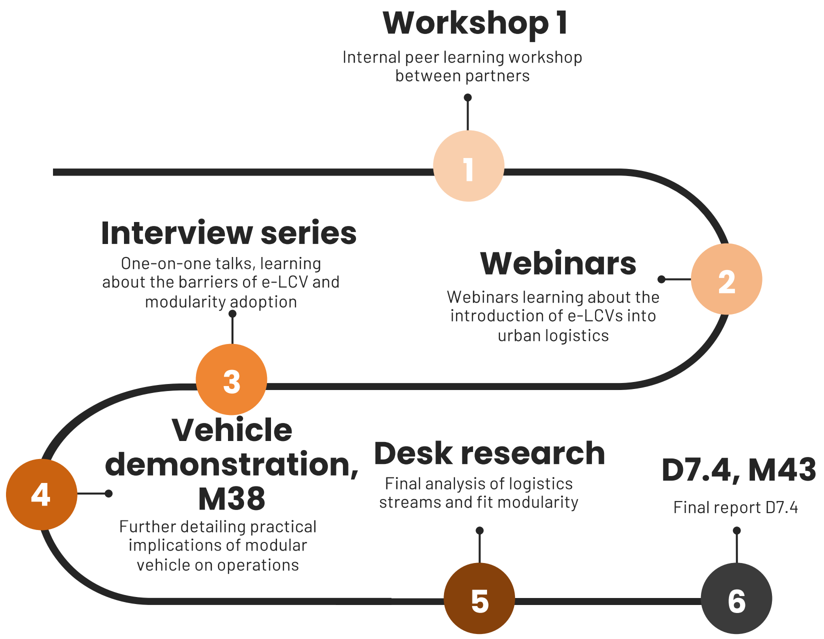

Figure 1. Activities of D7.4

2. Swappable and modular cargo bodies

In the current context of urban logistics and last-mile deliveries, logistics operators must continuously adapt to new business models and logistical frameworks. Incumbent logistics companies are experimenting with operational innovations, while startups are introducing disruptive concepts, including novel vehicles and innovative interactions with both customers and staff. Among these innovations, modular delivery vehicles stand out as a pivotal technology, enabling diverse logistics models and helping fleet owners reduce redundancy and boost efficiency (see Figure 2 for innovation in URBANIZED).

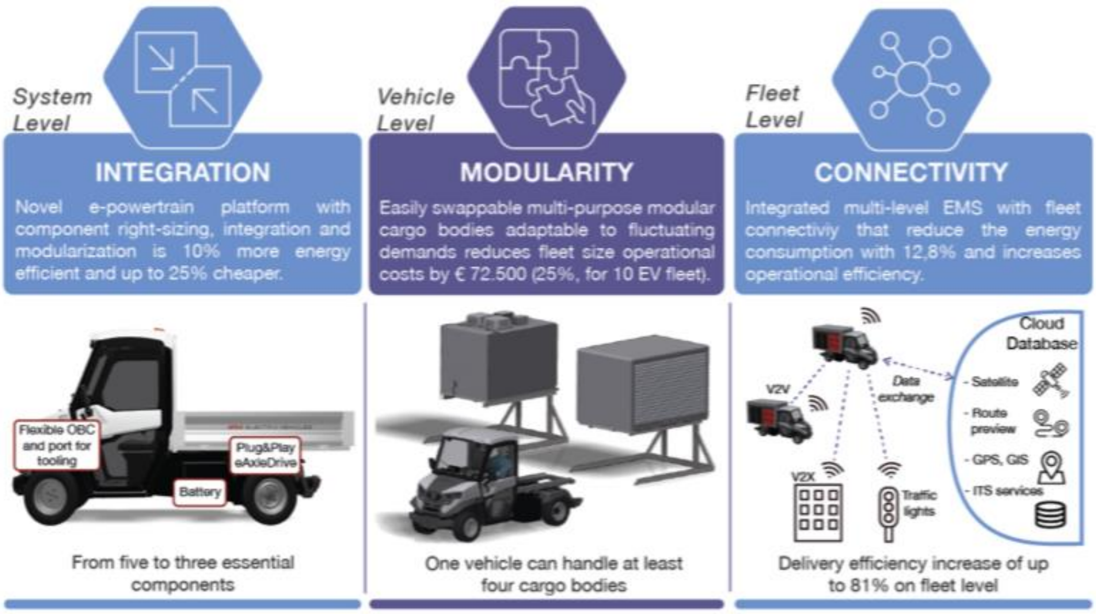

Figure 2. Innovations in URBANIZED

Traditionally, logistics trials have relied on vehicles with fixed cargo bodies, limiting their adaptability. However, modular cargo bodies can revolutionise this approach thanks to versatility, allowing the swift removal and replacement of cargo units, transforming the vehicle within minutes. This flexibility supports a broader range of logistics models, particularly shared and reverse logistics. The benefits of this technology include:

Multi-purpose Fleet Optimization

Swappable and modular cargo bodies offer significant benefits for multi-purpose fleet operators. Logistics demands fluctuate over time, making it challenging for operators to rightsize their fleets effectively [1]. This often results in acquiring excess transport capacity to meet peak demands, leading to overall fleet under-utilization. By employing a singular vehicle equipped with multiple interchangeable cargo bodies, fleets can be resized more flexibly and efficiently. Operators such as leasing companies, municipal services, and suppliers in the

HoReCa (Hotels, Restaurants, and Cafés) sector can greatly benefit from this innovation, using a single vehicle for various logistics purposes over time.

Reducing the Carbon Footprint of Electrification

Modular vehicles can play a crucial role in reducing the total carbon footprint associated with the electrification of transport by facilitating fleet rightsizing. While electrifying delivery vans is a widely accepted measure to mitigate the environmental impact of last-mile delivery—endorsed by the EU Parliament's proposal to ban the sale of petrol and diesel vans by 2035 [2]—simply replacing the existing fleet with electric vehicles (EVs) introduces new challenges. The increased demand for EV batteries places a strain on global supply chains and the environments surrounding mining operations for raw materials [3]. By enabling more flexible fleet management, modular vehicles can help reduce the negative externalities associated with EV battery production and deployment.

Enhancing Warehouse Trans-shipment Efficiency

Modular cargo bodies can also drive innovation in existing logistics streams by expediting trans-shipment processes at warehouses. As last-mile delivery vehicles become smaller and deliveries more on-demand, pre-filling modular cargo bodies at warehouses can significantly enhance operational efficiency. This approach reduces idle time at warehouses, particularly beneficial for delivery vehicles conducting multiple delivery rounds daily. Employing Physical Internet principles, which advocate for modularizing loading units, can further streamline trans-shipment processes, making them more efficient and responsive to dynamic logistics demands.

Modular delivery vehicles contribute to sustainable logistics by optimizing fleet utilization and reducing environmental impact. Their ability to adapt to various cargo requirements minimizes the need for maintaining large, single-purpose vehicle fleets. This reduction in fleet size lowers emissions and operational costs, aligning with the growing emphasis on eco-friendly logistics solutions. Furthermore, modular technology supports the integration of advanced technologies such as electric propulsion and smart logistics systems. The interchangeable nature of cargo bodies allows for easy upgrades and customization, ensuring that logistics operators can stay at the forefront of technological advancements and regulatory compliance.

2.1 Knowledge transfer and replicability actions

To maximize the impact and ensure the successful adoption of modular vehicles and innovative logistics models, we proposed a series of actions aimed at stimulating knowledge transfer and promoting replicability. These actions focus on fostering the uptake of project results, guiding exploitation strategies, and creating learning opportunities within the logistics community.

Stimulate Project Result Uptake

Encouraging the adoption and application of project outcomes is crucial for driving innovation and improving logistics operations. To achieve this, the activities carried out in URBANIZED included:

- **Disseminate Findings**: Actively share the results and benefits of the project through industry conferences, publications, and online platforms.
- **Demonstration Events**: Organize demonstration events where potential users could see the modular vehicles and logistics models in action, providing firsthand experience of their advantages.

Guide ALKE's Exploitation Strategy

Providing clear direction to concretize potential new applications for ALKE is essential for leveraging the full potential of modular vehicles. To support this, this report includes information on:

- **Market Analysis**: Conduct comprehensive market analysis to identify emerging opportunities and tailor ALKE's strategies to meet these needs.
- **Roadmaps for Development**: Develop detailed roadmaps that outline the steps required for the practical implementation of new applications, ensuring a clear path from concept to market.
- **Strategic Partnerships**: Forge strategic partnerships with industry leaders and innovators to expand the reach and application of ALKE's solutions.

Create Learning Opportunities for Knowledge Transfer Between BPost and COI

Facilitating the exchange of knowledge on the potential uses of URBANIZED vehicles and electric light commercial vehicles (e-LCVs) between BPost and COI is essential for mutual learning and improvement. To foster this, some activities carried out included:

Peer Learning Workshops: Online sessions where BPost and COI were able to share experiences, insights, and lessons learned from their respective mission profiles. The last one took place on the 11/06/2024 also including RTOs (TOI, CERTH), where Bpost and COI could discuss and align with ALKE on the potential of project innovations. In this interactive session, participants discussed challenges, solutions, and innovations in the use of URBANIZED vehicles and e-LCVs. The knowledge exchanged on applications of modular vehicle concepts be the baseline for follow-up opportunities and the definition of new relevant use cases.

Logistics Stakeholder Interviews: Conduct interviews with stakeholders from organizations to gather in-depth information on their specific needs and experiences. Series of interviews to understand how barriers impact companies differently based on their size. This gave detailed insights that inform the refinement and adaptation of modular vehicle solutions to meet diverse logistics needs.

Between the end of April and the beginning of May 2024, thirteen logistics companies were interviewed via Google Meet or phone. These companies were mostly French, with some Spanish, Finnish, and international participants. Of the thirteen, ten are involved in last-mile deliveries, two are associations representing them, and one focuses solely on long-distance courier services. The interviews aimed to gather their viewpoints on the feasibility and willingness to use delivery vehicles, particularly electric ones. The questionnaire, consisting of ten questions, focused on the choice of delivery vehicles and the reasons for using or not using electric vehicles, allowing interviewees to express their opinions freely.

It was found that barriers to electric vehicle (EV) adoption are particularly challenging for small companies due to limited capital and the high costs associated with EVs and necessary charging infrastructure. It revealed significant differences in EV adoption capability among large, medium, small, and micro-sized companies. Large companies, which often operate internationally, benefit from zero-emission vehicles through impactful marketing campaigns as customers increasingly value sustainability. All large companies interviewed are using EVs for last-mile delivery, especially in urban areas, seeing this as a competitive advantage that boosts business and benefits the environment.

Medium-sized companies have the capital to invest in EVs but require a guaranteed return on investment before committing to significant operational changes. While some medium-sized companies attract increased business by using EVs, others prefer to wait for customer demand for sustainable delivery options before making the switch.

Furthermore, logistics companies encounter challenges with the availability and reliability of EVs, particularly for high-mileage operations requiring larger vehicles: concerns about the trustworthiness and maintenance of EVs, which may need more resources to manage, also exist. Adjusting routing operations for EVs adds complexity, as companies must consider charging station availability and vehicle range when planning delivery routes, requiring additional resources.

Despite these challenges, some logistics companies are making progress. Solutions like the mutualization of delivery vehicles help reduce the need for multiple smaller vehicles and trips. Others invest in smaller electric vehicles such as e-scooters and tricycles for densely populated areas where larger vehicles are impractical. While EVs have the potential to significantly reduce the environmental impact of logistics operations, their adoption is still in its infancy. Logistics companies face several barriers, but ongoing technological advances and increased sustainability awareness may drive the industry towards cleaner and more sustainable transportation methods in the future.

In conclusion, by implementing knowledge transfer and replicability actions, we aim to foster a collaborative environment where knowledge is shared, innovations are adopted, and logistics operations are continuously improved. This approach will support the widespread adoption of electric modular vehicles and sustainable logistics models, ultimately contributing to a more efficient and environmentally friendly logistics sector.

3. Introduction to the concept

Urban logistics is plagued by pollution, safety issues, and high spatial demands. In urban settings, freight accounts for 15-25% of all vehicle kilometres travelled, contributes 20-40% of urban transport-related CO2 emissions, occupies 20-40% of motorised road space (Towill, 2005) and emits 30-50% of other transport-related pollutants (PM, NOx, etc.)(ERTRAC & ALICE, 2014).

With increasing consumption, the rise of e-commerce, and the limited implementation of ambitious policies, such as LEZs, these issues will exacerbate if logistics operations remain unchanged. Since the COVID-19 pandemic, global e-commerce deliveries have surged by 25%, intensifying last-mile deliveries. By 2030, the last-mile delivery vehicle fleet in the top 100 cities worldwide is projected to increase by 36%, potentially leading to a 32% rise in delivery-related emissions and a 21% increase in congestion, adding an average of 11 minutes to daily commute times per passenger (POLIS & ALICE, 2021).

Recognizing these challenges, the zero-emissions logistics guidelines from POLIS and ALICE emphasize the urgent need for interventions focusing on clean fleets and enhanced logistics operations. Similarly, the new EU Urban Mobility framework calls for accelerated deployment of zero-emission technologies and vehicles in urban logistics (European Commission, 2013). It highlights their economic benefits such as reduced maintenance costs and increased efficiency in congested city centres.

3.1 State-of-the-art in the market before the project

Original equipment manufacturers (OEMs) and urban logistics operators have implemented significant structural changes to develop and adopt smaller, cleaner electric light commercial vehicles (e-LCVs) tailored for urban environments. Currently, the e-LCV market offers limited options, primarily dominated by two models: the Renault Kangoo Z.E. and the Nissan E-NV200. However, many major OEMs are actively introducing new e-LCV models or have plans to do so shortly, indicating an upcoming expansion of choices in this market segment.

In recent years, the proportion of new N1 vehicle purchases in Europe (including the UK) that are e-LCVs has risen from 1.2% in 2019 to 2.9% in 2021. However, the overall uptake of e-LCVs within the total N1 fleet remains low, at less than 0.6% (approximately 166,000 vehicles), out of a total of around 5.5 million N1 vehicles in Europe.

This transition is still in its early stages, with e-LCV penetration showing a near-exponential increase, indicating an accelerated adoption rate in recent years. As we progress through this transition, the combined share of the fleet using alternative fuels, including e-LCVs, accounts for 11% of the market. Despite this progress, a substantial gap remains to be bridged to achieve widespread adoption. Considering the trends of the past decade, it is reasonable to project that e-LCVs could achieve at least a 6% market share by 2030 under a conservative scenario (Frost & Sullivan, 2021). More optimistic market forecasts suggest that e-LCVs could capture between 40% and 73% of the market by 2034. These projections highlight the potential for significant growth in e-LCV adoption as technological advancements continue and policy support for cleaner urban logistics strengthens (Intelligent Transport, 2022).

While some pilot programs have experimented with containerized last-mile delivery vehicles, their full potential remains largely unexplored beyond the research stage. Despite the technology being mostly ready for scaling up and AxleDrive to meet specific market demands, significant gaps persist in market readiness, policy frameworks, societal acceptance, and organizational preparedness for modular vehicles and their associated logistics models. To bridge these gaps, there is a pressing need for smart public-private collaboration and ample opportunities for experimentation and innovation.

The state-of-the-art modularity and swap box technologies for last-mile logistic delivery vehicles show significant promise in enhancing efficiency, flexibility, and sustainability. While the technology is ready for scaling up, broader adoption will require concerted efforts in market readiness, policy development, societal acceptance, and organizational preparedness. Collaborative efforts between the public and private sectors, alongside continuous innovation and experimentation, will be key to realizing the full potential of these transformative logistics solutions.

3.2 Logistic segments in sustainable logistics

Transitioning to sustainable logistics involves more than simply replacing all postal delivery vans with zero-emission alternatives. While postal delivery is a highly visible aspect of daily life, various forms of last-mile delivery exist, each presenting unique challenges in the pursuit of sustainability.
The presence and characteristics of these delivery segments vary significantly across different cities and countries. These variations dictate the specific actions needed to achieve sustainable logistics in each context. This section gives an overview of the different last-mile delivery segments where innovations on URBANIZED projects can be applied and their paths to sustainable logistics.

Parcel & Post

Due to the rise of e-commerce, the parcel segment has expanded significantly, with the B2C market now constituting the majority of the transported volume. This market is dominated by a few large players who are striving to increase their drop density in this primarily cost-driven environment, where many e-commerce recipients expect deliveries to be free.

A parcel deliverer typically delivers about 140-180 parcels per day. Delivery trips are often limited by available time, time slots, or volume, but rarely by the combined weight of the parcels. Since the average delivery route from a sub-hub is approximately 75 km, electrification is a feasible option. At PostNL, about 80% of deliveries are carried out by subcontractors, who mostly use their vehicles.

The order value is generally higher in the B2B segment, while purchase frequency is higher in the B2C segment. Purchasing behaviour differs between business and private markets, with B2B customers buying larger quantities through a longer and more rational purchasing process.

Regarding letters and posts, this segment focuses on delivering business correspondence, including contracts, invoices, and promotional materials, to offices and commercial establishments. Despite the rise of digital communication, a significant volume of business correspondence is still delivered physically. This includes legal documents, contracts, invoices, and promotional materials.

Business correspondence delivery demands high reliability and timely delivery, as delays can impact business operations, cash flow, and legal processes. Postal services often offer tracked and expedited delivery options to ensure that important documents reach their destination on time.

Waste

Waste comes in various forms, including industrial, agricultural, sewage, construction, and energy-related waste. Among these, construction and industrial waste constitute the largest portion. However, the majority of waste collected in urban areas originates from households and businesses (trades, services, and government).

Household Waste Collection: Characterized by higher collection density, often managed by municipalities. Municipalities may either use their in-house collection services or outsource them through contracts ranging from 4 to 20 years, based on price, service level, and type of refuse truck.

CO_2 emissions from household waste collection are comparable to those from business waste collection. These emissions primarily stem from the energy required for lifting and compacting waste into the trucks.

Business waste involves the collection and transportation of waste generated by commercial and industrial activities. This segment plays a crucial role in maintaining urban cleanliness and environmental sustainability, with collection methods including: (i) scheduled Pickups, regularly scheduled pickups based on the volume and type of waste generated; (ii) On-Demand Services, flexible, as-needed pickups for businesses with irregular waste generation patterns; and (iii) Centralized Collection Points, designated collection points where businesses can drop off waste for consolidation and transportation.

Service and facility logistics

The Delivery of services and supplies includes the delivery of goods and services essential for the maintenance and operation of residential, public, and commercial buildings, such as houses, offices, hospitals, schools, hotels, and museums. Transport costs are typically included in the total price of the service contract (DDP) and are not separately visible to buyers. Several of the largest suppliers typically have a market share of about 50% of the total freight volume. Suppliers of services often arrive by car, van, public transport, or bike, whereas suppliers of goods mainly use vans and trucks of various sizes.

There is growing attention to and awareness of the environmental footprint of organizations and facilities. Consequently, there is increasing consolidation of supplies, either at source (e.g., a supplier like Staples) or at one or more smaller hub locations at the city border.

Construction, Housing utility and infrastructure

After the general cargo segment, construction logistics is the second-largest CO_2 emitter in city logistics. The construction segment can be divided into two main market segments: housing and utility, and infrastructure. Each of these segments goes through a planning and tendering phase, a project execution phase, and finally an operating and maintenance phase. An important distinction in construction logistics is between the highly frequent flow of bulk solid and raw materials transported in full truckloads by heavy-duty vehicles during the site preparation and structural phases, and the delivery of semi-finished products, parts, and services in less than full truckloads during the rough and final fitting-out stages.

One factor that adds complexity to construction logistics is that transport orders are often received only one day in advance. This short notice makes it harder to plan transport efficiently and minimizes the potential benefits of bundling deliveries.

Traditionally, there is no overall coordination of logistics at construction sites. Each subcontractor manages their tasks and logistics independently, driven primarily by cost considerations. The approach is highly cost-driven, with minimal focus on sustainability. Factors such as the origin of suppliers, delivery reliability, and environmental impact are often overlooked. Furthermore, there is little monitoring of logistics costs, which makes it difficult to assess and implement logistics innovations. This lack of oversight hinders efforts to improve efficiency and sustainability in construction logistics.

Large infrastructure projects typically involve the transportation of substantial volumes of earth, asphalt, and concrete. Infrastructure developments are often managed by semi-governmental entities with extensive experience in employing innovative approaches to minimise external impacts. Sustainable construction logistics are being enhanced through Building Information Modelling (BIM), which enables virtual construction planning and real-time information sharing with suppliers and partners.

General Cargo

There is an increasing need for agility and responsiveness in supply chains due to more demanding customers. Retailers in these segments are starting to adopt practices similar to e-commerce to offer comparable services. The entire segment is becoming more like the 'fresh' supply chain as the shelf life of goods declines rapidly.

Besides consolidation, there is a noticeable diversification of logistics service providers specializing in urban distribution. These providers are now handling a broader range of products, including fashion and healthcare, not just books.

Large retail chains primarily deal with non-perishable goods. Logistics are centrally organised by the retail chain (the shipper), leading to the consolidation of volumes. Vehicles are typically fully loaded, with drop sizes varying based on the frequency of deliveries.

Partial Delivery: with small Retailers and SMEs, the delivery is often organized by the receiver, with logistics managed by a logistics service provider (LSP), private carriage by the supplier, or the retailer itself. The LSPs handle warehousing and distribution for multiple shippers, frequently serving similar markets (e.g., fashion, books, white goods). They can operate with a few or many distribution centres (DCs).

Many small independent retailers use private vehicles, which are often inefficient and environmentally burdensome. These private deliveries are less affected by Urban Vehicle Access Regulations (UVARs). These stores aim to provide unique experiences, are less focused on scale and volume, and may start to mimic online consumer behaviour, resulting in more frequent, smaller trips. City hubs are especially relevant for this subsegment.

Home Delivery of Large Goods, including Furniture and White Goods, is a smaller segment within home delivery compared to postal and meal delivery, often more expensive. These deliveries involve longer trips due to the greater inter-drop distances. This segment is growing, with innovations such as using a semi-trailer's swap body to carry furniture to the city perimeter, requiring only the last mile to be completed by two persons.

Temperature controlled

Retail Logistics of Large Supermarket Chains, involving fresh Foods**.** Large logistics service providers (LSPs) often handle last-mile delivery from a select number of fresh distribution centres (DCs), compared to the larger number of non-fresh DCs. The supply chain is optimized for high-volume, large-scale, low-cost, and efficient operations.

Wholesaler Food Services to HoReCa and Office Catering (B2B): Transport from DCs to hotels, restaurants, cafes (HoReCa), and office catering in cities involves medium volumes per customer, scheduled transport with medium-sized rigid trucks, and high load factors. Trucks typically make numerous stops in the city, delivering daily supplies of fresh products to around 5 to 10 customers. Wholesalers may use their fleets or outsource this service.

High-value specialist Supplies to Restaurants and SME Specialist Shops (B2B): This segment involves high-value products, low volumes, and inefficient logistics with very low drop density—often only a few stops per city. High-end restaurants may receive up to 20 drops per week. These products are transported using a variety of privately owned cars, vans, and small trucks. Although currently limited in size, this segment is expected to grow significantly as urban areas attract more visitors and generate more restaurant visits.

Home Deliveries of Fresh Products and Meals (B2C) for Supermarkets and Meal Delivery Companies: Home deliveries of online food and fresh products such as vegetables, fruits, and meals (e.g., HelloFresh) represent a rapidly growing market. Experts anticipate that suppliers will need to share their networks to remain cost-competitive. With the disappointing results of pick-up points, supermarkets are now heavily investing in the development of home-delivery networks.

3.3 URBANIZED innovations at vehicle level

The adoption of zero-emission vehicles demands greater use of Urban Consolidation Centres (UCC) (POLIS & ALICE, 2021) and the development of mobility and logistics concepts, services, solutions, and business models to make zero-emission vehicles affordable and practical across diverse applications (2Zero, 2020). This technological and service adoption not only promotes zero-emission vehicle uptake but also enhances long-term mobility resilience in cities (ERTRAC, 2021).

The URBANIZED project developed solutions to facilitate the transition to sustainable urban logistics. The URBANIZED project aimed to innovate clean fleets and logistics operations through modular designs that enable multi-purpose vehicles. The URBANIZED vehicle, belonging to the N1 vehicle class, complements other small electric vehicle classes in urban logistics. While cargo bikes, for example, excel in specific areas (e.g., pedestrian zones), they often lack the load capacity, range, speed, safety, and driver comfort compared to vehicles in the URBANIZED class, making them suitable for diverse scenarios within delivery fleets.

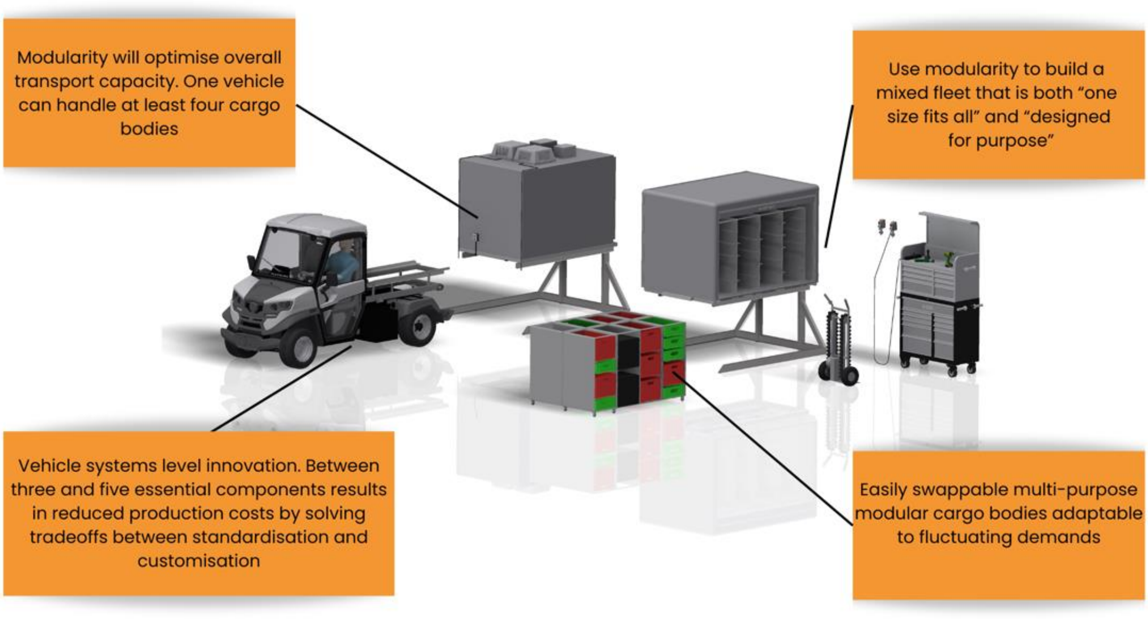

Figure 3. Urbanized innovations

4. Market replicability

It is crucial for scaling up innovations and ensuring that they can achieve widespread adoption and impact. Designing electric Light Commercial Vehicles (LCVs) with market replicability and modularity is key to addressing the rapid growth and evolving nature of urban deliveries and on-demand freight transportation. The market replicability of URBANIZED pretends to be successfully duplicated or implemented in different markets and regions.

To do so, we focused on an approach based on 5 complementary pillars: (i) Scalability: Vehicles should be designed to cater to various scales of operation, from small businesses to large logistics companies; (ii) Interoperability: Ensure that components and modules are interoperable with existing infrastructure and logistics systems; (iii) Cost-effectiveness: Focus on reducing the total cost of ownership through modular designs that allow easy upgrades and maintenance; (iv) Sustainability: Incorporate eco-friendly materials and energy-efficient technologies to align with environmental goals; and (v) User Needs: Design with flexibility to meet diverse user requirements such as cargo space, payload capacity, and range.

4.1 Key Factors Influencing Market Replicability

The modular design approach of the eLCVs ensures that they can adapt to the rapidly changing demands of urban delivery and freight transportation. By focusing on scalability, standardization, customization, and smart connectivity, it is possible to create versatile, cost-effective, and sustainable vehicles that meet the diverse needs of the market. Several factors influence market replicability, including market conditions, regulatory environments, cultural differences, and the adaptability of the product or service.

a) **Market Conditions:** (i) Demand**:** Understanding the level of demand in different markets is essential. This includes identifying target customer segments and assessing their needs and preferences, and (ii) Competition**:** Analysing the competitive landscape to determine the presence of similar products or services and potential barriers to entry.
b) **Regulatory Environment:** (i) Compliance**:** Ensuring that the product or service complies with local regulations, standards, and policies; and (ii) Supportive Policies**:** Availability of government incentives, subsidies, or supportive policies that can facilitate market entry and growth.
c) **Cultural Differences:** (i) Consumer Behaviour**:** Adapting the product or service to align with local consumer behaviours, values, and expectations; and (ii) Marketing Strategies**:** Tailoring marketing and communication strategies to resonate with the local audience.
d) **Adaptability of the Product or Service:** (i) Customization**:** The ability to customize or modify the product or service to meet local needs and preferences, and (ii) Scalability**:** Ensuring that the business model can be scaled without compromising quality or efficiency.
e) **Operational Considerations:** (i) Supply Chain**:** Establishing a reliable supply chain and distribution network in the new market; and (ii) Partnerships**:** Forming strategic partnerships with local businesses, suppliers, and stakeholders to facilitate market entry and expansion.

Market replicability is crucial for several reasons, as it enables businesses to expand their reach and grow their market share by entering new regions and markets. By operating in multiple markets, businesses can diversify their risks and reduce dependence on a single market. Furthermore, replicating a successful business model in different markets can lead to economies of scale, reducing costs and increasing profitability, and it helps in the diffusion of innovations, allowing more people to benefit from new technologies.

To enhance market replicability, it is important to conduct thorough market research to understand local conditions, customer needs, and competitive dynamics. The next step is the implementation of pilot projects in new markets to test the vehicle and gather feedback before a full-scale launch, adapting it to the markets, and end users to fit local contexts. It is important to partner with local businesses, organizations, and influencers to gain market insights and build credibility, as well as maintain flexibility in business operations to quickly adapt to changing market conditions and customer feedback.

In summary, market replicability is a critical factor for the successful expansion and scaling of businesses. By understanding and addressing the unique challenges of each market, the modular vehicle can effectively replicate their business models and achieve sustainable growth.

4.2 Sustainable Solutions and trends relevant to URBANIZED

The adoption of electric and low-emission vehicles in urban logistics is crucial for reducing air pollution and greenhouse gas emissions. Many cities are encouraging this transition through incentives and infrastructure development, such as charging stations and exclusive lanes.

Specially, some examples of Sustainable Solutions and Trends Relevant to Urbanized Vehicles include:

On-Demand Economy

- **New Consolidation Methods**: The shift towards an on-demand economy requires innovative ways of consolidating cargo.
  - **Omnichannel Retailing**: Previously, retail chains could consolidate deliveries with one-stop solutions at physical stores. With the rise of omnichannel retailing, there is an increased need for more frequent and smaller deliveries to various locations, including homes, lockers, and stores. This change demands new strategies to maintain efficiency and reduce environmental impact.

Proximity Logistics

- **Localized Warehousing and Distribution**: Establishing smaller, strategically located warehouses closer to urban centres helps reduce delivery times and transportation emissions.
  - **Urban Warehouses and Micro-Hubs**: By using urban warehouses and micro-hubs, companies can ensure faster and more sustainable deliveries. This approach minimizes the distance travelled and can use smaller, more efficient vehicles such as electric vans or cargo bikes.

Shared Logistics

Shared last-mile logistics services are experiencing renewed interest, driven by urban regulations, government incentives, and shifting consumer preferences towards sustainable delivery methods. For instance, initiatives like the Antwerp-based CULT community exemplify how modular cargo bodies can enhance shared logistics by reducing fleet sizes and increasing operational flexibility. By utilising a single-vehicle chassis with interchangeable cargo bodies, shared logistics operators can efficiently manage a diverse array of delivery needs, improving economic viability and operational flexibility. This approach allows operators to invest in a smaller fleet while maintaining the ability to adapt to varying market demands and capacity requirements.

- **Collaborative Delivery Networks**: Shared logistics involves multiple companies pooling their resources to optimize delivery routes and reduce empty miles.
  - **Multi-Company Delivery Systems**: By sharing delivery networks, companies can maximize vehicle utilization, reduce traffic congestion, and lower carbon footprints. This collaboration can extend to the shared use of warehouses and distribution centres.

Reverse Logistics

Reverse logistics, particularly in business-to-business operations, can significantly benefit from the modular vehicle concept. Establishing additional consolidation points at delivery locations can streamline the return process. In business-to-consumer models, parcel lockers have become a popular solution, enabling customers to return packages conveniently.

Expanding this concept, modular cargo bodies can facilitate more specialized reverse logistics processes. For instance, clothing stores could pre-package returned items in designated modular cargo bodies, while restaurants and supermarkets could collect leftover food in refrigerated units. This adaptability not only supports the circular economy but also enhances the efficiency and sustainability of reverse logistics operations.

- **Efficient Returns and Recycling**: Reverse logistics focuses on the return journey of goods from consumers back to the seller or manufacturer for returns, recycling, or disposal.
    - **Sustainable Return Processes**: Implementing efficient reverse logistics systems ensures that products, packaging, and materials are returned in an environmentally friendly manner. This can include using electric vehicles for returns, establishing convenient drop-off points for consumers, and integrating recycling processes to minimize waste.

By embracing these sustainable solutions and trends, the application and expansion of urbanized on urban logistics can become more efficient, environmentally friendly, and adaptable to the evolving demands of urbanized areas. Furthermore, URBANIZED solutions will be able to be applied, expanded, and adapted to meet evolving demands.

4.3 Solution readiness of the URBANIZED cargo bodies

Deployment of the technology

Small to mid-size manufacturers of e-LCVs have generally customized their cargo bodies to meet the specific needs of their client fleet operators, particularly within the market segment where modular cargo bodies are becoming increasingly ready for market uptake. While the concept of modularity is well-defined, significant work remains to be done. Logistic operators are currently prioritizing electrification before addressing modularity, necessitating a phased transformation that includes staff training, the development of new infrastructure, and structural operational changes. Strong incentives will be essential to drive this development forward.

Logistic operators face the dual challenge of electrifying their fleets and adopting modular cargo bodies. Electrification is often the first step due to regulatory pressures and environmental goals. The transition to modular systems requires: (i) Staff Training: Personnel need to be trained in handling and maintaining modular systems, which differ significantly from traditional logistics operations; (ii) Infrastructure Development: New facilities equipped to handle modular cargo bodies and the necessary charging infrastructure for e-LCVs are essential; and (iii) Operational Changes: Implementing modular systems may necessitate changes in logistics workflows and fleet management practices.

Policy and Regulatory Support

To fully implement logistics models based on modular cargo bodies, supportive policies and regulations are critical. Cities are gaining experience from the emergence of urban logistic hubs and dark stores, but most public policies currently prioritize electrification over space-based restrictions and shared logistics spaces. Key areas requiring policy intervention include:

- **Standardization**: Establishing standards for modular cargo bodies to ensure compatibility and interoperability across different logistics operators and vehicle manufacturers.
- **Incentives for Modularity**: Beyond EV subsidies, specific incentives for adopting modular cargo systems could accelerate market uptake.
- **Urban Planning**: Facilitating space for logistic hubs and modular cargo operations within urban planning frameworks to optimize last-mile delivery efficiency.

Economic and Environmental Impact

The majority of last-mile modular vehicles are zero-emission, and EV subsidies and incentives have positive spillover effects on modular adoption. However, the commercial benefits of the modular concept and related logistics models need clearer demonstration. Key considerations include:

- **Cost Efficiency**: While modular systems can potentially reduce fleet sizes and improve utilization rates, the initial investment and operational costs must be justified by long-term savings and efficiency gains.
- **Sustainability**: Modular cargo bodies can contribute to sustainability goals by reducing the number of vehicles needed and optimizing load management, thereby lowering emissions and congestion.

Societal Pressure and Citizen Awareness in Sustainable Logistics

Societal pressure for sustainable logistics, though currently limited, is beginning to grow as environmental awareness increases. To accelerate the transformation towards sustainable logistics, it is crucial to enhance citizen awareness and support for innovative logistics models. However, logistics models based on modular vehicles have not yet been widely tested or adopted, leaving the public support base for these innovative systems largely unestablished.

Raising awareness about the environmental impact of traditional logistics systems and the benefits of sustainable alternatives is essential. This can be achieved through: (i) Public Campaigns: Government and environmental organizations can run campaigns highlighting the importance of reducing emissions and promoting sustainable logistics practices; (ii) Community Engagement: Local events and workshops can educate citizens on how modular and electric logistics systems contribute to a cleaner urban environment.

As consumers become more environmentally conscious, their preferences can drive demand for sustainable logistics solutions. Encouraging consumers to choose companies that utilize eco-friendly delivery methods can create market pressure for broader adoption. For instance, companies that adopt sustainable logistics practices can use eco-labels to inform and attract environmentally conscious customers. Furthermore, providing incentives such as discounts or rewards for choosing green delivery options can encourage consumer participation.

To build public support, pilot programs and real-world demonstrations of modular vehicle logistics models are necessary. For instance, cities can designate specific areas as testbeds for modular logistics systems, allowing for controlled experimentation and data collection. Moreover, partnering with local businesses for pilot programs can help demonstrate the feasibility and benefits of modular logistics models to both the public and private sectors.

Engaging the public in the development and evaluation of these logistics models can help tailor solutions to meet societal needs and gain support. For instance, gathering feedback from citizens through surveys and focus groups can provide insights into public perceptions and expectations. Creating online platforms where citizens can learn about and discuss sustainable logistics initiatives can foster a sense of community involvement and ownership

Case Studies and Examples

Parcel Lockers: Parcel lockers are a leading example of reverse logistics opportunities facilitated by modular systems. They allow for efficient package drop-off and pick-up, reducing the need for repeated delivery attempts and optimizing delivery routes.

Urban Logistic Hubs: Emerging urban logistic hubs are experimenting with modular cargo systems to streamline last-mile delivery. These hubs serve as centralized locations for pre-sorting and consolidating deliveries, enabling quicker and more flexible distribution.

As the technology matures and more data becomes available, the commercial viability and benefits of modular logistics systems will become clearer. Continued innovation and pilot programs will be essential in demonstrating the full potential of these systems.

4.4 Steps of Market Replicability

To support the adoption of modular vehicles in last-mile logistics, several direct and indirect actions are necessary. All developed modular LCVs to date are zero-emission, and with the EU's 2035 ban (European Parliament, 2023) on the sale of petrol and diesel vans, it is expected that manufacturers will continue to focus on zero-emission powertrains for modular last-mile delivery vehicles. Consequently, actions proposed to stimulate the adoption of eLCVs will also benefit modular vehicles. Here are the recommended steps to integrate modular vehicles into last-mile logistics effectively:

1. **Support for Shared Logistics City Hubs**:
   - **Financial Support and Research Funding**: Municipal and governmental subsidies, as well as financial support during the development stage, can provide shared city hub developers the time needed to scale operations and achieve sufficient logistics volume for economic feasibility (Kin & M. C., 2016).
   - **Real Estate Support**: Infrastructure plans should cater to both logistics and other local needs, requiring research and development towards the use of brownfields, architectural, and urban integration of logistics facilities, as well as business models for shared logistics hubs. The emergence of Low Emission Zones (LEZ) and Zero Emission Zones (ZEZ) could further ensure the financial viability of these hubs.
2. **Smart Collaboration and Policy Integration**:
   - **Collaboration Between Logistics Operators and City Planners**: Effective and innovative policies can be designed through smart collaboration between logistics operators and city planners. This includes integrating Sustainable Urban Mobility Plans (SUMPs) with Sustainable Urban Logistics Plans (SULPs) to fully exploit synergies between personal mobility and logistics as mentioned in the New EU framework for Urban Mobility (European Commission, 2021).
   - **Policy Trials**: Conduct policy trials to stimulate the development of underutilized spaces for logistics purposes.
3. **Urban Vehicle Access Regulation (UVAR) Policies**:

- **Clarity and Involvement**: Logistics operators need clear information about UVARs to plan their fleets and operations effectively. Involving logistics stakeholders in the early stages of decision-making, as recommended by Sustainable Urban Logistics Plan guidelines, is essential. Examples include the Logistiek010 community in Rotterdam, which collaborates with the municipality to introduce a Zero-Emission Zone.

4. **Charging Infrastructure**:
   - **Wide-Scale Deployment**: Policymakers should focus on the wide-scale deployment of both public and private charging infrastructure. As described by ALICE and POLIS guidelines (POLIS & ALICE, 2021), sufficient grid capacity is needed for full fleet electrification. This involves upgrading the national electricity grid infrastructure to meet freight needs and considering shared ownership and services at city hubs to facilitate smaller logistics companies.

Facilitating the adoption of modular vehicles in last-mile logistics requires a multi-faceted approach, including financial support, smart collaboration, clear policies, and robust charging infrastructure. By addressing these areas, we can ensure a smoother transition to sustainable logistics models that leverage the benefits of modular vehicle systems. This approach not only supports environmental goals but also enhances the efficiency and flexibility of urban logistics operations. Specifically in the case of Bpost and Coffee Island the market needs, and the forecast for the next 3-5 years are mentioned in Table 1:

Table 1. Market needs and next 3-5 years

Bpost	**Coffee Island**
BPost will test several models of Light Electric vehicles and will evolve together with cities towards zero-emission delivery	Coffee Island expects significant growth in the Greek coffee market and beyond.
Considering rising parcel volumes vs increasing number of emission-free zones, concept of swappable cargo could become interesting	Focus will be on adapting to evolving consumer preferences, integrating advanced technologies, and staying ahead in a competitive landscape.

5. Technical replicability

To advance the societal, market, organizational, and policy readiness of modular vehicles, research and trials are essential. These efforts will validate use cases and their potential to reduce fleet size and operational costs. Implementing a new delivery vehicle into a fleet requires a sound logistics model, and the complexity for logistics operators is significant. They must consider factors such as available capital, charging strategies, customer demands, zero-emission zones, delivery windows, and drivers' vehicle preferences (Marthaler & A. L., 2022). As described in ERTRAC's Urban Mobility Roadmap (ERTRAC, ERRAC, & ALICE, 2017), large-scale demonstrators should show the impact of logistics concepts, tools and innovations (such as modular vehicles) to city planners. This means any adoption of a new delivery vehicle must be carefully considered. Specifically in the case of Bpost and Coffee Island the market needs, and the results and learnings as well as key innovations from urbanized are mentioned in Table 2:

Table 2. Highlight Key Innovations

Bpost	**Coffee Island**
Physical tests and pilots -Cargo area was experienced as very user-friendly: Dimensions, Accessibility, but need for compartmentation -Action radius was more than sufficient for tested rounds - Engine power sometimes too limited (e.g. slopes) - Limited (driving) comfort (vs current e-vans): Hard suspension, Almost no heating	Through the URBANIZED project, Coffee Island has significantly understood how to optimize its supply chain and logistics operations, achieving remarkable improvements in transportation efficiency and environmental sustainability. Key innovations include the adoption of modular, zero-emission delivery vehicles, advanced route planning systems, and energy-efficient practices.

5.1 Key Areas for Research and Trials

User Interaction and Co-Development:

- **Driver and Fleet Manager Preferences**: Urban logistics drivers have high levels of autonomy, and fleet managers generally consider their needs and preferences. The same applies to cargo recipients and citizens who interact with new logistics models introduced by modular vehicles. Co-developing modular vehicle concepts and logistics models with these stakeholders is crucial for successful adoption.
- **End-User Engagement**: Engaging end-users, including drivers, warehouse operators, cargo recipients, and citizens, in the development process ensures that the vehicles and logistics models meet their needs and preferences, enhancing acceptance and effectiveness.

Equity Among Logistics Stakeholders:

- **Support for SMEs**: Smaller logistics operators, comprising 85% of last-mile delivery companies (ERTRAC & ALICE, 2014), need support to transition to zero-emission operations due to capital, innovation, and absorptive constraints. Involving SMEs in the transition to sustainable urban logistics is vital.
- **Support Tools and Awareness Campaigns**: Developing tools such as Total Cost of Ownership (TCO) calculations and awareness campaigns tailored to the needs of smaller logistics companies can facilitate their interaction with new delivery vehicles and logistics models.

Advanced Logistics Control Systems and Data Sharing Frameworks:

- **Shared and Reverse Logistics Models**: Advanced control systems and data-sharing frameworks are needed to support innovative logistics models. The Physical Internet vision emphasizes the importance of cross-sectoral and cross-stakeholder data sharing in urban logistics.
- **City-Led Data-Driven Collaborations**: Cities can play a significant role in initiating data-driven collaborations that enable efficient shared and reverse logistics operations, fostering trusted operating models where data can move freely.

Standardization of Swappable Cargo Bodies and Infrastructure:

- **Swappable Cargo Bodies and Packaging**: Standardizing swappable cargo bodies, packaging, and surrounding infrastructure can facilitate swifter transhipment across logistics nodes. ALICE's roadmap to the Physical Internet (ALICE, 2020) highlights the need for standardization in loading units, packaging, and infrastructure.
- **Universal PI Container Designs**: Focusing research and trials on integrating universal Physical Internet (PI) container designs throughout supply chains can harmonize the flow of goods and enhance efficiency across logistics chains.

Knowledge Transfer of Urban Logistics Best Practices:

- **Development and Spread of SUMP and SULPs**: The development of Sustainable Urban Mobility Plans (SUMP) and Sustainable Urban Logistics Plans (SULPs) across Europe, partially funded by the European Union, presents an opportunity to disseminate best practices by transport professionals.
- **Prescriptive SULP Guidelines**: Once benefits are demonstrated through research and trials, the EU could include modularity references in SULP guidelines (NOVELOG, 2019), helping decision-makers understand and implement best practices across various city typologies.

Advancing the readiness of modular vehicles for last-mile logistics requires a multi-faceted approach that includes research, trials, and strategic collaboration among stakeholders. By focusing on user interaction, equity among logistics stakeholders, advanced logistics control systems, standardization, and knowledge transfer, we can foster a smoother transition to sustainable logistics models. This comprehensive approach not only supports environmental goals but also enhances the efficiency and flexibility of urban logistics operations, paving the way for a more sustainable and efficient future in urban delivery.

5.2 Surrounding infrastructure

We see a significant opportunity for modular vehicles to be a key enabler in the transformation towards sustainable logistics. These vehicles can incrementally improve the efficiency and reduce redundancy of current fleet operations while also supporting more radical logistics models.

Collaboration for Innovation

There is an urgent need for public and private stakeholders to collaborate and jointly drive innovation in this sector. Currently, the lack of coordination between logistics stakeholders and governmental bodies is hindering progress. By fostering better collaboration, stakeholders can overcome barriers and accelerate the adoption of sustainable practices.

Role of Policymakers

Policymakers have the opportunity to create an optimal environment for logistics stakeholders to innovate. This can be achieved through:

- **Supportive Legislation**: Establishing clear and consistent policies that promote the use of modular vehicles and sustainable logistics practices.
- **Incentives and Subsidies**: Providing financial support to encourage the adoption of zero-emission vehicles and the development of shared logistics hubs.
- **Infrastructure Development**: Investing in robust charging infrastructure and standardizing swappable cargo bodies to facilitate efficient logistics operations.

Role of Logistics Operators

Logistics operators can enable effective policymaking by:

- **Sharing Insights and Data**: Providing valuable data and insights to inform policy decisions and optimize urban logistics operations.
- **Trialing Innovative Models**: Experimenting with new logistics models, even those that deviate from traditional practices, to demonstrate their viability and benefits.

To fully harness the potential of modular vehicles in sustainable logistics, a concerted effort is required from both the public and private sectors. By working together, stakeholders can drive innovation, create supportive policies, and develop the necessary infrastructure including charging stations at warehouses, and renewed warehouses to transform urban logistics operations. This collaborative approach will not only support environmental goals but also enhance the efficiency and flexibility of logistics services.

6. Replicability guidelines for the eAxleDrive

Motivation for the development

Today's EV drivetrains are usually customer specific solutions. For each vehicle manufacturer this is combined with high development efforts in form of money and time. Many small companies and start-ups cannot afford this development or the vehicle target price doesn´t allow it. In addition, the electric LCV market is actually very small, compared with the passenger BEV market and thus potential suppliers of e-drives are not willing to invest in a development that would bring more profit in the existing, significantly larger BEV market. Thus, OEMs of electric LCV are often forced to use existing products "off the shelf" that might not perform ideally in their vehicles.

To make it more attractive for e-drive suppliers like Vitesco to enter into the electric LCV market, this product should have a structure that doesn´t need to be modified for each new application (best case). So, it might be an appropriate solution to create a "scalable" e-drive; the core components of that drive are adoptable to a specific vehicle type, with the lowest efforts in engineering and only with marginal changes at the production line. This concept would lead to the opportunity to "pool" a lot of small business volumes over several OEM at reasonable business outcome. URBANIZED elaborated such a promising concept.

Vehicle classes and technical properties to be targeted

Below are shown some examples of vehicles and their core properties that shall be covered by the URBANIZED e-AxleDrive.

Alkè URBANIZED Vehicle (23 kW)

Voltage:	48 V
Max. Speed:	50 / 70 km/h
Acceleration:	0,9 / 0,8 m/s²
Max. e-machine torque:	153 Nm
Gradeability:	> 18%

Microlino (12,4 kW)

Voltage:	N/A
Max. Speed:	90 km/h
Acceleration:	0-50 km/h in 5 sec.
Max. e-machine torque:	17,9 Nm
Gradeability:	N/A

Tata *ACE* (16....20hp ≡ 11,9...14,9 kW)
Tata *ACE EV* (36hp ≡ 26,8 kW)

Voltage (*ACE EV*):	96 V
Max. Speed:	N/A
Acceleration:	N/A
Max. e-machine torque:	130 Nm
Gradeability:	22 %

Nissan *Sakura* (47 kW)

Voltage:	350 V
Max. Speed:	130 km/h
Acceleration:	N/A
Max. e-machine torque:	195 Nm
Gradeability:	N/A

According to these technical highlights related to A-segment cars, there can be defined the following properties of an e-drive, that should be covered by the possible variations allowed by the URBANIZED e-AxleDrive:

- Voltage range

- Torque range
- Speed range } = Power

In addition, also the mounting position and orientation of such a drive is very often a point of discussion.

Scalability in detail

The e-AxleDrive consists of three components: e-machine, inverter, reducer. Focusing on the e-machine, the following requirements were defined:

Parameter	Target Values @ 48 V	Simulated Results 48 V	Simulated Results 350 V	Comments
Max. torque $M_{max,S2}$	150...200 Nm	**154 Nm**	**206 Nm**	short-term operation mode S2 (ca. 30 s)
Max. torque $M_{max,S1}$	75...100 Nm	**105 Nm**	**121 Nm**	continuous operation mode S1 (continuous)
Field weakening starting at	≥ 1.800 rpm	**1.800 rpm**	**5.100 rpm**	
Max. mech. peak power	28...38 kW	**32 kW**	**124 kW**	
Max. continuous power	20 kW	**20 kW**	**73 kW**	
Max. current consumption I_{max} (RMS)	640...870 A	**350 A**	**318 A**	
Maximum rotation speed n_{max}	8.000...10.000 rpm	**12.000 rpm**	**12.000 rpm**	
Stack length	N. A.	**90 mm**	**90 mm**	

The reducer scalability affords the fulfilment of these properties:

- Suitable for configurations with flexible output shafts
- Possible gear ratios between 6 : 1 and 13 : 1 to cover a wide performance range related to the used e-machines
- Nominal max. output torque 1.700 Nm
- Specific interface for the attachment of different e-machines

The concept allows to create gear ratios in the desired range simply by:

- Change of the primary stage gear wheel, that is part of the intermediate shaft
- Adapted location of the intermediate shaft by varying α

The design of the housing shall be kept without changes (one exception: the bearing positions of the intermediate shaft), independently from the realized gear ratio. All other parts will always remain unchanged. This concept offers also for variants running at small volumes a good cost base due to a marginal number of modifications and due to a lot of parts also used in high volume applications. In the Fig. 4 below the basic variation concept is shown.

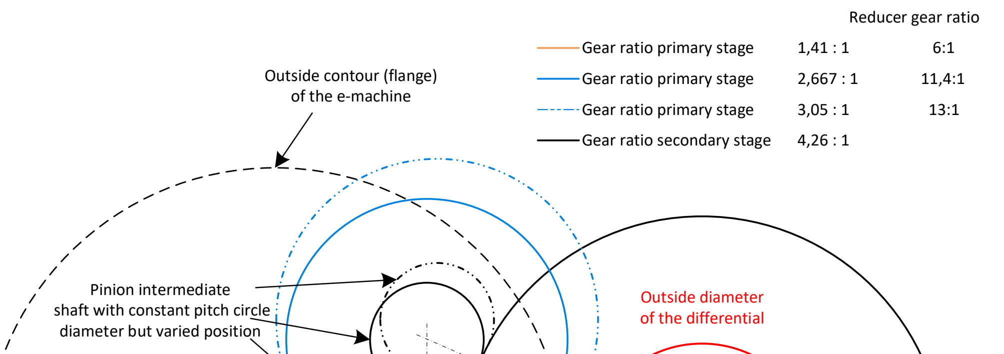

Figure 4. Basic variation concept, e-AxleDrive in detail

Due to its unique lubrication system the reducer allows a flexible mounting position as shown below.

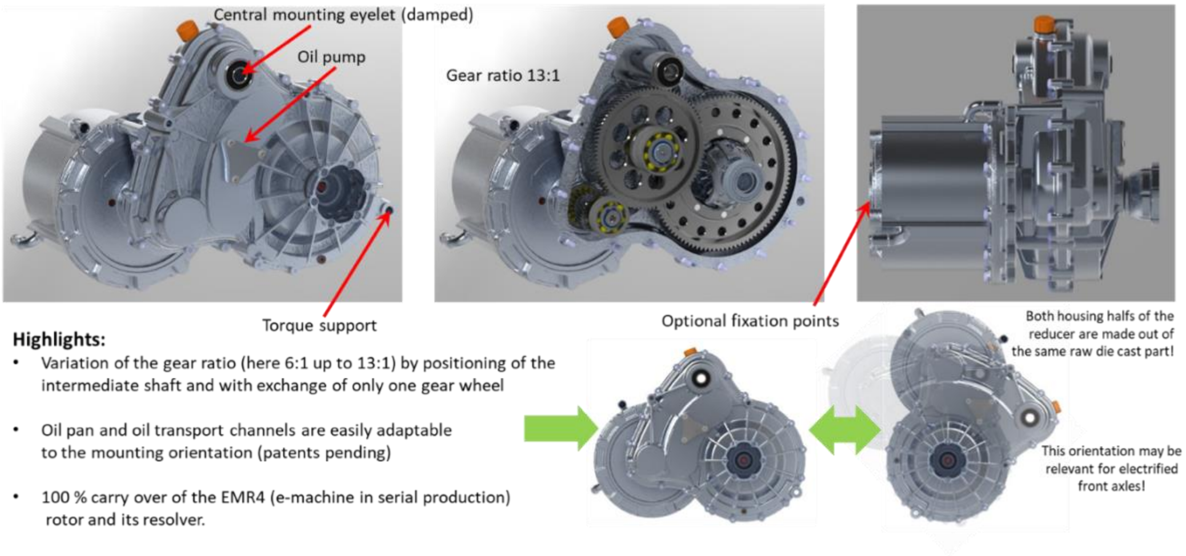

Figure 5. Flexible mounting position, e-AxleDrive reducer

7. Replicability indicator

To ensure the effective replicability of modular cargo bodies across different logistics flows, the following guidelines should be considered:

- **Standardization**: Develop standard sizes and connection interfaces for modular cargo bodies to ensure compatibility across different vehicle models and logistics applications.
- **Customization and Flexibility**: Design modular cargo bodies that can be easily reconfigured to meet the specific needs of various logistics flows. Include adjustable shelving, customizable compartments, and specialized storage solutions.
- **Interchangeability**: Ensure that cargo bodies can be quickly and easily swapped out to minimize downtime and enhance operational efficiency. Standardized locking mechanisms and connections are key to achieving this.
- **Durability and Maintenance**: Use durable materials that can withstand the rigours of different logistics operations. Modular components should be designed for easy maintenance and repair to prolong their lifespan.
- **Temperature Control**: For logistics flows requiring temperature control, such as meal box delivery, ensure that modular cargo bodies are insulated and equipped with refrigeration or heating capabilities as needed.
- **Regulatory Compliance**: Design modular cargo bodies to comply with relevant regulations and standards, including safety, environmental, and urban access requirements.
- **Data Integration**: Incorporate technology for tracking and monitoring the cargo, such as sensors for temperature, and humidity, and GPS for location tracking. This integration helps ensure the integrity of the goods and provides valuable data for logistics optimization.
- **User Training**: Provide training for logistics operators on the use of modular cargo bodies, including how to reconfigure, swap, and maintain them. Proper training ensures efficient and effective use of modular systems.

By following these guidelines, modular cargo bodies can achieve high replicability across diverse logistics flows, enhancing the flexibility, efficiency, and sustainability of urban logistics operations.

Specifically, the replicability indicator assesses how well a modular vehicle can adapt to various logistics flows, enhancing its utility across different sectors and services. This indicator focuses on the vehicle's flexibility and its capacity to be used effectively in diverse operational contexts. The specific use case needs and solutions are shown in Table 3 below.

Table 3 end-users needs and solutions

Company	use case needs	Solutions
BPost	• Large, light parcels. • Need for small vehicle to carry enough parcels. • Standardized compartmentalization for fast loading/unloading. • Price-sensitive, consider lifetime costs. • Daily range < 100 km.	• Modular power electronics adaptable to different battery capacities and charging powers. • Component right-sizing for decreased cost of ownership. • Daily range < 100 km.
Coffee Island	• Accommodate fluctuating demands (chilled and non-chilled products). • Customer-oriented demand with dynamic re-routing. • Delivery of heavy items (up to 30 kg).	• Self-adapted EMS for changing cargo body configurations. • Flexible, integrated on-board charger and vehicle-to-load interfaces.

	• Extra energy from battery for power tools.	• Component right-sizing for decreased cost of ownership.

The primary logistics flows considered include:

Service Engineers:

- **Requirements**: Service engineers need vehicles that can carry tools, equipment, and spare parts efficiently. The vehicle should have compartments or modular sections that can be easily customized and reconfigured.
- **Application**: Modular cargo bodies can be designed with tool racks, storage bins, and secure sections for valuable equipment, ensuring that service engineers have all necessary tools on hand while maintaining organization and ease of access.

Meal Box Delivery:

- **Requirements**: Meal box delivery requires temperature-controlled environments to keep food fresh during transit. The vehicle must also allow for easy loading and unloading of boxes.
- **Application**: Modular cargo-bodies with insulated or refrigerated compartments can ensure meals remain at the correct temperature. Swappable units allow for quick changes between delivery rounds, maintaining efficiency and freshness.

Post and Parcel Delivery:

- **Requirements**: This flow requires vehicles that can handle a high volume of parcels of various sizes. Easy access to parcels for quick loading and unloading is essential.
- **Application**: Modular cargo bodies with adjustable shelving, sorting bins, and secure storage for valuable items can enhance efficiency. The ability to swap out modules quickly can reduce downtime between delivery rounds.

Large Supermarkets:

- **Requirements**: Supermarkets need vehicles that can transport a variety of goods, including perishables, non-perishables, and bulky items. Efficient loading and unloading at multiple stops are crucial.
- **Application**: Modular cargo bodies equipped with separate compartments for different types of goods can streamline supermarket logistics. Swappable units can be pre-loaded at distribution centres, reducing waiting times at each stop.

Urban Consolidation Centres (UCC):

- **Requirements**: UCCs need vehicles that can handle consolidated loads from multiple suppliers, requiring flexibility in cargo space configuration.
- **Application**: Modular cargo bodies that can be customized based on daily load requirements help optimize space and reduce the number of trips needed. This flexibility can improve overall efficiency and reduce urban congestion.

Municipality Services:

- **Requirements**: Municipality services require vehicles for a variety of tasks, including waste collection, maintenance, and transportation of equipment.
- **Application**: Modular cargo bodies designed for specific tasks, such as waste collection bins, tool storage, or equipment transport, can be swapped out as needed, allowing one vehicle to serve multiple purposes.

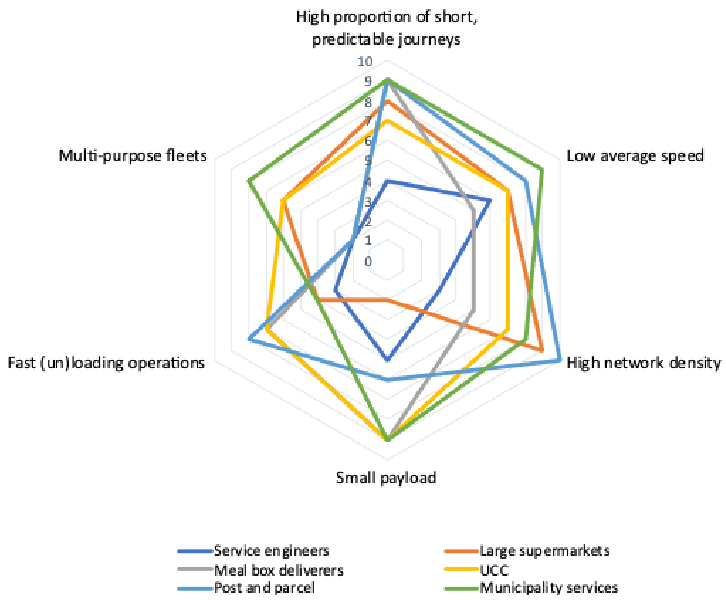

Figure 6. Replicability indicator

Especially for post and parcel (the case of Bpost), it has high network density and ranks low in multipurpose fleets. For the case of meal box deliveries (as is the case of Coffea Island), it ranks high in small payload and similarly low in multipurpose fleets.

Conclusions

Adopting modular and swappable cargo bodies presents a transformative solution for reducing redundancy and increasing efficiency in logistics operations. By allowing for flexible fleet resizing, minimizing the carbon footprint of vehicle electrification, and optimizing warehouse trans-shipment, these innovations can help logistics operators navigate the complexities of modern delivery demands. Embracing these modular solutions will enable operators to achieve greater sustainability, adaptability, and operational excellence in their logistics practices. As the logistics industry continues to evolve, the adoption of modular delivery vehicles will be a critical step towards achieving long-term sustainability and operational excellence.

URBANIZED vehicle innovations collectively enhance the functionality, efficiency, and user-friendliness of the baseline platform by ALKE:

- Full Body Modularity (SWAP System): the vehicle features a fully modular body design, using a SWAP system that allows for quick and easy replacement of the vehicle body. This adaptability enhances the vehicle's versatility for various applications and makes it easier to maintain and upgrade.
- Inner Body Modularity: the vehicle's inner body is designed for modularity, enabling pre-loading at the warehouse level and facilitating quick transhipment. This reduces downtime and increases efficiency in logistics operations.
- On-board tools for last mile deliveries: equipped with an e-hand truck and other essential tools, the vehicle supports last-mile delivery tasks, ensuring that end-users can efficiently handle deliveries right up to the destination.
- Flexible In-Cargo Power Supply: the vehicle provides a flexible in-cargo power supply, allowing users to power tools or specific devices such as portable refrigerated boxes and heating units for food. This feature ensures that perishable items and temperature-sensitive goods are maintained in optimal conditions during transit.

These innovations are valued by end-users in various logistics market segments and applications. As part of this D7.4, we defined a replicability indicator assessing the fit of a modular eLCV to specific logistics flows (service engineers, meal box deliveries, post and parcel delivery, large supermarkets, UCCs, municipality services). That allowed us to compare the specific needs of URBANIZED use cases vs. other replicable scenarios (see Fig. 6).

Finally, as a result of the physical testing in URBANIZED, BPost found that the cargo area was highly user-friendly, offering convenient and efficient space utilization for various types of cargo. The vehicle's action radius exceeded expectations, proving more than adequate for the tested rounds, and ensuring reliability for typical use cases. For the case of Coffee Island, the company showed that the total kilometre driven increased as the cargo area was reduced from 12 to 3 pallets. The utilization of the cargo area increased significantly, from 67% to 94%, with the use of the URBANIZED vehicle, and the daily CO2 emissions were projected to decrease dramatically, from 73.3 kg/day to 8.35 kg/day: one URBANIZED vehicle can serve up to 91.5% of the demand while reducing CO2 emissions by 81%.

To foster the transformation towards sustainable logistics it is important to complement educational activities (for consumers' awareness), supportive policies and urban planning integration. These efforts can help establish a strong public support and drive the widespread adoption of sustainable logistics solutions. As modular vehicle systems are tested and demonstrated, their benefits will become clearer, garnering greater public and industry support for more sustainable logistics.

Acronyms

Acronym	Meaning
BEV	Battery Electric Vehicle
EMS	Energy Management System
HiL	Hardware-in-the-Loop

HoReCa	Hotel/Restaurant/Catering
HV	High Voltage
ITS	Intelligent Transport Systems
ICE	Internal Combustion Engine
KPI	Key Performance Indicator
LCV	Light Commercial Vehicle
LV	Low Voltage
MiL	Model-in-the-Loop
OEM	Original Equipment Manufacturer
OBC	On-Board Charger
SiL	Software-in-the-Loop
SotA	State of the Art
SUMP	Sustainable Urban Mobility Plan
SULP	Sustainable Urban Logistics Plan
TRL	Technology Readiness Level
TCO	Total Cost of Ownership
UFT	Urban Freight Transport
URBANIZED	modUlaR and flexible solutions for urBAN-sIzed Zero-Emissions last-mile Delivery and services vehicles
ViL	Vehicle-in-the-Loop
WBG	Wide Band Gap
WBS	Work Breakdown Structure
WP	Work Package
XiL	X-in-the-Loop
ZE(V)	Zero Emission (Vehicle)

References

ALICE. (2020). Roadmap to the Physical Internet. Retrieved from https://www.etp-logistics.eu/wp-content/uploads/2022/11/Roadmap-to-Physical-Intenet-Executive-Version_Final-web.pdf

2ZeroPartnership. (2020). Draft proposal for a European Partnership under Horizon Europe Towards zero emission road transport. Retrieved from https://www.eralearn.eu/documents/final_report_ms_partnerships.pdf

ERTRAC. (2021). Urban Mobility Resilience Roadmap. Retrieved from https://www.ertrac.org/wp-content/uploads/2022/07/ERTRAC-Urban-Mobility-Resilicience-Roadmap-V3.pdf

ERTRAC, ERRAC, & ALICE. (2017). Integrated Urban Mobility Roadmap. Retrieved from https://www.ertrac.org/wp-content/uploads/2022/07/2017-ERTRAC-Urban-Mobility-Roadmap-web.pdf

ERTRAC, & ALICE. (2014). Urban Freight research roadmap. Retrieved from https://www.ertrac.org/wp%20content/uploads/2022/07/ERTRAC_Alice_Urban_Freight.pdf

European Commission. (2021). The New EU Urban Mobility Framework. Retrieved from https://eur-lex.europa.eu/legalcontent/EN/TXT/?uri=CELEX%3A52021DC0400&qid=1623311742827

European Parliament. (2023). Reducing car emissions: new CO2 targets for cars and vans explained. Retrieved from https://www.europarl.europa.eu/topics/en/article/20180920STO14027/reducing-car-emissions-new-co2-targets-for-cars-and-vans-explained

Frost & Sullivan. (2021). Global Electric Light Commercial Vehicle Growth Opportunities. Retrieved from https://store.frost.com/global-electric-light-commercial-vehicle-growth-opportunities.html

Intelligent Transport. (2022). The potential of modular electric vehicles for sustainable urban freight transport. Retrieved from https://www.intelligenttransport.com/transport-articles/139594/modular-electric-vehicles-sustainable-urban-freight-transport/

Kin, B. V. S. V. L. T., & M. C. (2016). Is there Life after Subsidy for an Urban Consolidation Centre? An Investigation of the Total Costs and Benefits of a Privately-initiated Concept. *Transportation Research Procedia, 12*, 357-369. Retrieved from https://www.sciencedirect.com/science/article/pii/S2352146516000739?via%3Dihub

Marthaler, L., & A. L. (2022). The diversification of a logistics fleet- what does it mean for a manager? Retrieved from https://urbanized.eu/the-diversification-of-a-logistics-fleet-what-does-it-mean-for-a-manager/

NOVELOG. (2019). Topic Guide: Sustainable Urban Logistics Planning. Retrieved from https://urban-mobility-observatory.transport.ec.europa.eu/document/download/9b248341-5a2e-4706-9dc2-5fa334fdcf58_en?filename=sustainable_urban_logistics_planning.pdf

POLIS, & ALICE. (2021). Guide for advancing towards zero-emission urban logistics by 2030. Retrieved from https://www.etp-logistics.eu/wp-content/uploads/2021/12/POLIS_ALICE_Guide-Zero-Emission-Urban-Logistics_Dec2021-low.pdf

Tidblad, A. A., et al. (2021). Future material developments for electric vehicle battery cells answering growing demands from an end-user perspective. *Energies, 14*(4223). Retrieved from https://www.mdpi.com/1996-1073/14/14/4223

Towill, D. R. (2005). The impact of business policy on bullwhip induced risk in supply chain management. *International Journal of Physical Distribution and Logistics Management*, *35*(8), 555-575.
Retrieved from 10.1108/09600030510623339