

Innovative Sustainable Urban Last Mile

Small vehicles and
business models



Nordic
Innovation



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About i-Smile

The objectives of i-Smile are to explore how innovations in last mile may reduce the negative effects of e-commerce, create world-class delivery services for consumers, and increase sustainability in urban last mile deliveries.

i-Smile develops an innovation platform for upscaling sustainable business models for urban last mile deliveries. The platform is both a knowledge base and used to connect different stakeholders to achieve common goals and to further develop Nordic partnerships. The project investigates the rationale of stakeholders in last mile deliveries to identify the drivers for making sustainable choices and propose innovative business models. Primary stakeholders are consumers, shippers, and logistics service providers, as well as municipalities. To meet the growing demand for logistic services due to e-commerce, the project will further investigate the use of light electric freight vehicles (LEFVs) and automatized delivery vehicles in last-mile deliveries. The project also develops new Nordic partnerships that enable the establishment of innovative, sustainable, and integrated urban last-mile logistics chains and to build a strong consortium for future collaboration.

i-Smile investigates existing and potential innovations and value creation in the ecosystem of last-mile deliveries. Also, stakeholders' motivation for developing and/or choosing sustainable last-mile deliveries are studied. A vital research approach for i-Smile is the potential for upscaling the use of light electric freight vehicles in parcel delivery service. The project also maps the impact and exploitation potential of the proposed logistics innovations and analyses the export potential of concepts and governance for export based on the logistics innovations. As a result, the project expands the Nordic level network both with the existing consortium and adding businesses, cities, and other partners for future applications of innovative last mile solutions.

The project has four principal partners and a diverse range of collaborative partners in Finland, Sweden, Denmark and Norway. The four principal partners are Hanken (Finland), VTI (Sweden), Copenhagen Business School (Denmark), and Institute of Transport Economics (Norway).



Executive summary

The report begins with an introduction to the last-mile delivery landscape and provides a list of relevant terminology. It highlights the stakeholders involved in last-mile deliveries, including shippers/retailers, logistics service providers, customers/consumers/citizens, and local authorities.

The focus then shifts to Light Electric Freight Vehicles (LEFVs), defining what they are and presenting case studies showcasing their operational experiences in the field. The case studies were conducted with a diverse range of companies using LEFVs for their urban last mile deliveries.

The report also delves into the development and innovation in the last-mile delivery landscape, analysing media reports and discussing various business models in the sector. A snapshot of the last-mile market development is provided, shedding light on current trends and insights.

Sustainability considerations and the impact of innovation are emphasized, stressing that sustainable last-mile delivery goes beyond just reducing CO2 emissions. Environmental and social factors are discussed, including their effect on urban space and the socio-technical approach.

A case study of DHL Express is presented, illustrating the application of the Dynamic Capabilities approach and microfoundations for the success of e-cargo bikes in their operations.

The report identifies gaps and barriers within the last-mile delivery landscape, which include difficulties in finding staff, transitioning to electric vehicles, and the immaturity of the sector. There is also a lack of involvement from local authorities to address some of the factors that affect urban space and the implications for citizens. To overcome some of these barriers, larger players in the logistics field need to collaborate with smaller companies as well as local authorities such as city governments to implement sustainable solutions.

In conclusion, the report offers recommendations based on the findings, highlighting the importance of sustainable practices and innovation in the last-mile delivery sector to meet the evolving needs of stakeholders and enhance overall efficiency and sustainability.

Introduction

The world faces many challenges today. Climate change causes natural disasters and geo-political unrest. The COVID19 pandemic locked down many economies for months. These events affect the economy and wellbeing of many people. They also change the way people shop and consume goods. The lockdowns boosted e-commerce and online shopping, which require more last mile deliveries, especially in cities. This leads to more noise, emissions, and congestion from urban freight transport. How can we reduce these negative effects and keep the economy, environment, and social conditions balanced? The Nordic Innovation i-Smile project explored this question. It focused on Light electric freight vehicles (LEFVs), such as electric cargo bikes, as a possible solution for more sustainable urban last mile transport.

A recent report from Swedish Trafa (2023) (fig. 1) states that there are around 600 000 light trucks (vans or LGVs) in service in Sweden, double that of 20 years ago. Despite their growing numbers, these vehicles constitute just 2 percent of the total ton-kms being transported. However, they also constitute about two thirds of the total vehicle kilometres, around half the NOx and particulate matter emissions, and a third of all CO2 in Sweden. A vast majority of these light vehicles are driving in our cities, where the NOx and particles are directly harmful to the inhabitants living there. A swift electrification of last mile distribution would thus have a great impact on emission reduction targets.

However, electrification alone does not solve issues related to particulate matter from tires and brake dust, nor does it reduce the amount of space used. E-commerce is expected to grow and with that the need for more freight vehicles in our cities. It is therefore of interest for cities and companies to find ways of reducing the impact of freight activities related to e-commerce. A mixed fleet that includes a significant number of LEFVs could address many of these challenges. LEFVs could alleviate many of the negative impacts that would result from more freight vehicles, and this project has studied these types of vehicles and the possibility of making them a less intruding and more frequent addition to the cityscape by replacing either electric or conventionally fuelled larger vehicles.

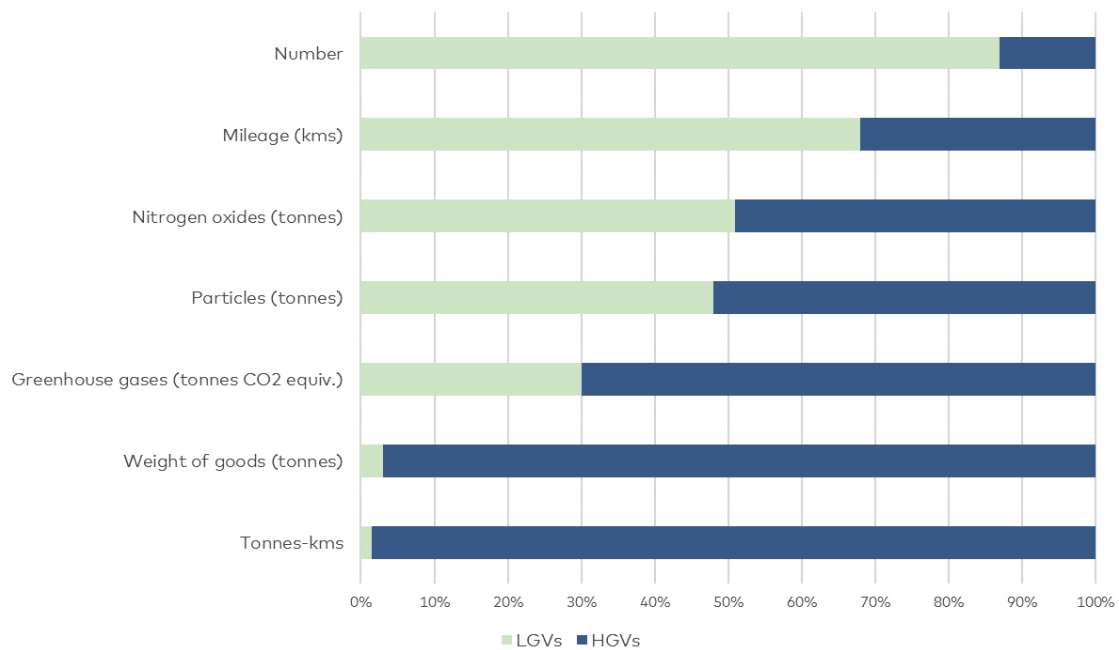


Figure 1 Shares of light and heavy goods vehicles with respect to a range of variables 2023 (trafa.se)

The project adapted a socio-technical approach to the transition towards sustainability of urban last mile deliveries and logistics. This means that in addition to researching technical solutions, a social aspect in the form of business models was integrated. Technical solutions and business models are therefore seen as interdependent entities of the system and if change should happen, this must be done in a socially shared way. Therefore, change takes time and although technical change is not enough, change in the longer run may very well be initiated by technical innovations as well as overall pressures from the macro-environment. In addition to this approach, the dynamic capabilities approach was adapted with the purpose of explaining how LEFVs may lead to competitive advantage for involved LSPs.

This publication is the final report of the i-Smile project, encompassing the main results and recommendations for companies operating in the context of last-mile deliveries. The report includes practical research with case companies as well as a theoretical approach. The socio-technical model is explained thoroughly in the report and juxtaposed with the development in the last-mile landscape.

List of terminology

Term	Definition
Alternative Delivery Location (ADL)	An ADL can be any alternative location to homes where a parcel can be delivered to. This can be a local kiosk, a mobile or permanent parcel locker, or store pick-up.
Automated delivery vehicle	An ADV is a self-driving vehicle that delivers goods on public roads with little or without human intervention. An ADV uses sensors, cameras, artificial intelligence, and navigation systems to drive itself from a retailer, service provider or larger vehicle to a customer's location. An ADV can be a car, van, truck, or robot, depending on the size and nature of the goods it delivers. An ADV can also avoid some of the problems faced by human drivers, such as traffic congestion, parking availability, and driver fatigue.
E-commerce	E-commerce is the online buying and selling of goods or services. It uses websites, apps, or other digital platforms to conduct commercial transactions. E-commerce benefits businesses and customers by offering global reach, operational efficiency, and convenient shopping. E-commerce can operate in different markets, offer various products and services, and use different technologies. E-commerce is a disruptive technology that has changed the retail industry and consumer behaviour.
Last Mile Delivery (LMD)	The delivery of goods to the final destination and/or user. The last leg of the supply chain. The last mile can for example be the delivery of an online order from the terminal or parcel sorting centre to the home of the consumer or to a parcel locker. Types of delivery include for example, attended or non-attended home delivery, mobile or permanent parcel locker, store pick-up and other solutions.

Light Electric Freight Vehicle (LEFV)	Light Electric Freight Vehicles (LEFVs) are vehicles that use electric power to transport goods in urban and suburban areas. LEFVs are typically smaller and lighter than conventional vans or trucks, and can have two, three, or four wheels. LEFVs can be pedal-assisted, such as electric cargo cycles (e-cargo bikes), or fully electric, such as electric scooters or quadricycles.
Logistics Service Provider (LSP)	Company offering logistics services, including last mile deliveries. LSPs may be global companies such as DHL, but also their sub-contractors that do for example home deliveries.
Micro hub	Small logistics facilities where goods are prepared for delivery to the final destination, often using low-emission freight vehicles (LEFVs) such as cargo cycles. They can be operated by a single user or by multiple users who share the space, but do not consolidate their shipments as they would in an urban consolidation centre (UCC). Micro hubs are often located in former retail spaces, underground parking facilities, former gas stations or dynamic containers.
Platform Economy	The platform economy, also called the gig-economy, refers to new forms of businesses and employment where individuals are self-employed freelancers providing services for multisided-platform companies that serve customers providing for example food and grocery delivery.
Retailer/shipper	A retailer or shipper is a business that sells goods or services to final consumers. Retailers can sell in different ways, such as in stores, online, or door-to-door. Retailers can offer different or specific products and provide extra services to the consumers.

Urban consolidation centre (UCC)	UCCs are facilities that aggregate goods flows from multiple carriers, consolidating delivery rounds in the city centres, usually run by one company. UCCs aim to reduce the number of vehicles entering the urban area, improve the efficiency of urban freight transport, and lower the environmental and social impacts of urban deliveries. UCCs can offer various services to their customers, such as storage, sorting, packing, labelling, inventory management, and reverse logistics. UCCs can also use low-emission freight vehicles (LEFVs) such as electric vans or cargo cycles to perform the last-mile deliveries from the UCC to the final destination.
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Table 1 Terms and definitions

Stakeholders in the sustainable last mile landscape

The i-Smile project has focused on gaining a better understanding of how last mile stakeholders, such as LSPs and retailers, operationalize their work with sustainability in their daily last mile operations. This section of the report clarifies the role different stakeholders (Figure 2) play in the pursuit of a more sustainable last mile delivery system.

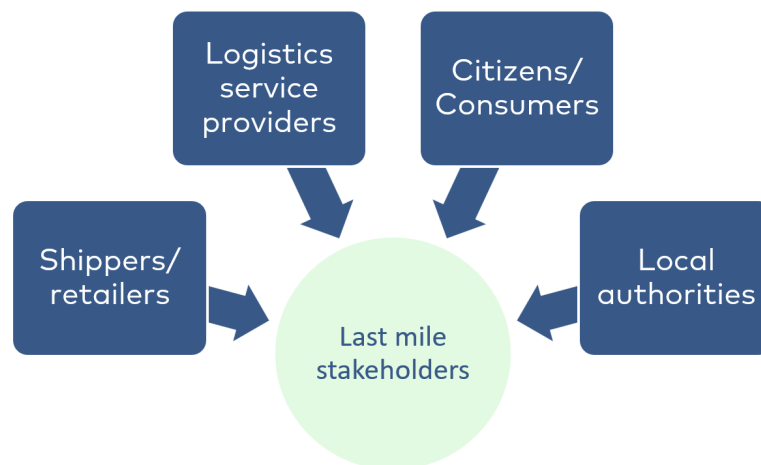


Figure 2 Principal stakeholders in the last mile landscape

Shippers/retailers

Results from both a case study, media analysis, as well as literature suggests there are key focus areas for retailers within last mile operations, including the role of customers, strategy, and daily operations.

For most retailers, their sustainability strategies do not outline specific measures for the last mile, and logistics is scarcely represented in sustainability strategies and reporting. Actions could involve widening the scope of sustainability to include not just environmental considerations for logistics and transport, but also social considerations. In general, the strategic nature of the last mile could warrant it getting more attention at a strategic sustainability level inside companies. From a

strategic perspective, data sharing with partners such as LSPs or payment providers is also a critical aspect of gaining a better understanding of sustainability related aspects. However, it needs to be noted that the availability of electric or other more sustainable delivery options was also mentioned as hindering the development of sustainable LMD from the retailers' perspective.

Retailers currently report rather scarcely on the sustainability of delivery options that are offered to customers at check-out. Many retailers report they feel pressure from customers on including sustainability measures, but few have acted on communicating their efforts. For retailers and LSPs, their main sustainability actions concern the environment, especially CO2 emissions. Customers mainly consider speed and the cost of delivery, but providing them with additional information about the social and environmental sustainability makes it more likely they choose a sustainable option. Retailers are aware they could influence the customer choice by the order in which they present the delivery options at checkout, as most customer are likely to choose the first/top option. This, in addition to information, could be used to influence the choice of a more sustainable delivery option.

In daily operations, companies do already work with sustainability for their last mile deliveries, but more actions could be added. Below is a list of suggestions based on the findings of the i-Smile project:

- Take an active role in promoting sustainable last mile delivery by presenting delivery options with sustainability information at check-out and prioritizing sustainable options
- Utilize the connection with the consumer
 - Provide comprehensive information on products to avoid returns
 - Offer a multitude of delivery options
 - Provide information on the sustainability of deliveries (abiding the EU Green Claims directive)
 - Acknowledge their role in influencing consumption
 - Provide accessibility information for delivery options (in accordance with the European Accessibility directive which mandates specific and additional accessibility requirements for e-commerce services)
- Utilize data and technology to solve sustainability problems: optimization and consolidation solutions utilizing machine learning or AI
- Increase the use of non-emission delivery vehicles, such as electric vehicles
- Prioritize sustainability in the form of land use and electricity when planning and executing fulfilment facilities
- Minimize the return flow utilizing data and technology
- Use of recycled packaging materials and/or returnable packaging

- Data sharing with LSPs
- Carbon compensation (should be used as an additional tool, not a single solution)
- Create frameworks for considering social sustainability including:
 - o Employees (welfare, health, and safety)
 - o Customers (availability, accessibility, health, safety)
 - o Citizens (impact of last mile on society and citizens, including parking, safety, noise, driving)

Logistics service providers (LSP)

LSPs play a crucial role in sustainable last-mile deliveries. LSPs need to maintain efficient and cost-effective services, whilst reducing their environmental effects and ensuring that social externalities are addressed.

Some of the main roles of LSPs in sustainable last-mile deliveries include:

- Route optimization: Logistics providers use for example routing and scheduling software to plan the most efficient delivery routes. This reduces fuel consumption, minimizes emissions, and lowers overall transportation costs.
- Vehicle selection: by selecting eco-friendly vehicles it is possible to reduce greenhouse gas emissions and address other externalities of last-mile deliveries.
- Alternative transportation modes: They explore and implement alternative transportation modes, such as LEFVs or ADVs for deliveries in urban areas to reduce congestion and emissions.
- Green packaging and materials: Logistics providers work with their clients to optimize packaging materials and reduce excess packaging, leading to less waste and more efficient use of cargo space in delivery vehicles.
- Collaboration and partnerships with local authorities, retailers, and other stakeholders to develop sustainable practices throughout the supply chain.
- Last-mile innovation: Investing in innovative technologies, such as autonomous delivery vehicles or drones, can help logistics providers further enhance sustainability.
- Driver training and eco-driving practices: Logistics companies train their drivers in eco-friendly driving techniques, which can lead to significant fuel savings and emissions reduction.
- Monitoring and reporting: They track and report on key sustainability metrics, such as emissions reductions and fuel consumption, to assess and improve

their environmental performance continually.

LSPs delivering in cities have difficulties with obtaining both environmental sustainability, social sustainability, and economic sustainability at the same time. In these endeavours some have introduced e-cargo bikes for particularly environmental sustainability. Still, it may be difficult to obtain economic and social sustainability at the same time. As DHL is one such logistics service provider that has implemented e-cargo bikes in cities, we investigated the factors that could explain their success. If their success can be explained, it is easier for other companies to consequently do the same with improvement of the overall environment.

Deliveries using e-cargo bikes differ to a certain extent from traditional road transport deliveries due to energy source constraints of the vehicles, which are typically human powered. The age and physical health of bike couriers reduce the pool of eligible workers. The use of cargo bikes for last mile deliveries may lead to increased labour costs due to the physically demanding nature of the job, as well as higher health insurance and benefits costs. Additionally, weather conditions such as rain, snow, and extreme heat can also pose a challenge for cargo bike deliveries, as they can make the delivery process more difficult and potentially dangerous. Topography, such as hills and steep inclines, also impacts the feasibility of cargo bikes, as it requires more physical effort from the courier and may limit the amount of cargo being transported.

Customers/consumers/citizens

The omni-channel retail environment has presented consumers with a myriad of purchasing choices and consequently choices regarding the LMD of the items purchased. Our research indicates that consumers have adapted well to the increasing supply of services, but as the playing field is growing and changing quickly, there is a need for more flexibility and innovation from the supply side.

Consumers' attitudes towards decision making are partly based on convenience: the cost of delivery is one of the main aspects valued by consumers, surpassed only by speed. Consumers' reluctance to waste time and/or money is exacerbated with online orders, where the success of the purchase is not clear until delivery, and the wait is perceived as longer than when making purchases in physical stores. The cost of shipping is a deciding factor for consumers as well.

Both the scientific literature as well as the empirical research had some contradictions regarding how consumers prefer to receive their orders. Some research indicates that consumers still choose home delivery, while others argue that pick-up points and parcel lockers are gaining popularity. In our study, what

made a difference in this regard was the context of the consumers. Cities differ significantly in their urban infrastructures, policies, and cultures, which indicates that a one-size-fits-all solution is not viable. In a North American context for example, the use of a private vehicle is very common, whereas in the large cities in China, people do not use cars. In Copenhagen the choice of vehicle is a bicycle and in Helsinki public transport is the norm, particularly among young people. These preferences/choices need to be taken into consideration not just by shippers and LSPs, but also city governments in urban planning. Installing parcel lockers in busy transport hubs would give commuters an option of picking up their orders on the way home from work, for example.

Sustainability in urban logistics is a fertile ground for new innovations and technologies, and many companies have jumped on that bandwagon. Again, consumers are at the centre of this discussion in theory, but few researchers and companies know very much about the consumers' preferences. Communication is understood as one of the main pathways to understanding the needs of both the consumer and the retailer/LSP. Open information is integral in terms of transparency and therefore sustainability, as clarity on the supply chain practices is at the core of sustainability. Participants in the focus groups echoed this sentiment as the lack of information regarding for example sustainable packaging options was missing from retailers' and LSPs' communications. Aspects such as what type of vehicle the order was delivered in were not something participants had actively considered but admitted that now that they knew more about the options, they would pay more attention. Some researchers include factors such as RL, design and packaging, scheduling, and logistical structures in their communication framework, and this ties in with the empirical study in this paper.

When it comes to novel technologies such as ADVs, hedonic motivations come to fruition. Consumers show significant enthusiasm for ADVs and other novel delivery technologies and the potential they have for e.g. reducing congested streets. Hedonic motivations refer to a sense of fun and enjoyment, which can be a significant indicator in consumer choices. Participants who had the opportunity to interact with ADVs through pilots conducted in Helsinki were decidedly positive about their experiences, largely due to the novelty of the technology as well as the enjoyment they got from the interaction.

The sustainability of LMDs is a multifaceted arena, where consumers are influenced to behave in certain ways by a myriad of conditions and motivations, but also bound by for example the facilitating conditions of their economic and time constraints. The context in which they operate in, i.e., the city where they live or the products they are ordering, impacts their decisions as well. Ordering a large appliance such as a washing machine requires different service levels and facilitating conditions (time, finances) than ordering a meal.

Local Authorities

This part of the i-Smile project investigates the impact of local authorities on the transition towards sustainability in urban last mile deliveries and logistics. By local authorities, we here primarily mean city municipalities. We interviewed civil servants directly involved in transport issues from Oslo and Bergen in Norway, Gothenburg in Sweden, Helsinki, and Espoo in Finland, and in Denmark the municipalities of Copenhagen, Aarhus and Lyngby-Taarbæk. In Denmark we also interviewed Copenhagen Electric, a part of the Capital Region in Denmark, as they have specific and deep knowledge of projects and initiatives in both the city of Copenhagen and its suburbs. In addition to the interviews, we further analysed public reports and other material published on websites. Information about the development in Denmark was also collected in the so-called Goods Network, organized by the Capital Region. They further contributed to the i-Smile workshop in the spring of 2023, where they presented their report about urban freight initiatives in the region.

Three of the cities are capitals of their respective countries, namely Oslo, Helsinki, and Copenhagen. Bergen is the second largest city in Norway with approx. 220.000 citizens, as is Aarhus in Denmark with approximately 360.000 citizens. Espoo, with approximately 260.000 inhabitants, is a suburb of Helsinki. Espoo has no specific city centre. Lyngby-Taarbæk, on the other hand, has a dense city centre and is likewise a suburb, but to Copenhagen. The number of inhabitants is approx. 56.000.

All cities emphasize their role in setting the framework conditions for businesses including transportation. As such, a direct impact on the development of sustainable last mile logistics seems to be limited. However, these framework conditions are quite powerful in supporting light electric vehicles or the opposite. Well localized parking spots and times, duration of parking, as well as speed limits in city centres are elements that municipalities are in control of, and specific framework conditions to benefit electric vehicles may have positive impact on the feasibility of light electric freight vehicles.

However, municipalities must comply to national regulations that again are impacted by EU regulation and/or UN agreements for the Norwegian cities. In respect to sustainability, all cities follow the recommendations of emission neutrality no later than 2030 and some even zero emissions by 2050. Oslo has an ambitious climate strategy setting the goal of being a 'carbon negative' city by 2030, thereby contributing to overall reduction of emissions. Bergen targets a 1.5% increase in temperature by 2030 as agreed in the UN Paris Agreement as Norway is not member of the EU.

All cities have published a climate strategy. Transport as such is a part of the strategies, but urban freight usually does not play a significant role in these strategies. Urban freight often disappears among many other and important policies of cities when it comes to climate discussions. One explanation of this could be that there is basically a dilemma between reducing urban goods freight in cities and the needs for supplies of citizens. Furthermore, urban goods freight is part of the private sector which municipalities in general do not have the right to interfere directly with. People transport and mobility that impacts most citizens in their daily life usually gets much more attention in public policy debates.

There is, however, one area where municipalities can have a direct impact on emissions in cities. This area is procurement by the municipalities themselves. Municipalities in Nordic countries manage day care, schools, nursing homes, etc., so sustainable last mile transport to these institutions will matter emission wise. Helsinki and Copenhagen are good examples of this, and Lyngby-Taarbæk is working on expanding their arrangement with a city logistics service provider driving electric vans. They also encourage private actors in the dense city centre to use this solution. The general problem in Denmark is that the law of public procurement dictates that all tasks must be sent to tender, and the cheapest option must be selected. As electric transport solutions are often more expensive than solutions based on fossil fuel, an additional cost must be accepted.

Regarding regulation, the cities generally chose setting of framework conditions to reduce emissions. However, there are some important differences between the countries in that respect. In Norway, Oslo facilitated companies in reserving space for local micro distribution hubs close to the harbour that is very close to the city centre if not a part of the city centre. DB Schenker and DHL Express are using these hubs.

Finland, on the other hand, is eager to support new technologies in distribution such as drones and automated delivery robots. The city of Helsinki accepts applications for new technologies and even calls for such new solutions at times. Espoo often participates in tests of such new technologies. In Sweden, Gothenburg has initiated tests of new technological mobility solutions and transport systems in the project Gothenburg Green City Zone. Finally, Copenhagen has implemented e-cargo bikes deliveries of medicine, tests, and blood samples to and from hospitals. These deliveries are managed by the Capital Region.

All municipalities collaborate with other departments in their own organization as well as with other government entities. As mentioned, urban freight transport is most often not a primary concern of the municipalities. Oslo is one exception due to their ambitious climate strategy. Their focus on urban freight is due to livability in the city centre. Helsinki is another exception due to their 'City Logistics Action Program' and general interest in promoting new technological solutions to

sustainable distribution. Gothenburg is also focusing on urban freight, but in their test areas urban freight is seen as only one part of the larger mobility issue.

Despite the relatively low priority of urban freight solutions, Gothenburg, Helsinki, and Copenhagen have developed systematized meetings with central stakeholders – private and public – in urban freight in the so-called Goods Networks. The purpose of these meetings is to get feedback and input from stakeholders on policy development regarding urban freight and logistics. Importantly, collaboration between stakeholders of urban freight is not always easy due to conflicting goals. Bergen has, for example, postponed the idea of establishing a goods network somewhat due to less successful experiences with collaboration with the private sector. In Aarhus, that is a major port city in Denmark, the municipality is incorporating the private sector in a so-called climate alliance through a working group. Although positive to transformation to renewable fuels, the working group points to the many barriers to transformation. The provisional result of this initiative may have disappointed the municipality, but on the other hand they get very concrete information about the barriers as experienced and perceived by the private sector. The municipality will continue their collaboration with the working group so transformation to renewable energies is still on the table.

The cities often collaborate with other cities in regional, national, or even international networks, the latter in connection with EU projects. EU and national research projects are an important way to increase knowledge about urban freight and last mile logistics. Tests of new solutions and knowledge sharing are important to the cities.

Despite limited direct influence on last mile logistics, cities are important actors in shaping a sustainable future of last mile deliveries and logistics through framework conditions, collaboration with stakeholders, and participating in knowledge sharing and development in research and other types of networks.

Business Models in the Last Mile

Business models in LMD play a crucial role in addressing environmental and social concerns, and optimizing the delivery process for a more sustainable and efficient last mile delivery network. This section presents business models that have a crucial role in the LMD landscape and were explored in more detail within the i-Smile project.

The platform economy has in recent years had a big effect on the last mile, both in terms of increased delivery speed, technology development, as well as new types of freelance or the platform economy. A news media analysis shows trends in different types of last-mile-related platforms that include both corporate use software platforms and digital multi-sided marketplaces (e.g. apps). The emergence of "super apps" has blurred the boundaries between commercial delivery, micro-mobility, and transit, making the last mile even more complex and integrated with other traffic and urban spaces. Some examples of super apps include Venezuelan Yummy, Nigerian Gokada, and Estonian Bolt. Platform business models are part of the sharing economy and affect especially the social sustainability of the last mile, as they are part of the platform economy. However, hyper-local and community-based services like Super and ShopUp play a role in last mile innovation and can have positive effects on social sustainability. In this context it also needs to be noted that FinTech enables new business models for last mile delivery, including secure and quick payments for gig workers. Last mile innovations also appear in agriculture technology (AgriTech) with positive social sustainability impacts.

As last mile is the most resource intensive part of the supply chain, numerous innovations have come forward as solutions to make the last mile more economically, socially and environmentally sustainable. In this report we want to highlight three different business models and innovative technologies in the realm of last mile deliveries that are disrupting traditional delivery methods and business models.

Some strategies that LSPs and other last-mile stakeholders have implemented are:

- omnichannel solutions for fulfilment and pick-up
- flexibility for delivery and pick-up for both LSPs and consumers
- transparency and communication in real time

There are several different business models and solutions that aid in implementing

these strategies. **Parcel lockers** have emerged as a viable solution to involve consumers in the supply chain and remove some of the strain on urban environments and delivery services by consolidating pick-up to a central location. Parcel lockers are an integral part of the omnichannel model for last mile and provide flexibility as well as transparency within the supply chain. They have been a subject of much research interest recently due to their increased prevalence as part of the last-mile delivery process. The flexibility is rooted in the consumer participating in the service in two roles: as the service receiver and the service creator. For consumers, the location of the parcel locker is the most relevant factor for user acceptance, i.e. if the lockers are not placed strategically in places people would visit otherwise, they will rather opt for another delivery solution.

To increase flexibility, **autonomous delivery vehicles** is a solution explored by many companies. They are defined as 'electric and self-driving ground vehicles driving on sidewalks and streets and can manage all driving tasks themselves without human intervention in an urban environment with deliveries/stops and interactions with pedestrians and cyclists'. Previous research has shown some benefits in using the ADVs. It is suggested to reduce greenhouse gas emissions and energy consumption, cost savings, faster service to customers, energy conservation and sustainability, safety for delivery personnel, and accuracy delivering the right package to the right customer. There are several ways in which ADVs are used in the logistics services, some examples of these are presented in Table 2

Type	Description	References
Autonomous support vehicle for letter and parcel deliveries	Use of (multiple) self-driving vehicles that follow the delivery person during the delivery of several packages in an area might decrease the walking distance of couriers. One such example is the German start up Ducktrain. This type of assisted delivery vehicle could be equipped with a number of auxiliary systems to make the delivery job easier. This type of delivery aid could be appropriate to support urban delivery processes. The biggest advantage is its potential to increase the productivity of each delivery person, which makes their job easier and at the same time more attractive.	https://ducktrain.io DHL (2015) Self-driving vehicles in logistics: a DHL perspective on implications and use cases for the logistics industry, DHL Trend Research, p. 35.

Autonomous and integrated mobile parcel lockers	Autonomous and integrated mobile parcel boxes are parcel lockers on wheels that customers open using a personal code. These are also called autonomous ground vehicles (AGVs). These mobile lockers can make door-to-door deliveries or park in a location advertised to customers so they can collect their parcels. These ADVs can make door-to-door deliveries or park in a location advertised to customers so they can collect their parcels and they can come closer to the customer than 'traditional locker boxes. The IT system of logistics company can relay information to customers when the vehicle is nearby. These ADVs have a potential to reduce labour costs, but they require high population density to be economically viable. One example of this is the pilot reported in this paper. Other examples include Dipper and Hugo.	https://www.lmad.eu/use-cases https://www.dipp-r.com https://hugodelivery.com (Bouton <i>et al.</i>, 2017)
Mothership with small autonomous robots/droids	Droids are designed to handle the last logistic step of the delivery process; that is, to navigate the last few kilometres to the end customer. They can be distributed from a static hub, such as a local store, or from a mobile hub, such as a van carrying the robot units and dropping them off outside the intended residential area. They can operate both day and night.	Vans & Robots: Efficient delivery with the mothership concept - YouTube Mercedes van will be a mothership for fleets of delivery robots New Scientist https://univrses.com/case-study/last-mile-delivery-robots-new/

Table 2 Autonomous sketch board and pilot examples from Europe



A Snapshot of Last Mile Market Development

The total size of the global last mile market is expected to reach 200 billion euros in 2027. Since 2010, nearly 330 million dollars have been invested in in mobility technologies and roughly two thirds of this money have been funnelled towards autonomous technology and smart mobility. According to market research reports, the last mile delivery robot market is expected to grow from being valued at 18.1 million dollars in 2021 to reach 36.2 million dollars by 2032. Even if the general investment trend in mobility and vehicle technology has flattened, technology enabling electrification has gained most acceleration in investment. In total, investors have spent over 100 billion dollars on technology in four main sectors of technology:

- **Autonomous** (radar, camera, maps, object recognitions, driving strategy, steer/break, and lidar),
- **Connectivity** (Vehicle to infrastructure, cybersecurity, voice recognition, augmented reality, gesture control, blockchain)
- **Electrification** (Lithium-ion batteries, other battery technology, battery analytics, digital twins)
- **Smart mobility** (including mobility demand management)

Smaller and more targeted technology investments are expected in the future. Funding rounds are very prevalent in technology news and have a great impact on last mile delivery development. Same day deliveries are on the rise and the importance of delivery speed is growing in all sectors. New technology and innovations such as drones, delivery robots, crowdsourcing, dynamic pricing, and different forms of app-based on-demand delivery are part of the rapidly changing last mile landscape.

Sustainable Last Mile Delivery – More than Reducing CO2 Emissions

The findings of i-Smile indicate that there is a need to broaden the discussion on sustainability in the last mile. The business models introduced in the previous section demonstrate that there is growing interest in practical iterations of improving last mile practices and making them more sustainable from diverse social and environmental perspectives.

However, currently the focus relies heavily on CO2 emission. Reducing CO2 emission and other greenhouse gases (GHG) is in itself a very important goal, but sustainability work could benefit from a larger view on sustainability aspects, as visualized in Figure 8. The last mile is very complex and contains a multitude of stakeholders, including, but not limited to customers, retailers, logistics service providers (LSPs), cities/municipalities, and citizens. All these stakeholders hold different interests when it comes to sustainability. Especially social sustainability has been identified as an underrepresented research topic in both previous research and in this project, and a better understanding of the scope of sustainability as well as the varying interests is needed to facilitate a better adoption rate of sustainable innovations in last mile delivery (Kiba-Janiak et al., 2021).

As businesses are built on the premise of economical sustainability and profit-making, this remains the most researched topic within the last mile. The research project has revealed that managers of retailers and LSPs alike still mainly consider CO2 emissions and in terms of social sustainability, working conditions. This means that considerations like safety, noise pollutions, microparticles from wheels and other important effects of the last mile remain largely unaddressed by businesses. Thus, the research in the i-Smile project has been focusing on both the environmental and social considerations within the last mile and urban delivery.

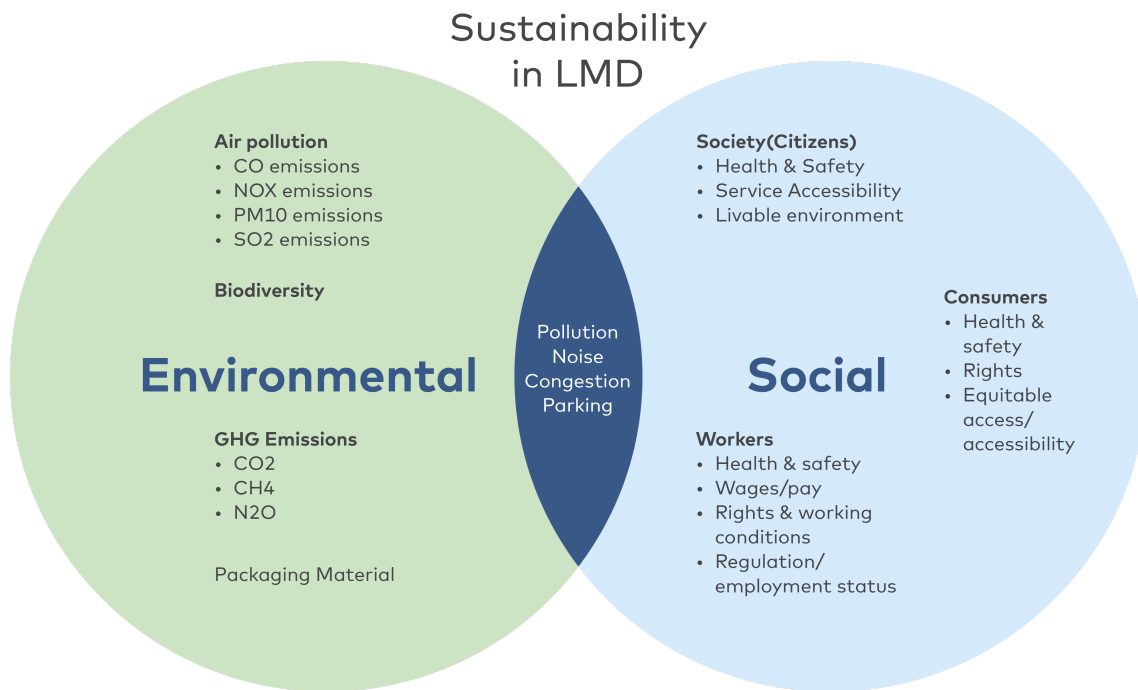


Figure 3 Factors of sustainability in last mile deliveries

Figure 3 illustrates the different aspects of sustainability described in research literature as being of importance when discussing sustainability in the last mile.

Environmental and social considerations in the last mile

In this report environmental sustainability focuses on CO2 emissions. However, the full scope of environmental sustainability needs to be included when considering environmental sustainability for the last mile. This means all sustainability related challenges pertaining to the environment, including CO2, nitric oxide (NO), nitrogen dioxide (NO2), sulphur dioxide (SO2) emissions, microparticle emissions (PM10), and direct and indirect effects on biodiversity. Some examples of environmental considerations and their effect on the last mile:

- Using delivery droids (curb-side autonomous delivery robots) can be a cost-efficient way to improve environmental sustainability, but trade-offs include social sustainability challenges regarding safety and equity
- The environmental sustainability of LMD depends partly on to which degree the delivery can substitute the customers personal car travel, and by which means the freight of the delivery is organized
- Efforts like using more environmentally friendly LMD vehicles such as cargo bikes and automated delivery vehicles can block traffic flows, so traffic

effects need consideration in the adoption of such solutions

Social sustainability refers to all social impacts, challenges, and considerations caused by the last mile. Here it is important to highlight not just the workers, but also the consumers, as well as society at large as social stakeholders. Examples include worker rights in the platform economy, safety and accessibility of services for consumers, and the effect the last mile can have on the liveability of urban space. Due to the complexity of sustainability issues, many concerns are intertwined, for example how noise pollution affects both the health of citizens and urban wildlife. Especially new LMD schemes brought by the platform economy have highlighted issues like working conditions, road safety, bad weather conditions, overloaded cargo bikes and other work-related accidents as well as issues with employment status and payment uncertainty. Some recent social sustainability issues identified for workers within LMD are time pressure and tight deadlines and country specific work regulations that impact working conditions. The pandemic brought new pressures and safety risks for delivery riders, as they faced long working hours and job pressure as well as a fear of financial loss leading to speeding and other risky behaviours. Social sustainability issues for the end-customer related to LMD include the available delivery times and opening hours that can cause segregation, the security of parcels and the security of the customers when picking up deliveries, as well as the availability of deliveries to underprivileged populations.

Urban space

The concept of urban space varies considerably depending on geographic locations. Issues such as traffic congestion, traffic safety, and pollution are examples of some over-arching issues, but the scales vary significantly. Citizens are particularly focused on alternative, eco-friendly transportation modes like walking, public transit, and cycling, and these were not given sufficient attention.

Safety in urban areas, including concerns related to the LMD process, was a recurring topic. Many citizens expressed reservations about picking up orders from parcel lockers, deeming them unsafe. Logistical operations, particularly the presence of delivery vans, were viewed as encroaching on urban space, often at the expense of pedestrians and cyclists. Several participants cited concerns about food delivery services, where multiple vehicles would converge on the same city block due to separate orders. Even when couriers used electric bikes or scooters, they were perceived as disregarding standard traffic regulations, leading to disruptions.

In terms of LMD, citizens have strong interest in exploring various vehicle types, including electric and autonomous vehicles. However, citizens also acknowledged

that they had not fully grasped the relationship between lighter, more efficient vehicles and the optimal use of urban space. In particular, the potential expansion of Autonomous Delivery Vehicles (ADV) sparked curiosity. Citizens from Helsinki have had experiences of a robot delivering groceries, highlighting the evolving nature of last-mile delivery in urban settings.

Key points to consider in the context of urban space and last-mile delivery:

- **Variation in Urban Space:** Urban space dynamics differ based on geographical location, leading to varying transportation preferences and infrastructure priorities.
- **Traffic Congestion:** Some cities, like Vancouver, face significant traffic challenges, which affect transportation choices and prioritization of eco-friendly options.
- **Safety Concerns:** Participants expressed safety concerns related to LMD, including the safety of picking up orders from parcel lockers.
- **Logistical Intrusion:** The presence of delivery vans and multiple delivery vehicles in urban areas was perceived as encroaching on space designated for pedestrians and cyclists.
- **Disruptions in Traffic:** Participants noted that couriers, even on electric bikes or scooters, often did not adhere to traffic rules, causing disruptions in urban traffic flow.
- **Interest in Alternative Vehicles:** Participants showed a keen interest in exploring electric and autonomous vehicles for last-mile delivery.
- **Potential for ADVs:** Autonomous Delivery Vehicles (ADV) garnered attention, representing a potential evolution in last-mile delivery solutions.
- **Evolving Last-Mile Technologies:** The use of robots for delivering goods, as seen in examples like the robot delivering groceries in Helsinki, highlights the ongoing technological advancements in last-mile delivery.

Light Electric Freight Vehicles

This section delves into the dynamic landscape of last-mile deliveries, focusing particularly on the role of Light Electric Freight Vehicles (LEFVs).

Defining light electric freight vehicles

These vehicles, encompassing cargo cycles, electric mopeds, and other L-category options, are gaining attention for their potential to address environmental concerns associated with traditional logistics in urban areas. Despite their energy efficiency and environmental benefits, integrating LEFVs into established logistic systems poses challenges. Their small size, advantageous for navigating congested city centres, comes with limitations in terms of volume and weight capacity. This section explores the regulatory advantages, operational strategies, and challenges associated with LEFVs through real-world case studies and operational experiences, shedding light on the drivers and barriers for their successful adoption in last-mile delivery systems.

In the ever-changing landscape of last mile deliveries, LEFVs have drawn attention as a potential solution to many of the negative externalities associated with logistic activities in cities. They are more energy efficient, emit less pollution, and take up less space than traditional vehicles. However, it can be a challenge to integrate these newcomers into established and sometimes rigid logistic systems that have developed alongside traditional vehicle types (such as vans). Despite their advantages, LEFVs have different requirements and capabilities that must be addressed for them to be considered a suitable alternative.

LEFVs can be roughly defined as freight vehicles smaller than a van with a maximum capacity of 750kg, and can be again divided into cargo cycles, electric mopeds, and other L-category vehicles such as microvans and quadricycles (van Amstel et al. 2018). These categories are somewhat flexible and constantly being challenged by new innovations in vehicle technology and design. Cargo cycles have proven especially resistant to hard categorization, with the recent acceptance of a series of hybrid drive trains by the EU allowing new chain-less designs of three- and four-wheel heavy cargo cycles to flourish (Roetynck, 2022).



Figure 4 Paxster electric quadricycle (left) and Velove cargo cycles (right) are two examples of LEFVs. Photo credit: Howard Weir

One of the major advantages LEFVs offer is their small size, allowing them to operate with ease in areas that are challenging for larger vehicles to navigate. This applies not only to driving in dense city centres, but can also have implications for how terminals are organized; the small size of LEFVs allows vehicle loading zones to be more compact and flexible, saving space. Their small size can also make it possible to park closer to customers as they can bypass barriers such as bollards that prevent access for larger vehicles.

Depending on the type of LEFV and the city and country in which it is implemented, there may also be a number of regulatory advantages to be gained over traditional vehicles. They are, by definition, zero emission vehicles and face no restrictions in cities that have implemented low or zero emission zones. Drivers may require a more simplified moped license or, in the case of cargo cycles no license at all to operate the vehicle, which increases the pool of potential employees. Cargo cycles have the added benefit of not being restricted to where they can travel and park, using both road and cycle infrastructure. In some countries, such as Norway, these vehicles are also allowed to use the sidewalk.

Automatic delivery vehicles (ADV)s have been suggested as one solution to sustainability challenges in LMD. To advance and scale up the use of ADVs, it is important to understand the perspectives of different stakeholders LMD; the consumer and/or citizen, the sender, and the city authorities in charge of urban infrastructure. From a sustainability perspective these developments are important to track as the use of ADVs in urban areas can significantly reduce CO2 emissions and reduce energy consumption. There is a large variety of so called “micro-vehicles” intended for delivery, and they differ in terms of size, sensor technology, driving behaviour, and infrastructural needs and in how they affect different aspects of sustainability.

However, their small size naturally limits their capacity for both volume and weight. According to the type of LEFV used and the type of goods to be delivered, different strategies must be implemented to address their limitations and make them competitive with other vehicles. The two primary strategies seen are to either 1) limit the type and size of goods delivered such that an entire workday's worth of goods can be carried without needing to reload or 2) to arrange transloading points

in the delivery area so the LEFVs can take multiple rounds to refill.

Transloading points can be as simple as an exchange of goods between a large vehicle and a smaller one at a designated location or they can be facilitated using more permanent infrastructure such as a micro terminal or city hub. Some of the LEFVs used by companies involved with the i-Smile project could reload as many as five times in the course of a day at a city hub, which greatly expanded the size, weight and type of goods that could be delivered by these smaller vehicles.

However, transloading can introduce significant costs to the supply chain, both through the increased complexity that results from adding an extra stop, as well as the costs related to the space and infrastructure needed in desirable locations near the delivery area. The cost of the additional goods handling needs to be offset by increased efficiency and benefits as a result of using smaller vehicles to make the final delivery. While the extra costs are often borne by the LSPs, the benefits (such as reduced traffic or pollution) are more difficult to capture from an economic perspective, which can make finding a viable business model challenging.

Case studies on operational experiences of LEFVs in the field

To better understand the use of LEFVs, researchers from i-Smile collaborated closely with the partner companies to collect data. Through interviews, site visits, route data and surveys, the i-Smile project was able to gain insight into the real-world operations of LEFVs and better understand some of the drivers and barriers for their success. An overview of the data collection activities is available in Table 1. Three case studies were conducted. Two companies' (A and B) use of cargo cycles in coordination with a city hub were examined to better understand how different delivery profiles (weight, volume, goods type) could impact the use of cargo cycles. Company C's rapid adoption of the Paxster electric moped for their delivery operations also offered the possibility to better understand how drivers experienced the transition from using a private vehicle to using a LEFV.

Type of data	Quantity
Interviews	20
Email exchanges	Approx. 500
Company websites	Approx. 50
Company documents	20–25
Route data	2 companies
Site visits	2
Survey	1

Table 3 Overview of interaction/data collection from companies

Company A used electric vans, trucks and cargo cycles based on a city hub to distribute packages in the city centre. The overlapping routes meant that these vehicles interacted closely with one another and operated in slightly different ways. Drivers working in the same area of the city had the possibility to exchange packages with one another based on their experience as to which vehicle type would be best suited for a specific delivery. Drivers reported that the cargo cycles were better suited to delivering smaller packages in areas that were harder to reach for vans, whereas the vans were more likely to have a larger number of packages to areas such as shopping centres. The different delivery profiles for Company A show up in Table 2 as a large relative difference between the number of deliveries versus the number packages. We also see that the cargo cycles refilled three times and carried less weight on average.

Company B used cargo bikes to replace vans and the delivery loads were characterized by smaller, lighter packages (often envelopes). This proved to be the ideal use case for a cargo cycle as they were not limited by needing to return frequently to the hub to refill, and instead could maximize their advantages of using multiple types of infrastructure and traveling closer to the customer without being hindered by traffic. It is also important to point out that the actual weight per parcel on the cargo cycles for Company B was even lower than 2,5 kg, since Company B used a sweeper van for the heavier parcels. A sweeper van is a term for a van that delivers (heavier) parcels within the same delivery zone as, in this case, smaller vehicles. In both cases we see that cargo cycles travelled significantly fewer kilometres than vans, suggesting they were better able to utilize short cuts and

take more direct routes to customers.

Averages	Rounds	Number of deliveries	Volume (m3)	Number of packages	Kilometre /day	Total weight (kg)	Package weight (kg)	Delivery weight
Cycles (company A)	3	37.9	2.2	64.7	23.4	320.8	5.0	8.4
Vans (company A)	1.5	43.2	3.7	102.6	52.8	492.6	4.8	11.0
Cycles (company B)	1	76,9	n/a	n/a	23.0	Max 125kg	<2.5	n/a
Vans (company B)	1	67,8	n/a	n/a	73.0	n/a	2,5	n/a

Table 4 Overview of route data from two companies using cargo cycles and vans

Company C's switch from having drivers use their own vehicles to make deliveries to providing each employee with a Paxster was of particular interest. The company experienced benefits in terms of the speed at which routes were completed using the new vehicles and were better able to standardize some of their loading and sorting processes, but wanted more information about the reception of Paxster by their drivers.

To this end, a survey was designed and sent out to 1179 drivers at a national level. 321 answered, among them 94 users of the new LEFV and 227 who used their own private vehicle for work. The survey included questions about vehicle use, workload, and challenges in the workday. Perhaps unsurprisingly, the results showed quite strongly that weather protection is a major concern for drivers, suggesting a need for adaptations that better protect from the rain and cold.

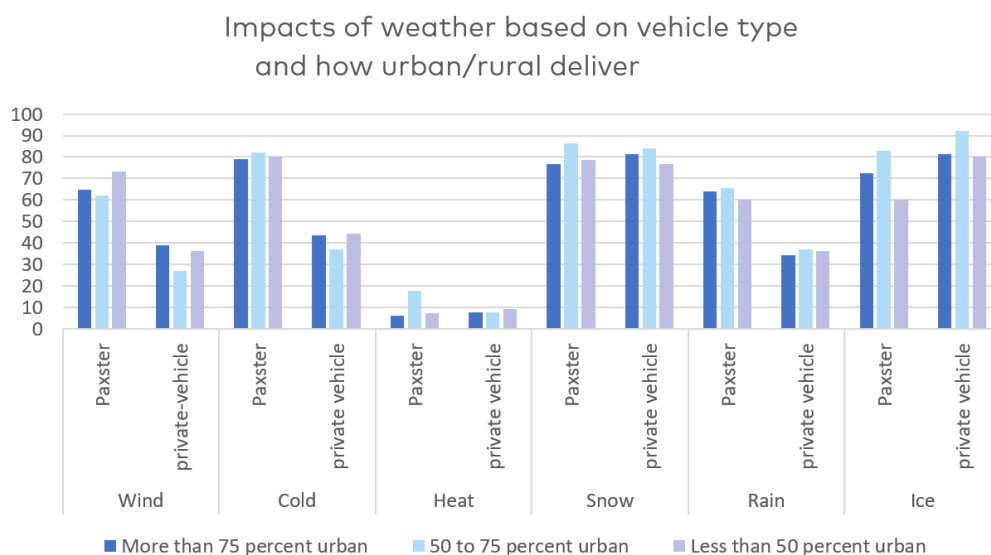


Figure 5 Percent answering often or sometimes challenging according to vehicle type, how urban/rural delivery route is, and weather type

Better weather protection could be accomplished both through changes in hardware, such as heated seats and floors, or through adaptations using clothing and equipment and teaching drivers how to dress to remain warm. Interestingly, while snow and ice created challenging conditions for LEFV drivers, the drivers using normal cars responded that they were just as, if not more, negatively impacted by poor road conditions. Whether a route was mostly urban or rural had little impact on how challenging weather and road conditions were perceived by the drivers. Drivers of both cargo cycles and Paxsters reported in interviews that they felt it was often easier to navigate snowy and icy conditions with a smaller vehicle.

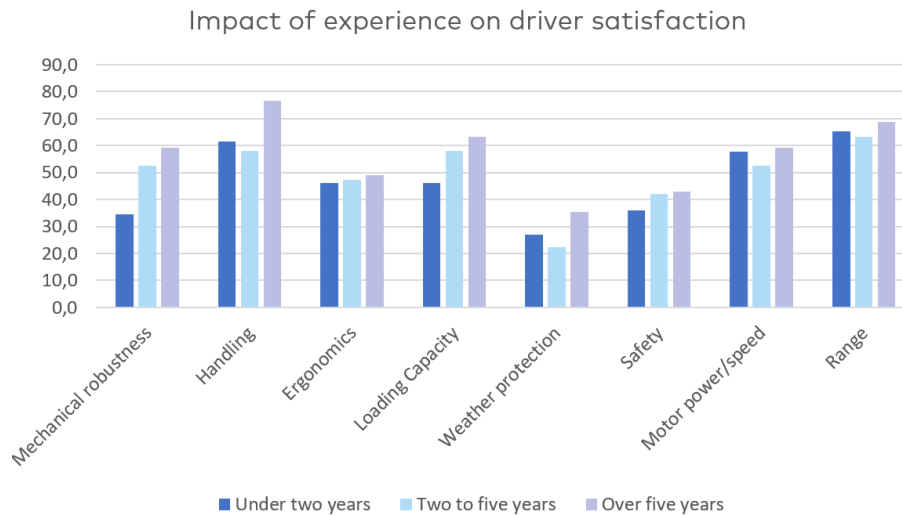


Figure 6 Percent of drivers either very or somewhat satisfied with different aspects of the LEFV used at work.

Results from the survey also showed that driver satisfaction for eight different aspects of LEFV use increases over time (Figure 5). However, there is clearly room for improvement in areas such as weather (discussed above) and safety. The drivers in this survey were using either their own private vehicle or a Paxster, and we saw generally that they were more willing to be critical towards the Paxster. However, when asked what type of vehicle they would choose to do the job, 70% of Paxster drivers reported that they would choose Paxster again. On the other hand, those who use their own car were interested in continuing to use either their own vehicle or a van. These results show a certain scepticism towards using LEFVs, but also that it can become the preferred vehicle choice if it is well suited to its task.

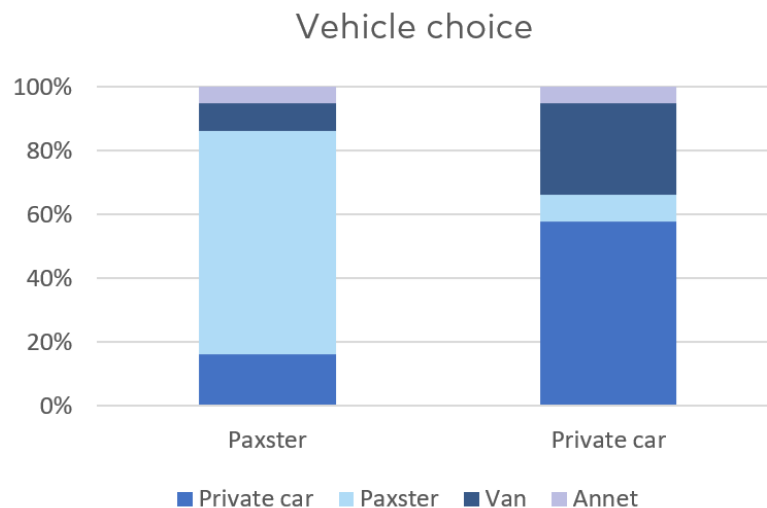


Figure 7 Given a choice, which vehicle would you choose? According to which vehicle drivers currently use.

LEFVs for sustainability and innovation

From a sustainability perspective, these developments are important to track as the use of autonomous delivery robots (ADR) in urban areas can significantly reduce CO2 emissions and energy consumption. There is a big variety of so called "micro-vehicles" intended for delivery and they differ in terms of size, sensor technology, driving behaviour, and infrastructural needs, and in how they affect different aspects of sustainability. In the news analysis it was evident that sustainability is not a key topic when discussing last mile development, aside from electric vehicles being zero-emission vehicles. Social sustainability considerations included the safety of customers and pedestrians when encountering autonomous vehicles. In most cases sustainability is implicit, meaning it is not the focus in articles, but the technology contains measures that could be considered to impact sustainability. The main issues that are reported are related to social sustainability and the working conditions of couriers who work as entrepreneurs or freelancers for platform providers in sharing-economy schemes. Here strikes and concerns have gained media attention, but also the lack of available workfares and delivery drivers are emerging topics globally. These themes are also supported by interviews conducted within this research project.

The transformation of the last mile landscape, visible in the news media, includes rapid innovation in both vehicles, software, and business models. These changes all impact sustainability and even though the focus within the news is on vehicle

development, previous research as well as interviews conducted within the scope of the i-Smile project, suggest sustainability impact could be considered in a more nuanced manner, including trade-offs between environmental and social values.

A more comprehensive understanding of sustainability implications requires considering business models and stakeholders' roles. Future research could focus on mapping stakeholders and their contributions to new last mile business models. Additionally, studying the dynamics of the retailer-LSP-consumer triad and the impact of platform or marketplace solutions on sustainability needs further attention. The emergence of vehicle subscription services for couriers in sharing-economy delivery schemes also presents sustainability paradoxes that warrant further investigation, along with how real estate affects warehousing developments and the city landscape. Also, reverse logistics would need to be included in last mile research and development of new reverse last mile services provide an innovation opportunity for both LSP and retail companies.

Gaps and barriers to scaling up on LEFVs

Several companies, especially the larger ones, identified recruitment as an issue. Nordic weather conditions, relatively low unemployment, and competition for staff from companies like Foodora and Wolt have likely made recruiting and retaining couriers more challenging. Companies that have historically focused on van and truck drivers have also experienced problems in transitioning these drivers to LEFVs. On the other hand, the smaller companies saw recruitment as a unique selling point and often supplied the bigger companies with staff. Cargo cycle drivers tend to be younger, enjoy working outside, see the physical exertion as an attractive aspect of the job, and to some degree are bike enthusiasts.

The same partner companies that find recruitment to be an issue, mention difficulties in finding staff to ride cargo bikes due to the challenging Nordic weather conditions, and this is a hindrance to upscaling. Finding cargo bike riders requires a different recruitment process and it can be challenging to transition a van driver to be a cargo bike rider. LEFVs that offer weather protection are seen by some companies as better candidates to replace vans as they share more similarities, making it easier to ask employees to use a new vehicle. However, these types of vehicles lose the flexibility of cargo bikes regarding for example use of city infrastructure. It is important to delve deeper into the different forms of employment used by delivery companies to see which system works the best.

Suggested solutions: One thing in common for these partners that view this as an issue is size. The larger LSP companies see recruitment as an issue. The smaller ones see it as a unique selling point (USP) to recruit cargo cycle

drivers^{[1] [2]}. The smaller ones only have cargo cycle drivers, no van drivers, and they often work with supplying cargo cycle drivers to the larger companies. There are even smaller cargo operators based in north Sweden, where the weather is less than ideal for bikes in general. The problem with recruitment seems to be a perceived problem mostly by the larger companies. As mentioned, this process requires a slightly different recruitment process, a van driver and a cargo cycle driver value different things and to find them companies have to look for different types of qualifications in the human resource process.

Lack of sector maturity manifests itself in the form of maintenance issues and parts availability that reduce the uptime of cargo cycles to the extent that some companies use uptime as a KPI. It can also make developing routes specifically tailored for cargo cycle more challenging if there is uncertainty on whether or not a cycle will be available due to maintenance issues. The number and type of cargo cycles available for purchase is rapidly expanding, but few are from large manufacturers. This can make the selection process difficult as companies are buying vehicles they have little experience with and may not choose the best solution. Larger manufacturers entering the cargo cycle sector would help increase standardisation and drive down costs, while also building trust in using cargo cycles as a dedicated logistics tool.

Suggested solutions: This is such an important part of the cargo cycle industry that they even use "uptime" as a key performance indicator in operations. A potential solution to this issue is for larger, more experienced manufacturers to enter the market, and this seems to be the case. Renault, for instance, recently announced that they will start to manufacture cargo cycles drivers. More larger players with experience are needed. Greater standardization across the sector would also help alleviate issues related to maintenance, parts availability, and the general knowledge base, etc. It is surprising, as researchers, that billions of dollars are put into electric scooters in all our major cities by venture capital, but almost none of this is directed towards cargo cycle operations.

The city design and transport policy issues play an important role as cities and citizens are vital stakeholders and beneficiaries from the introduction of LEFVs, but cities often lack the knowledge of how to involve themselves in what is often seen as a private sector domain. Regulation for a more people centric and multimodal city is important and can be achieved through regulations such as environmental zones, parking regulations and lower speed limits for cars. This would have benefits for safety, use of space, transport related emissions. Additionally, such changes can

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1. [RENAULT TRUCKS NOW ASSEMBLES AND DISTRIBUTES E-CARGO BIKES WITH KLEUSTER | Renault Trucks Corporate \(renault-trucks.com\)](https://www.renault-trucks.com/en/press-releases/renault-trucks-now-assembles-and-distributes-e-cargo-bikes-with-kleuster)
 2. [e-cargo bikes | Renault Trucks Corporate \(renault-trucks.com\)](https://www.renault-trucks.com/en/press-releases/renault-trucks-now-assembles-and-distributes-e-cargo-bikes-with-kleuster)

give a competitive advantage to LEFVs over more traditional vehicles and push companies to find innovative solutions in how they organize and carry out urban logistics.

Suggested solutions: Cities (and their citizens) play an important role here, since they are the ones that benefit the most from smaller, safer, zero emission solutions. Applying regulations to foster a more people centric city, such as environmental zones and lower speed limits for cars will not only have positive health effects but also increase the use of alternative modes in passenger and logistics operations. Factors such as public procurement and environmental zones that are specific for freight (not personnel transport) can be used to nudge in the direction of more LEFVs. Such policies can also help encourage the use of micro terminals and city hubs that can allow more widespread and efficient use of LEFVs. It is important to check the possibility of disconnecting passenger transport and logistics for the environmental zone laws. If it would be possible to create a zone where passenger transport has one set of rules and logistics another, this would be ideal. For instance, higher maximum speeds for bus lanes than car/truck lanes.

Apart from the extra handling, hubs located centrally in cities are expensive and make the creation of a profitable business model for cargo cycles challenging.

Suggested solutions: In the i-Smile project some of the benefits of cargo cycles has been put forward. But what about innovation to address the drawbacks? Innovation can be "new combinations of existing elements" and it is important to study how various elements connect and coordinate with each other, through hybridization and add-ons. However, transportation history is full of examples where this is a stepwise process. The steel ship came about with the help of hybridization, composite ships with steel elements reinforcing weaker parts on wooden ships existed before the first steel ship, the first steam ship was a sail ship with a steam engine that was used when there was no wind, the first car was a horse carriage with an engine. All innovations addressing limitations/weaknesses with the current technology. It can thus be argued that to improve the concept of cargo cycles with the help of hybridizations and add-ons could enable large-scale implementation of zero emission solutions the last mile. Operational models are quite similar for cargo cycles and other LEFVs including small autonomous vehicles. They also share many of the same disadvantages, 1) capacity (weight and volume), 2) range, and 3) costly intermediate reloading/storage. So, solving these issues is not only beneficial for cargo cycles, but for light electric freight vehicles in general. Perhaps looking into a simpler form of a "terminal" or micro hub for transloading between vehicles is a way forward, to use infrastructure that is available at least some of the time in a day. Like parking lots in centrally located malls or gas stations that most likely are looking into new business models for the use of their space,

especially in a future where the need for gas will dwindle. The Department of Transportation in New York City are currently testing a version of this, dedicating curb side for delivery operations, see NYC DOT (2023).

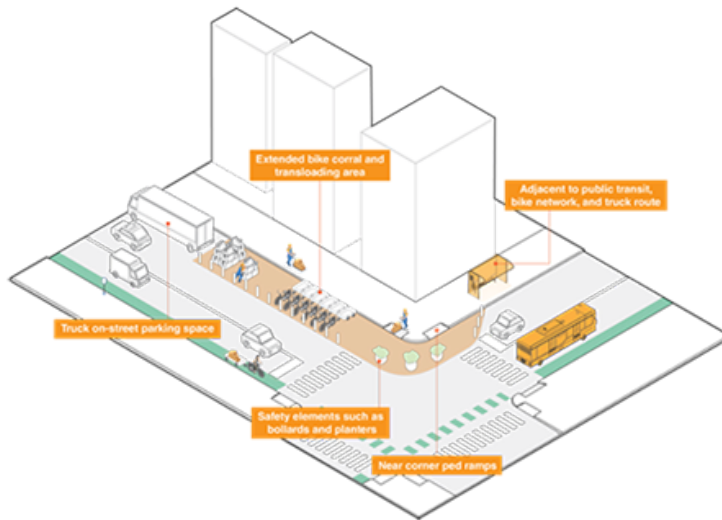


Figure 8 Delivery hubs on NYC's roadside parking for transloading from bigger to smaller vehicles.

[NYC DOT to Launch Local Delivery Hub Pilot to Reduce Negative Environmental and Safety Effects of Truck Deliveries](#)

Development and innovation in the last mile landscape – media analysis

The current state of development and innovation of last mile and sustainable last mile solutions was explored by analysing news media. This study covered 611 news pieces from six different international news sites that specialize in logistics and supply chain related news (four sites) and technology and innovation news (two sites). The results from the media analysis revealed that there is plenty of activity in the vehicle sector. Most news articles published on the six analysed sites between January 2020 and July 2022 (44%) relate to the physical transport and vehicle part of the last mile. Within the 44%, 28% describe different vehicle types under development or in trial use. Autonomous vehicle development is visible. The vehicle types that have gained most attention are curb-side autonomous delivery robots (ADRs), drones, and van-sized electric and or autonomous delivery vehicles. Most of the vehicle development seems to happen in the US, with also Chinese and German projects mentioned.

There has been a tremendous growth in last mile related news since 2020, as seen in Figure 8, depicting last mile news from 7 different news sites from January 2020 until July 2022.

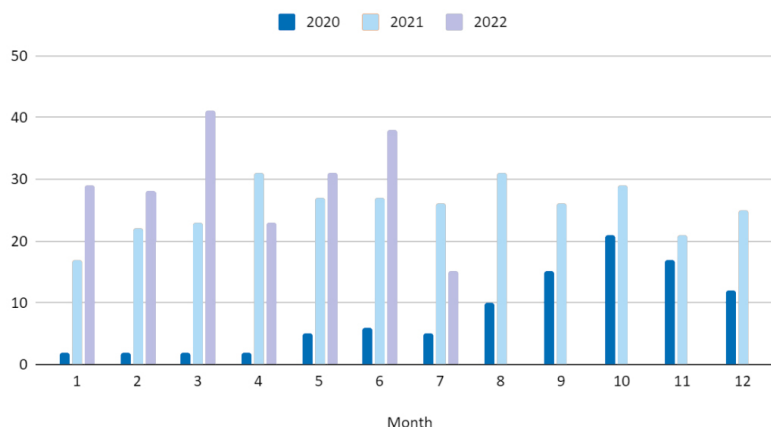


Figure 9 Last mile news

From a delivery perspective it is interesting that urban mobility solutions are merging with delivery services as many micro-mobility providers also offer

subscription-models targeted at couriers who work within the platform economy. Another area that seems to drive market development is the growth in e-grocery deliveries that is connected to the development of many innovative new vehicle types.

Regarding delivery as a service, news that specifically focus on the added value or the consumer experience of last mile delivery are widely discussed. Here collaborative business models and community or crowd-based services seem to be on the rise. Especially interesting are group-buying and community-based delivery models that are appearing in emerging economies.

The strategy of last mile logistics

LMD is a very practical field, but it has also been analysed from a theoretical perspective. In this section we discuss the theory of dynamic capabilities, which is increasingly used to explain the strategic value of operations such as logistics. The strength of this approach is that logistics is seen in comprehension with the company as a whole and its strategy. With this holistic approach, the i-Smile project goes beyond the relatively narrow perspective of transport via light electric vehicles and logistics.

The theory works with three overall dynamic capabilities, namely 'Sensing', 'Seizing' and 'Managing threats and transforming'. In addition, several so-called microfoundations of these capabilities have been identified. Microfoundations of 'Sensing' is about setting up systems to capture changes in technologies and markets and deciding how to shape new opportunities accordingly. 'Seizing' is about reconfiguring company structures to upscale the new opportunities (products or services), and 'Managing threats and transforming the organization' is about continuously aligning the company to the new opportunities that require intensive learning, knowledge management, and collaboration with external parties to protect the new products and services in new markets. Figure 9 illustrates the dynamic capabilities and their associated microfoundations in detail.

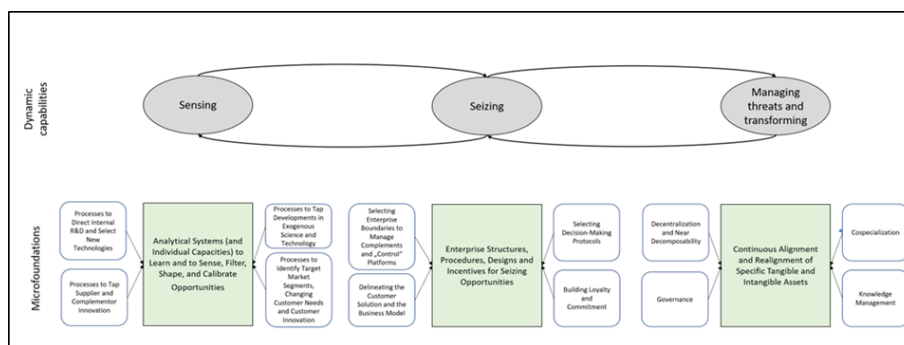


Figure 10 Dynamic Capabilities and corresponding microfoundations. Source: Bares (2023) based on Teece (2007).

Microfoundations for success of e-cargo bikes in DHL Express

The findings from the embedded case study show that 'Sensing' takes place at the corporate level as a strategizing entity. The study did not particularly focus on that capability as our sub-cases were in division in Denmark and Norway. However, we can say that even these divisions are deeply engaged in capturing information about sustainable urban logistics development; their engagement in the i-Smile-project shows this.

'Seizing' of e-cargo bikes solutions is currently not taking place on a larger scale, but it is on the other hand clear that the transformation enabling capabilities reside at the organizational level and should not be delimited to e-cargo bikes only. Alignment of incentives towards sustainability is important, as is building loyalty and commitment towards corporate strategy. Investment decisions and a decision-making protocol were shown to be central and the right such decisions were found to be an important microfoundation for success.

'Managing threats and transforming' was about governance and leadership. Cross-functional collaboration supporting internal integration and collaboration externally were further important microfoundations. External collaboration provided the opportunity for co-specialization that led to value co-creation in the form of a cargo box for the bikes. To make this possible, internal learning and knowledge management took place and were necessary.

Building microfoundations for dynamic capabilities of e-cargo bikes

Based on the analysis of microfoundations of Dynamic Capabilities in DHL Express DK and NO, we developed a process model of transformation of last mile deliveries towards e-cargo bikes. The model is depicted in Figure 9.

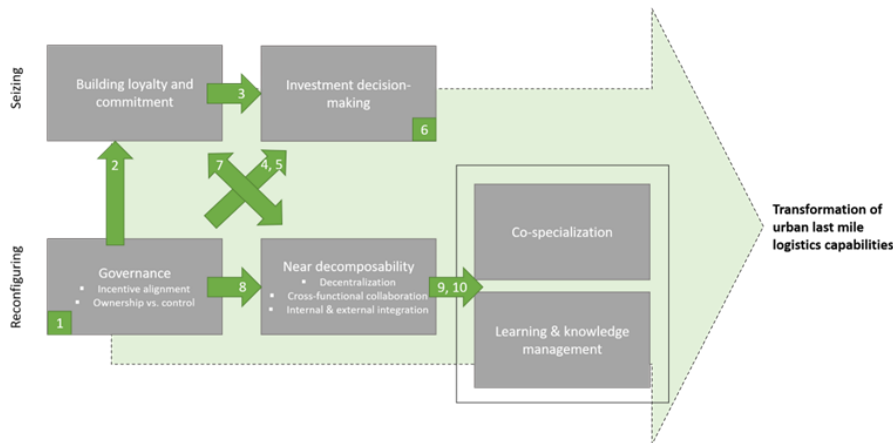


Figure 11 Microfoundations enabling transformation of last mile logistics towards e-cargo bikes.

The model is a process model following steps 1 to 10. Microfoundational elements are largely interdependent, but following the depicted process has the potential to lead to transformation of last mile logistics and deliveries to environmental sustainability. The analysis particularly points to the mixture of centralized and decentralized ownership of processes (governance) and emphasis on decentralization (near decomposability) as important for successful transformation as cities, f. ex. Copenhagen and Oslo, their geographies, policies, and stakeholders are different. The local divisions have special knowledge of their respective cities and therefore some empowerment of the local divisions is essential. However, if the logistics service provider is a conglomerate, alignment of incentives and control systems on a corporate level supports decision making on investments and the transformation process as such.

This process model is suited to serve as a recommendation to practice transforming urban transport and logistics towards sustainability. It outlines the necessary aspects (microfoundations) to consider when seeking to implement urban last mile deliveries and their interdependencies in proposing the path to making e-cargo bikes a dynamic capability.

Socio-technical approach

For practical changes to be implemented appropriately, a theoretical lens is often a pertinent instrument to start with. This can offer holistic insights to the matter and tie it in with the surrounding context. The socio-technical approach is socio-evolutionary. This means that deep change at the social level is necessary. This includes changes in motivations and behaviour of social actors including businesses and individuals such as consumers and buyers of e-commerce products and services. The I-Smile project therefore took its point of departure in investigating such motivations and behaviours of actors in last mile ecosystems in four Nordic countries, Norway, Finland, Sweden, and Denmark. In addition, the project examined the development of technical solutions and business models as potential driving forces of change. The premise of the applied socio-technical theory is that change of systems must be analysed in three levels to understand the transformation process towards sustainability. Notably, this theory is seen as a new approach to innovation that relates to the UN Sustainability Development Goals that are inclusive and also address social aspects of wellbeing. Socio-technical systems change is particularly well suited for developments of so-called backbone systems of societies such as transport (Schot and Steinmüller, 2018).

The three levels of socio-technical systems are so-called 'landscape', 'regime', and 'niche'. 'Landscape' depicts an exogenous context to a 'regime' that is a functioning and well-knit system of actors, technologies etc. The 'regime' is hard to change due to systems bonds, but impact can come from the 'landscape' such as climate change and energy crises. The 'landscape' has only indirect impact on 'regimes' and 'niches', and only when actors of these two system levels act upon changes in 'landscape'. The 'niche' level is constituted by entrepreneurs, inventions and innovations of new technology and business models. In the beginning, such newcomers of the last mile transport and logistics system struggle with their innovations' technology and economy and therefore it takes time to challenge the existing 'regime'. However, that is the task of this system level as fundamental change, and thereby transition, requires socio-technical innovations.

Figure 12 illustrates the three-layered model of urban last mile logistics adopted by i-Smile. Inspiration is gathered from Aurinen and Tuominen (2014) and Ballantyne *et al.* (2013) in selecting relevant analytical dimensions and actors in the last mile logistics systems.

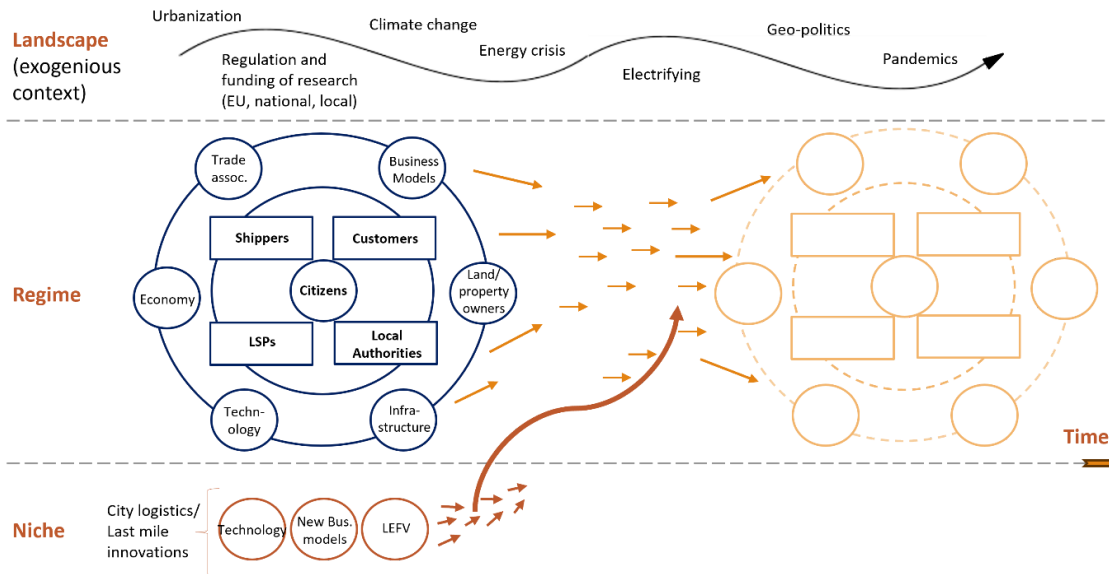


Figure 12 The socio-technical model

On the 'landscape' level, we see urbanization, regulation, and funding of research (particularly promoted by the EU and followed by national and local levels), and the energy crisis that has led to increased focus on electric vehicles. Further, this crisis has supported electrification of societies that is also a reaction to geo-political tensions. This development has been enforced by the climate crisis. Finally, the global disruptions caused by pandemics are also a part of the 'landscape'. Changes on this level may be slow, long-term, or rapid external shocks. As the focus of this project is sustainability, and changes seem to be considered long-term, we analyse the change as a transition rather than f. ex. a breakdown of the socio-technical systems caused by rapid shocks.

On the relative stable level of 'regime', the outer circle illustrates analytical dimensions that may have an impact on changes of the system, but which are not studied empirically in this project. Rather, actors in the next circle, Shippers including retailers, Customers including consumers, Local Authorities and Logistics Service Providers (LSP's) are studied empirically as they have direct impact on the 'regime' and potential changes herein. In the middle of the 'regime' are the Citizens. Citizens are stakeholders of the 'regime' and beneficiaries of changes towards sustainability.

In the model, the 'niche' consists of new technologies, new business models, and the use of light electric vehicles as potential game changers. Although changes within the regime take place to some extent, the thesis of this project is that change of the existing 'regime' to a new 'regime' with environmental and social sustainability as primary goals ("shaded" version of the 'regime'), must come as inspiration and

indirect pressure from the 'landscape' but importantly also from direct pressures from the 'niche'. The project found positive developments in that direction (small arrows in the model), but there still seems to be a way to go if recent climate change does not trigger a rapid shock in the existing socio-technical system of last mile logistics.

Case of DHL Express

The aim of the project's embedded case study of two divisions of DHL Express was to dig deeper into successful implementation of e-cargo bikes in cities despite the challenges to see what could potentially be learned from this case. An embedded case study is a case of one single entity such as implementation of e-cargo-bikes in DHL Express. However, in this case two subcases were studied to investigate potential differences within the case. These cases were DHL Express's implementation of e-cargo bikes in Copenhagen and Oslo.

DHL Express is a company that has worked with e-cargo bikes in cities such as Copenhagen (DHL Express DK) and Oslo (DHL Express NO) for some time. The i-Smile project has investigated the organization of e-cargo bike operations in these two cities to detect the success factors of implementation, the so-called micro foundations of operations originating from the theory of Dynamic Capabilities. This theory takes a strategic view on organizations and operations.

DHL Express is one of the Deutsche Post DHL Group's divisions. It is the global market leader in delivering urgent goods and documents reliably and on time from door to door. According to the DHL Group's GoGreen program, their goal is to achieve zero emissions logistics. One of the milestones pertains to the group's endeavours to enhance the quality of life in local communities by implementing environmentally friendly transportation alternatives. Specifically, the Group plans to "operate 70% of its own first and last mile services with clean pick-up and delivery solutions", such as bicycles and electric vehicles.

Aiming to go green to comply with the DHL strategy as well as new regulations and at the same time solve issues such as traffic, congestion, and pollution within inner cities like Copenhagen, DHL Express DK started to invest in, set up and operate a city hub, six electric cargo bike routes, as well

as three electric vans in inner Copenhagen end of 2019. The project and its realization were internally driven within DHL Express DK. To bring the new solution to life, a space within the inner city was rented, serving as front as well as back office. The cargo bikes utilized are front loaders called Bullitt, which are small and easy to manoeuvre. Within Denmark and the industry, DHL Express was the first company to implement cargo bikes.

In Norway, the Oslo municipality started an initiative in 2017 in which it engaged with DHL Express NO in conversations about the livability of the city and sustainable distribution. Entering a strategic partnership, their collaboration led the company to implement a micro terminal in form of a 25-foot container close to Oslo harbour. Three electric cargo bikes were utilized which were loaded and departed from the container. The cargo bikes were equipped with a loading system consisting of two containers, one located in the front of the bike and a trailer in the back. The trailer located at the back of the bike was easily attachable and detachable, enabling efficient and flexible transportation of shipments. Rental costs for the container location were funded throughout the first two years of operation by the municipality. Afterwards, rent should be paid for the square meters used.

Recommendations

Based on this report and the entire project there are several recommendations we would like to make for industry and research to further the sustainability of LMD, particularly in urban areas. The research was focused on the Nordic context, with the research carried out in Finland, Sweden, Norway, and Denmark, therefore the recommendations also pertain best to this geographic and cultural context. However, the recommendations can also be applied to a broader context with adaptations. For example, the Nordic weather is a unique factor which needs to be considered, but it can also give insight into other contextual and environmental factors present in other contexts.

LEFVs can only compete with other vehicles if they are more efficient in the last mile. However, the usual metrics for transport efficiency are based on long haul transport and do not capture the benefits of LEFVs in urban areas. Therefore, new KPIs that reflect the specific characteristics of last mile operations are needed. For example, tkm and vkm are not good indicators of productivity in the last mile, since they do not account for the environmental impact or the congestion caused by different vehicles. A report from Trafa (2023) showed that LGVs, which mostly operate in cities, had a much higher share of emissions and mileage than their share of freight tonnes or tkm in Sweden. This suggests that LEFVs could have a significant advantage over LGVs in terms of efficiency and sustainability in the last mile.

Last mile companies measure their efficiency not only by weight or volume, but also by time and energy. For parcel deliveries, the driver's workday is often the bottleneck, so the number of stops per route matters. The energy aspect reflects the companies' goals and the cost savings from using less energy. Joule per parcel and stops per route are useful metrics for the growing e-commerce sector, as they support the transition to electric vehicles. They show how much energy is used per customer, shipment or parcel, and how this can be reduced by increasing energy efficiency. This is a positive trend for the transportation industry, which is moving towards more energy-efficient and sustainable last mile operations.

An important finding that i-Smile has made shows that cargo bikes are more efficient and require less travel distance than vans. This has been discussed previously among practitioners and researchers as an assumption, but i-Smile has been able to present data from a major company that clearly shows this. The data showed the following results for the KPIs stops per route, stops per route per hour,

and distance. The results show that deliveries with a van incurred 30–50% more unnecessary driving, such as looking for parking or a suitable place to stop. Cargo bikes were also 10–20% faster in terms of time, as they were able to use various types of urban infrastructure, park anywhere, and make short cuts. Cargo bikes are more productive and require less unnecessary driving, leading to less emissions, traffic, and increased well-being in urban environments. However, the cost for intermediate storage might make it difficult for these solutions to be profitable. Furthermore:

- LEFVs offer operational advantages in many contexts and can be especially useful where time, not weight or volume, is the limiting factor in a driver's workday.
- Organizing transloading/transshipment points (city hubs, micro terminals) expands the flexibility and use cases of LEFVs, but can be difficult and costly to implement.
- It is clear that cargo cycles can only replace some activities within a transport system.
- A mixed fleet is likely to be the most efficient, but the balance of LEFVs to traditional vehicles can be impacted by factors related to policy, infrastructure and organization.
- Wider adoption of these vehicles would increase opportunities for standardisation and increase their potential to deliver a larger share of goods.

Going forward, the recommendation of this project is that a fuller spectrum and integration of sustainability aspects are included in all last mile innovations and activities. This means, all stakeholders need to be included and collaborating more. There are many well-known sustainability challenges related to LMD that include the lack of critical mass for LMD that can generate sub-optimal fill rates and the utilization of less energy efficient vehicles (Simoni et al., 2020), and externalities including air and noise pollution, traffic congestion, traffic accidents, and greenhouse gas emissions (Browne et al., 2012). The i-Smile project, as an innovation project, wants to highlight the need to understand the importance of technological and business model developments and its impact on the evolutionary road to sustainability in cities.

The contemporary landscape of urban last-mile deliveries is marked by the convergence of evolving technologies and changing citizen perspectives. In this dynamic environment, the citizen perspective holds a pivotal role, as it shapes the priorities and expectations of last-mile delivery services. This socio-technical approach considers not only the technological advancements, such as autonomous and electric delivery vehicles, but also the intricate relationship between technology

and society. Citizens' concerns about safety, traffic disruptions, and the utilization of urban space influence the design and implementation of these technologies. As cities aim to balance the convenience of last-mile deliveries with sustainable urban planning, the development of dynamic capabilities becomes crucial. This includes the ability to adapt to evolving trends in light electric freight vehicles and the last-mile delivery ecosystem, ensuring that cities can effectively respond to the evolving needs of their citizens while harnessing the potential of emerging technologies.

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