ULaaDS
URBAN LOGISTICS AS AN ON-DEMAND SERVICE

Impacts on logistics and traffic efficiency, land use and the environment

ULaaDS D5.5: Impacts

traffic efficiency, land use and the environment

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Project abstract

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

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

Keywords

Urban logistics, sustainability, impact assessment, cargo bikes, autonomous vehicles, parcel lockers space use efficiency, land use efficiency

Copyright statement

Executive summary

The ULaaDS research trials have looked at different methods for conducting zero-emission, shared and crowdsourced on-demand delivery of goods to customers in the light house cities of Bremen, Mechelen and Groningen.

This deliverable assesses the impacts of the trials on logistics efficiency, land use and the environment. Using the comprehensive list of KPIs developed in deliverable 5.1, the trial objectives as stated in deliverable 5.2, and the available data, a more targeted and practical list of KPIs was developed for use in this assessment. Two additional KPIs are suggested that focus on the land and space use efficiency of the different solutions to better consider the land and space use over time in relation to the amount of cargo transported.

Data collection during ULaaDs was hindered by events such as the pandemic, financial problems among trial partners and cooperation breakdowns. To help fill gaps in knowledge, supplement the collected data and better understand potential trial impacts, other EU projects focused on similar topics were examined. Given the varying levels of data, differing technology levels and scales of activity, the trials were separated into two tiers of assessment- a full assessment and a partial assessment. Due to these differences, the trials were not considered to be directly comparable.

Our assessment finds that the ULaaDs trials as carried out provide many potential advantages when considering space use and the environment, and more limited and/or mixed results for logistics efficiency. Using smaller vehicles frees up significant amounts of space in urban areas and can reduce negative impacts of logistics activities related to local pollution. Many of the trials offer significant improvements in land and space use efficiency, as measured by their ability to move a given amount of cargo considering the space they occupy over time.

The impacts on logistics efficiency were more difficult to determine as the different trials showed signs that they had not yet reached their potential, used business models that limited their efficiency, or occurred at a small scale that limited the amount of support and integration that could be achieved with existing logistic systems. Barriers that hindered logistics efficiency were identified and further work could be done to consider the practicalities of addressing limiting factors.

Overall, the trials also provided valuable experience for the project partners and gave insight into the future upscaling of the various trialed solutions. The ULaaDs research trials underscore the complexity of logistic activities and the need for trialing a diverse array of solutions that reveal areas of promise and identify where limiting factors might be. Municipalities would benefit from investing more energy into collecting data related to logistics activities so they can better understand the impact and potential of initiatives focused on improving urban logistics.

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1. Introduction

This deliverable assesses the impacts of the ULaaDs trials on land and space use, logistics efficiency and the environment. The deliverable is based on data collected from the individual trials, input from deliverables **3.5 (Final Validated Business Models), 4.7 (Summary of Practical Research Trials), 5.1 (Framework, methodology and KPI Identification) and 5.2 (ULaaDs: Fact sheets baseline and city profiles)** as well as a review of documents and literature relevant for the specific solutions trialed. The document is divided into five chapters - an initial discussion of the impacts measured and the methodology, a chapter for each lighthouse city, and a concluding chapter discussing the findings.

1.1 Areas of impact

The initial areas of impact relevant for the impact assessment of the ULaaDS trials are defined and described in deliverable 5.1. They are the following:

- Environment
- Land use
- Traffic conditions
- Logistics efficiency
- Economic impacts
- User experience and acceptance, and
- Awareness.

The last three areas are dealt with in deliverable 5.4 (Economic impacts, user experience, acceptance and awareness), while the first four areas are dealt with in this deliverable. These areas of impact are closely intertwined - for example, more efficient logistics can reduce kilometres driven which is both better for the environment, uses space more effectively and reduces traffic congestion. Initially, in deliverable 5.1, traffic efficiency was considered as its own impact area, however a general lack of data on the specific movements of vehicles involved in the trial, safety aspects and the overall traffic patterns in the city meant these impacts were difficult to assess. Additionally, many aspects related to traffic efficiency are covered in the other three areas of impact and so we decided to combine traffic efficiency with logistics efficiency in order to avoid redundancy. As a result, this deliverable looks at three specific areas of impact:

1) Land and space use
2) Logistics efficiency
3) Environment

1.1.1 Land and space use

Space is a scarce resource in cities and deciding how it is used can be a contentious issue for both businesses and citizens. In many ways logistics is a parking problem and availability of areas to conduct logistic activities is key to efficient operations.

The use of space is not just about the number of square meters a vehicle occupies, but also where, when and how that space is used. Additionally, different form factors for a vehicle can play an important role in both how they interact with the city and how they are in turn perceived by city residents. Larger vehicles are not only less agile in dense areas, but their drivers also have more limited visibility, can reduce traffic safety and block visibility for other road users.

As described below in 1.3.2, we have developed this area of impact further by not only examining land use but also what we call “space use” which also consider the volume of the vehicles. Indeed vehicles not only occupy an area on the ground but they also occupy a volume in the street, with the underlying hypothesis is that volume also has an impact on the urban environment. For this reason, we have renamed the area of impact “land and space use”.

1.1.2 Logistics efficiency

The ULaaDs trials explore different solutions for organising the movement of goods and people, often in combination. Reduced congestion, fewer kilometres driven, increased load factor and better utilization of vehicles are all important aspects of logistics and traffic efficiency.

Logistics efficiency has significant overlaps with the other impact areas as more efficient logistics is often more environmentally friendly, uses less space over time, creates less congestion and is less expensive. In section 1.3.2 below, we describe the use of indicators that look at how efficiently the solutions make use of area and space in terms of the number of kilograms delivered per unit time considering the size of the vehicle, which provides insights into their logistics efficiency.

1.1.3 Environment

All of the ULaaDs solutions introduce vehicles with zero tail pipe emissions. Many cities have committed to creating zero emission zones and to rapidly electrifying vehicle fleets, measures that can significantly reduce transport related GHG emissions. In addition to the critical work of reducing GHG emissions from transport, it is important to consider environmental impacts from a more local perspective.

Reducing vehicle size and weight and using electric vehicles can have immediate beneficial impacts for cities by reducing particulate matter from tire and brake wear, NOx emissions and noise. Smaller, lighter vehicles can also benefit other road users by providing better sight lines for those inside and outside the vehicle as well as a decreased risk of serious injury in the event of an accident, due to lower speeds and vehicle sizes. There were no reported accidents from any of the ULaaDs trials, though the scope of the trials was too small to assess traffic safety implications with a high level of confidence.

The nuisance of logistics activities in dense areas can also be impacted by using smaller vehicles. Goods receivers in pedestrian areas are dependent on goods activities yet can be negatively impacted if a service or logistic vehicle blocks the window or entrance to their shop. Outdoor seating contributes to 10-25 % of their average annual revenue but can conflict with the needs of goods delivery vehicles (Ringsberg et al. 2023).

1.2 Trial objectives

In each area of impact, objectives were defined for the ULaaDS trials in deliverable 5.1. These objectives have been fine tuned to each trial in deliverable 5.2. These new sets of objectives are more specific to each trial and more transversal (some of them correspond to different areas of impact).

These objectives are important in the assessment process because they govern the definition of KPIs. This deliverable focuses on the trials' objectives that correspond to the three areas of impact addressed in this assessment while other trial objectives are addressed in deliverable 5.4.

1.3 Key Performance Indicators (KPIs)

1.3.1 Revised list of KPIs

In deliverable 5.1, a preliminary and exhaustive list of 29 KPIs was developed in order to measure and compare the trial impacts. Deliverable 5.1 is the result of the first iteration of the impact assessment framework. As the trials were carried out and data collected, the second iteration of the framework took place, including development of the KPIs. This iteration has resulted in a revised list of KPIs that is targeted towards each specific trial and their objectives and better reflects the available data. The preliminary list of KPIs was narrowed and tailored for each trial, for reasons explained below. The final KPIs are presented in the specific chapters for each trial, as well as in Table 1.

Table 1: Revised list of KPIs corresponding to the following areas of impact: Land and space use, Logistics efficiency and Environment

AREA OF IMPACT	KPI
LAND AND SPACE USE	Land use efficiency
	Space use efficiency
	Area occupied by vehicle in traffic
	Land use of hub
LOGISTICS EFFICIENCY	Time per delivery
	Vehicle load factor
	Deliveries per tour per vehicle
	Time in operation per vehicle
	Days in operation per vehicle
ENVIRONMENT	CO_2 eq. emissions
	NOx and particulate matter emissions

	Noise emissions
	Cargo bikes replacing diesel vehicles
	Cargo bikes replacing fossil fuel cars
	Cargo bikes and other ZE vehicles replacing diesel vans
	Days in operation per fossil fuel vehicle

1.3.2 Development of two additional KPIs

The act of delivering or picking up goods involves a number of activities that require resources such as land/space (often a public good) and time. In order to consider these elements more thoroughly, we highlight the use of two indicators that focus on the efficiency of the ULaaDS solutions' use of area and space (volume) over time. These are expanded on from the KPIs originally called "Dimension weight per day per vehicle (kg/m^3)" and "Public space used for UFT activities (hrs/m^2)". They are built from three components: cargo, time use and land/space use. Though nominally called land and space use efficiency and belonging to the "land and space use" area of impact, these indicators also have significant implications for the environment and logistics efficiency.

$$Land\ use\ efficiency = \frac{\sum_{v=1}^{v=V} cargo}{\sum_{v=1}^{v=V}(time\ use\ \times land\ use)}$$

Measuring cargo (the numerator) as a generic unit of cargo, time use in minutes, and land use in square meters, the indicator of land use efficiency would essentially report the number of cargo units delivered for every minute use of each square meter. Or in other words, this indicator describes the necessary time to spend on each square meter to provide one unit of cargo.

A similar indicator is possible to construct focused instead on the size (volume) of the different vehicles i.e., the visual appearance and the fact that they occupied a varied amount of space – volume in the street.

$$Space\ use\ efficiency = \frac{\sum_{v=1}^{v=V} cargo}{\sum_{v=1}^{v=V}(time\ use\ \times space\ use)}$$

Both indicators can be used to compare alternatives against a base scenario. Three components must be defined or operationalized to determine land/space use efficiency. When comparing the use of land or space for different vehicle types, cargo and time should remain constant.

Cargo

In the equation above, efficiency is measured by how much cargo one can deliver. Cargo can be measured in numerous ways, such as volume, weight or number of shipments. It is important to consider the characteristics of both the cargo and the vehicle in order to determine which is most appropriate to use and what the limiting factors are. For example, a cargo bike that takes 200kg of bricks may have room (volume) for more cargo but is at its weight limit so must make a second trip. On the other hand, e-commerce goods are often small and weigh very little, so the number of shipments becomes more relevant than weight or volume.

Time use

Time use is essential as it reflects the time a vehicle occupies land/space. When considering time use, the period of time being measured must be defined as well as the type of activity being measured. For example, one can consider only the time spent traveling, only the time spent loading and unloading, or a combination of the two.

Land and space use

Land or space use can be measured in m^2 or m^3 and, as with time use, it is important to consider the context of the situation. Ideally one should measure more than the area or space occupied by the vehicle itself. Depending on the type of vehicle, the delivery operation itself also contributes to space use to varying degrees. The driver needs to leave the vehicle, take out packages, etc. If using a truck, a lift gate needs to be lowered and space accounted for to remove pallets. The lift often remains down while the driver is delivering the pallet. Also, there is a zone surrounding the vehicle which cannot be used for other purposes, so the vehicle will always be occupying more area or space than the footprint of the vehicle itself. The higher the speed of the vehicle, the larger this zone is.

The volume occupied by a vehicle is perhaps less interesting on a highway in which case land (in m^2) is more relevant, whereas volume (in m^3) becomes more relevant in denser areas where the visual obstruction of a vehicle can have impacts- an indicator of nuisance if you will.

In this deliverable, the different vehicle dimensions used in the ULaaDs trials are given in annex 1. To determine volume, the vehicle dimensions were used as if the vehicle shape was a cube or rectangular prism. This leads to an underestimation of the volume as the vehicles are not uniform heights or widths and the effect is most apparent for bicycles and cars, but not enough to dramatically influence the comparison.

1.4 Available data

Data collection for the trials was an ongoing process and occurred at different phases of the project, with some trials occurring over relatively short time periods and others over several years. In many cases, shifting realities on the ground and changing trial objectives adversely impacted data collection and especially the collection of a robust baseline which has required estimation of values in some instances. The lack of good baseline data can be attributed to a number of factors; the pandemic, changes to trials due to unforeseen circumstances, the limited scale of the project, the lack of existing data collection systems in the trial cities and the reticence of non project partners to share relevant data. While municipalities often have data related to the movement of people, access to logistics data is more challenging and the data is frequently more fragmented as logistics activities are more complex and encompass a wide range of behaviour- everything from on demand food deliveries to trash collection.

In addition, the impact of small-scale pilot studies, technological demonstrations and/or simulations will provide little in the way of measurable impacts on logistics and traffic efficiency, even at a neighbourhood level. Research trials are uncertain by their nature and it was thus considered important to set these trials in context and look at their contribution as part of a growing body of research involving trials and pilots focused on innovative solutions for urban logistics. This was done by looking at available literature, reports, documents and other EU projects.

Similar projects and studies, based on the same concept as each trial (e.g. containerised cargo bike logistics for the Rytle trial in Bremen), were used as a baseline to compare the trials with similar attempts in Europe. Starting with deliverable 3.1, we also updated the projects overview by reviewing more recent publications and other EU Horizon projects. The projects MOVE21 and SPROUT were also followed closely, due to their focus on cargo hitching. This has enabled us to collect relevant data and information in order to compare ULaaDS trials with similar concepts and to enrich and validate the impact assessment of the ULaaDS trials.

1.5 Approach to assessing the trials

1.5.1 Qualitative assessment

Due to the lack of baseline and quantitative data, it was not possible to quantify each KPI before and after each of the trials. One of the challenges in assessing the ULaaDs solutions is that pilot projects may not outperform existing solutions that are already well integrated into larger systems. Pilots may instead test specific technologies or try to understand a specific aspect of a technology or solution. This assessment attempts to provide insight into when, where and under what circumstances the ULaaDs solutions can create a positive impact- both in their existing state and in a theoretical scaling up of the service.

Nonetheless, the available data provided an indication as to whether the impact of the trial was positive, negative, or not relevant for many KPIs. For that reason, this deliverable uses a similar assessment scale to the project STRAIGHTSOL (cf. Figure 1**Feil! Fant ikke referansekilden.**).

Thereby, for each assessed KPI, the assessment results in a colour assigned depending on whether the trial has had a positive impact (green), a negative impact (red) or no impact (yellow). When the impact can differ depending on the circumstances, multiple colours can be assigned to one KPI (cf. Figure 2).

Figure 1 Assessment levels from STRAIGHTSOL

z	No change
n	Negative effect
p	Postive effect
	Not relevant
n/m	Not measured

Figure 2: Assessment levels used in this deliverable

p		**Positive impact**
–		**No change**
n		**Negative impact**
–	n	**Conditional**
–	p	**Conditional**

1.5.2 Two tiers of assessment

The ULaaDs solutions differ in scale, complexity and purpose, focusing on collaborative delivery models as well as the integration of freight and passenger transport. Within these two broader categories of solutions, the trials aim to test five different schemes (see Table 2), with some trials testing a single solution and scheme and others testing several at once. While a brief overview of each trial is available in this deliverable, a more comprehensive summary and description of the ULaaDs trials can be found in deliverable 5.2 and in the trial reports in deliverable 4.7.

Table 2 Overview of the focus areas for the trials

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

Some trials did not occur due to unforeseeable factors such as bankruptcy, cooperation breakdowns, or technical and regulatory issues (these issues are covered in depth in the final trial report, deliverable 4.7). In addition to the relative diversity of the trials at the outset of the project, it has also been necessary for the trials to adapt to changing circumstances (such as the pandemic or bankruptcy of trial partners) which has also led to alterations to their original design and objectives, resulting in limitations in how the trials were conducted. As developed in section 1.4, available data was generally limited, though the amount of available data varied significantly for the different trials.

For these reasons, not all trials were formally assessed according to the final list of KPIs, some were instead examined through a more theoretical and/or conceptual lens. Trial 1 in Mechelen was not assessed as the trial did not occur and there was no collected data. Despite (and sometimes because of) the various challenges, the trials still provided interesting results and valuable insights in terms of their impacts on aspects such as cooperation between actors, building acceptance for new technologies, operational implementation and developing regulatory frameworks.

The trials are separated into two tiers of assessment:

1) Full assessment based on KPIs,

2) Partial assessment based on trial objectives and discussion about potential.

Table 3 shows how the different trials are spread among the two tiers.

Table 3 Overview of trials and assessment tiers

	Bremen Trial 1	Bremen Trial 2	Bremen Trial 3	Groningen Trial 1	Groningen Trial 2	Mechelen Trial 1	Mechelen Trial 2
Tier 1: Full assessment	X	X		X			
Tier 2: Partial assessment			X		X		X

1.5.3 Overall assessment approach

As detailed in the introduction, the impact assessment framework developed in deliverable 5.1 has been adapted to the realities on the ground and the specific outputs from the different trials. Trials classified in tier 1 were assessed based on the list of KPIs adapted from the trial objectives. The assessment approach used is summarized in Table 4: based on the trial objectives, we selected the relevant KPIs to assess each trial. Each of these KPIs were then assessed following our qualitative scale. When it comes to trials belonging to tier 2, the assessment consists of a discussion on their potential impacts, depending on the conditions of implementation.

Table 4: Example of an assessment table

Trial objective	**KPI**	**Assessment**
AREA OF IMPACT		
Trial objective 1	KPI 1	p
	KPI 2	_
Trial objective 2	KPI 3	n
	KPI 4	_ n
	KPI 5	p n

Another adaptation of the methodology concerns the comparability of the different trials in terms of impacts. As the trials were developed and carried out, it became clear they were not always directly comparable, especially as several of them changed their original objectives and scope in reaction to operational or organizational challenges. For example, there was little perceived value in comparing a shared cargo bike trial focused on personal transport with a trial using cargo bikes to replace pallet deliveries by truck in city centres, despite both trials using cargo cycles. The objectives of the trials are too different to easily compare. The same principle extends to the other trials, which implement and test solutions using diverse and innovative technologies, from autonomous vehicles to shared vehicle sharing platforms for businesses, limiting the usefulness of a direct comparison. As a consequence, trials are assessed individually and discussed in relation with similar EU projects or research studies in the EU.

2. Bremen

2.1 Trial 1 Containerised urban last mile

2.1.1 Description of trial

Bremen trialed containerized urban last-mile delivery using a combination of purpose built cargo bikes and a micro terminal from the company Rytle. At the freight village on the outskirts of Bremen, parcels and general cargo are grouped together according to the delivery zone. The consolidated goods are then delivered by a 7.5 t truck to the micro hubs closer to the city centre where they are transloaded to the cargo bikes. Table 5 shows how the trial addresses one of the ULaaDS solutions across one scheme.

Table 5: ULaaDS solutions and schemes Bremen trial 1

Solution	Scheme
1) Collaborative delivery models to enhance logistics efficiency and multimodal mobility in cities	1. Containerised urban last mile delivery

The trial's objectives are presented below and all refer to the areas of impacts assessed in this deliverable.

Original objectives:

1. Reducing the number of polluting vehicles entering the city centre
2. Improving space management thanks to last-mile delivery by cargo bikes
3. Increasing the efficiency in the interaction between long distance freight transport and urban freight transport

Trialed objective: As trialed

The development strategy has been to start with a hub in the inner city and then add subsequent hubs if a business case can be justified. Of particular interest for this solution is that the bikes will focus on general cargo rather than Courier, Express and Parcel (CEP) freight. General cargo is considered a challenging segment for cargo bikes due to the high volumes and weights, but also creates the possibility to reduce the use of larger trucks in dense urban areas. The bikes are able to transport either a specialized container with room for multiple small packages or individual euro pallets and this flexibility creates the potential to streamline the transhipment process. For example, a pallet stacked with boxes can be loaded directly onto the bike instead of each box being transferred one by one into a bike's compartment, or a preloaded container can be rolled directly onto the bike from a transferring vehicle.

The first micro-hub is located in the inner-city, in Jakobikirchhof (cf. Figure 3). This micro hub came into operation in 2019, before ULaaDs, as part of the Urban-BRE project and was financed by Bremen Ministry SWAE, until the end of 2021. Its service area is the inner city. It is located on public land, using a special permit.

The second micro-hub is located in BREPARK Quartiersgarage, Lübecker Straβe (cf. Figure 3). Its service area is "Viertel", neighbouring the inner city. It started operations the 1st July 2021. After two months of operation, the freight volume moving through the hub had doubled from the first month, though this hub ceased operation when the subsidies for the parking area were discontinued.

The third micro-hub was incorporated next to the first hub. It serves two different areas: Findorff and the northern part of the inner city. For this hub, a new partner was added supplying pharmacies and medical practices. This hub is not included in the impact analysis as data was not collected from its operation.

Figure 3: Overview of micro hub locations: 1) Jakobikirchhof, 2) BREPARK Quartiersgarage, Lübecker Straβe.

The cargo bikes used for this trial are the Rytle MovR3. They can load up to a total weight of 370 kg including the driver. The maximum rear load is 273 kg including either a standard euro pallet or the interchangeable 1.8 m^3 Rytle box. Electric support enables them to drive up to a maximum speed of 25 km/h.

2.1.2 Relevant projects

Electric cargo bikes have received increasing attention in recent years as a potential alternative to larger vehicles for goods delivery in cities. The number of commercial trips that can be replaced is highly dependent on the type of goods, with estimates ranging from 10-83% of trips that could be potentially substituted in different sectors (Narayanan & Antoniou, 2022). Multiple EU and national projects have piloted the use of cargo bikes for urban logistics such as STRAIGHTSOL, SURFLOGH and KOMODO. While these projects generally show reduced emissions and increased efficiency while the vehicle is out delivering, operational costs and challenges related to sorting, transloading and routing can be major barriers to implementation and reduce the overall efficiency of the system.

Cargo bike pilots are most often focused on the delivery of relatively small packages or envelopes. For example, both Elbert and Friedrich (2020) and Llorca & Moeckel (2021) model cargo bikes and hubs assuming an average package weight of 7,4 and 7,5 kg respectively which they base on numbers reported by the industry and other studies.

In contrast, Robichet et al. (2022) model the use of micro hubs and cargo bikes in Paris and assume a maximum weight of 200 kg for cargo bike deliveries which includes both CEP packages and general cargo. The weight limit assumed by Robichet et al. (2022) better reflects the capabilities of the Rytle bikes used for ULaaDs and suggests a high proportion of goods moving through a city could theoretically be delivered by cargo bikes in combination with hubs (even if it may not be economically feasible).

2.1.3 Available data

Aggregated data on the cargo cycle performance was provided by Rytle and included average number of shipments, distance travelled, weight, volume, and days in operation. Conversations, email exchanges and interviews were also used to better understand the context of the trial as well as the operational and organisational challenges. An overview of available data can be seen below in Table 6.

Table 6: Data sources to assess Bremen trial 1

Data source	Provider	Type of variables	Period
Aggregated shipment data	Rytle	Number of shipments per month Weight, volume transported per month Number of operating days Kilometres per month	Jan. 2021 – June 2023
Interviews, Coordination with Rytle and Bremen (emails, meetings, discussions)	Radkurier, Rytle, Bremen	Operational and organizational context, courier workday	

2.1.4 Impacts

2.1.4.1 Land and space use

While the direct impacts of this specific trial were relatively small, the use of smaller vehicles such as cargo bikes to transport general cargo has the potential to dramatically impact the way space is used in inner cities. To understand how these vehicles impact space use we have to consider three primary elements: 1) the bike, 2) the hub, 3) the truck.

The data collected shows that two different truck routes previously included stops in the inner city. With the introduction of the micro hub, these stops were instead bundled into one truck that serviced both micro hubs before continuing its own route, reducing the number of trucks entering the city centre.

As seen in the table below (cf. Table 7), we consider both the physical footprint of the vehicles as well as their volume. Even in combination, the hub and the cargo bike have a significantly smaller footprint and a smaller volume occupancy.

Table 7: Area and volume occupancy comparison

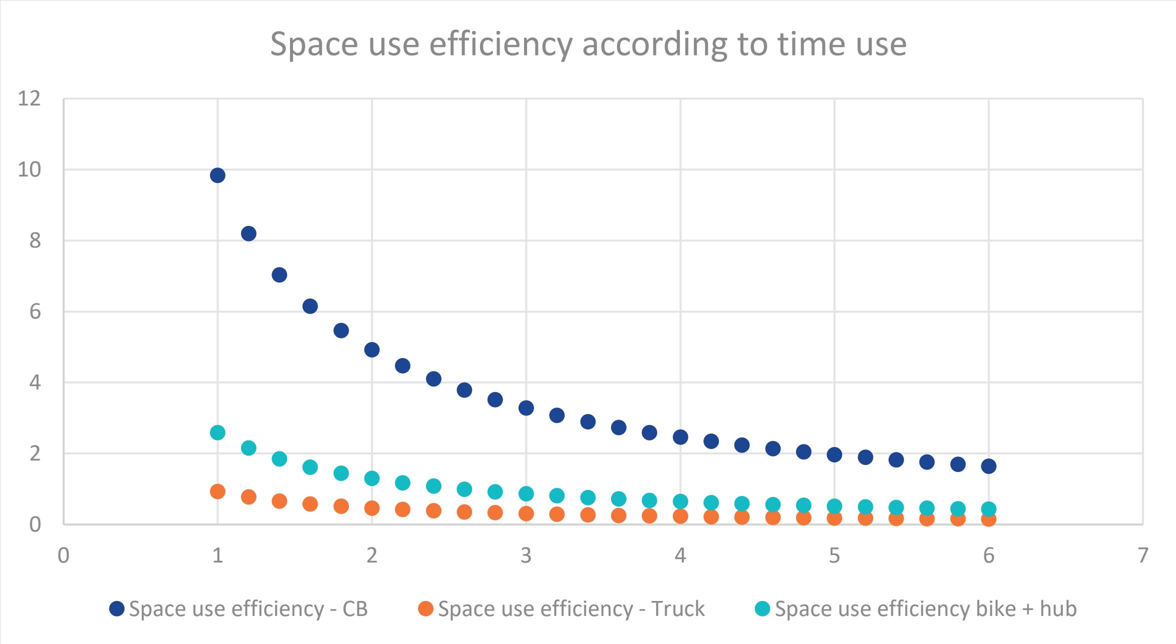
Vehicle	Dimensions (L x W x H cm)	Footprint/area occupancy m^2	Volume occupancy m^3
Rytle Movr	270 x 130 x 198	3.5	6.9
Rytle Hub (10 ft)	305 x 244 x 198	7,4	19,3
7.5 Ton truck	835 x 250 x 350	20.9	73.1

In addition to how much space is being used, it is also necessary to consider when and where space is being used. The hub is a semi-permanent installation and in the case of this trial, occupies parking spaces that could otherwise be used to store vehicles.

Since the hub is stationary and is located away from popular shopping and pedestrian areas, the impact on space and volume for the actual delivery process using the cargo bike is dramatically reduced. As a result, if we consider just the dynamic elements in the system (the bike and truck) we see that the cargo bike's space and volume efficiency is dramatically higher than that of the truck.

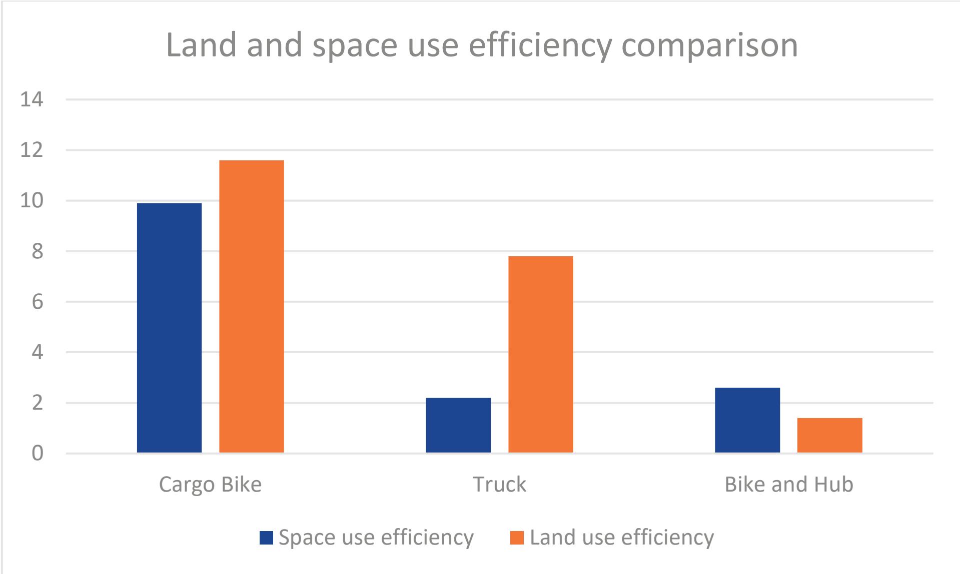
Using the indicator presented in section 1.3.2 we can visually represent the difference in how space is used by the different solutions (cf. Figure 4). For its size, the cargo bike utilizes space much more effectively. In this example, the given weight is 67.9kg the average weight delivered by the bikes per delivery. The cargo bike shifts were reportedly between 4-6 hours in length.

Figure 4 Space use efficiency of elements involved in the Bremen trial



If we assume a fully loaded truck has 12 pallets and is delivering 2,4 pallets per hour (reported by freight forwarders) while a cargo bike is delivering just 1 pallet per hour (as reported in interviews and project meetings as a worst case scenario) both with an average delivery weight of 68 kg, after 5 hours the truck would be finished with its route. The cargo bike would need 12 hours to perform the same amount of deliveries. Again, this assumes a worst-case scenario on the part of the cargo bike. Despite the efficiency gap in this example, the use of space still comes out in favour of the cargo bike. However, if we add in the hub we see that the truck becomes more efficient in terms of land use efficiency, though is still not as space efficient (see Figure 5). This example does not consider the space use of the hub outside of operating hours, as the parking spaces occupied are not in demand during these hours, so the impact is considered negligible.

Figure 5 Space and land use efficiency of delivering 12 pallets assuming 1 pallet/hr for cargo bikes and 2,4 pallets/hr for Trucks



2.1.4.2 Logistics efficiency

The results are a bit murky here as, based on the trial results and the data provided, it isn't possible to determine the limits of the cargo bikes' potential. As of this writing, Bremen is actively seeking additional companies to use the hub which would increase the efficiency of the bikes and they have stated they would need at least a doubling of volumes to make the hubs viable from a business perspective. At the same time, the cargo bikes are limited by their inability to take multiple pallets which results both in a loss of time and creates extra kilometres driven if a delivery consists of more than one pallet. In some extreme cases, we see the bike making three trips back and forth to the same location as the delivery consisted of three pallets.

As mentioned in the previous section on land use, freight forwarders in Bremen reported needing 2,4 pallet deliveries per hour to be considered sustainable from a business perspective. The bikes in the trials were unable to reach this number. This was primarily due to a lack of delivery volumes, but the delivery location in relation to the hub also has significant implications here. The furthest recorded delivery from the hub was 5.2 km, approximately 18 minutes[1] away, which implies 36 minutes of travel time to deliver a single pallet, not including any time needed for loading and unloading. However, the average delivery distance was 1,8 km from the hub, which should allow the bikes to reach their destination in 7.5 minutes depending on traffic and infrastructure conditions.

Using 7.5 minutes as a benchmark gives 15 minutes of travel time per pallet (7,5 minutes to and from the customer). If we assume 5 minutes of handling time (loading/unloading) per pallet, then the bikes could theoretically achieve 3 deliveries per hour if they had access to enough goods. If we

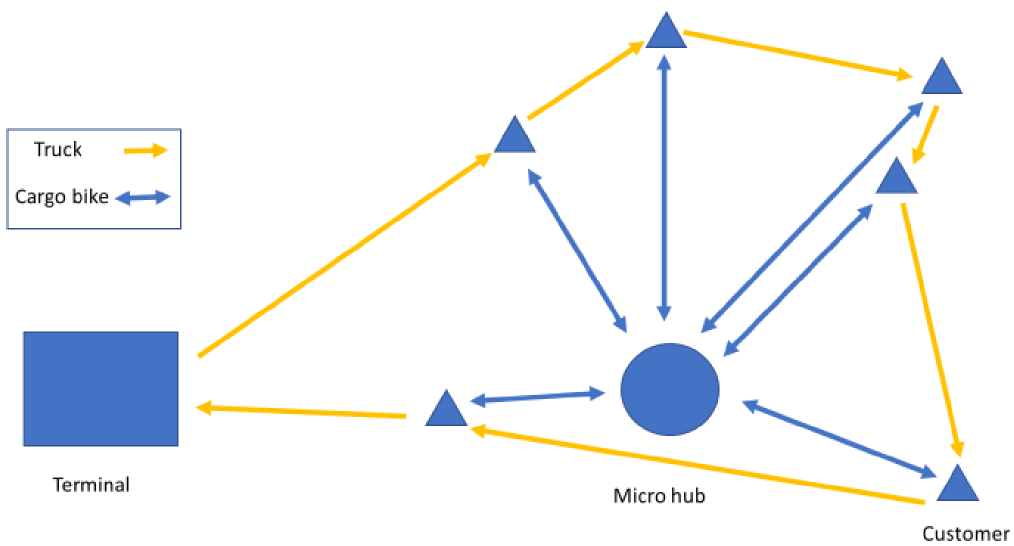
[1] According to google maps. Traffic conditions and infrastructure can influence travel times significantly.

instead use 2,4 pallets per hour as mentioned by the freight forwarders, then the bikes would have 25 minutes per delivery including handling time.

However, in reality we see that the bikes deliver just 5.9 shipments per day on average for the two hubs combined which confirms that the bikes were not close to reaching their potential during the trial. The workday for the cargo bike riders was between 4-6 hours but when not delivering pallets, the riders would deliver other goods not related to the ULaaDs trial.

The bikes reportedly move more quickly than trucks through the city as they are less limited by traffic and can take short cuts by using multiple types of infrastructure and bypassing modal filters. However, the delivery of pallets requires a more radial route structure, needing to travel to and from the hub repeatedly. By contrast the trucks can hold multiple pallets and are able to chain one delivery to the next. An illustration of the differences in route structure can be seen in Figure 6. Which strategy is more efficient is highly dependent on the distance of each delivery from the hub, as each kilometre ridden by the cargo bikes must be retraced back to the hub to pick up a new pallet. If a customer needs multiple pallets delivered, the issue becomes more pronounced.

Figure 6 Route structure of a truck and cargo bike with micro hub



The route structure and the nature of pallet delivery by cargo bike means that the bike is either at 100% or 0% capacity since it can only carry a single pallet at a time. In this sense, the bikes are always entering the delivery zone with a load factor of 100%. Their average load factor cannot exceed 50% unless they are able to incorporate pick-ups or returns into their route, which would also be true for a truck starting from the terminal loaded to 100% capacity and returning empty.

We do not have enough data on the truck routes to say precisely what their load factor is, but we do know that they have deliveries outside the city centre so that their load factor when entering the city centre is presumably lower than the cargo bikes. However, requiring high load factors for trucks entering cities will not necessarily create desirable outcomes if it leads to more inefficient route structures or long detours for operators to ensure they arrive at the city with high enough load factors (Arvidsson 2013).

2.1.4.3 Environment

A direct estimate of the GHG emissions reduced due to the implementation of this trial is difficult to calculate. Limited data was obtained on changing movements of the trucks that previously delivered packages in the city centre. From the collected data, the bikes travelled an average of 24 km per day which was used to deliver 5,6 pallets. Cargo bikes are well known to be extremely energy efficient and there are no surprises from the trial results in this regard. According to Rytle, the bikes use approximately 0,018 kWh/km. For comparison, a medium sized diesel truck uses approximately 0,17 L/km of diesel (Krause et al. 2020). Using a value of 10,7 kWh/L diesel, the truck uses 1,8 kWh/km. Despite the large disparity, the impact is relatively limited due to the small number of vehicle kilometres replaced during the trial.

Krause et al. (2020), gives a value of 450 g/km CO_2 emitted for medium trucks. Llorca & Moeckel (2021) use a value of 0,518 kg/kWh CO_2 emitted for the German grid in their analysis of cargo bikes. Using these numbers, we find that the cargo bikes in this trial emit 9,3 g CO_2 per km. The trial data shows an average of 466 km for the bikes each month, giving a value of 4,3 kg CO_2 emitted per month. We do not have accurate data for the truck movements, but to travel the same distance as the bikes, a truck would emit 209,7 kg CO_2. As noted in Llorca & Moeckel's analysis, cargo bike emissions are so small as to be almost irrelevant when compared to those from larger vehicles, even if the cargo bikes operate less efficiently and need to travel further to achieve the same operation. However, without more specific route data is not possible to determine how many truck vehicle kilometres were avoided by this solution.

When considering the local environment, the potential impacts are also substantial. The bikes are quieter, smaller and produce fewer localized pollutants due to tire and brake wear and NOx emissions. In this regard, the space use efficiency of a vehicle could also be considered as an indicator of nuisance in pedestrian areas. A larger vehicle is going to have a much larger impact on its surroundings and the character of a street and the activities on it impacts pedestrian behaviour (Hahm et al. 2019; Verlinde et al. 2020). As we saw in the previous section, the space efficiency of cargo bikes is much higher than trucks, allowing them to provide localized benefits even if they are less efficient from a logistic or economic perspective. Using the aforementioned delivery rate of 2,4 pallets per hour for the trucks and an average of 5,6 pallets delivered per day by the bikes, then the cargo bikes were able to displace about 140 minutes of truck movement in the areas in which they operated. This would have positive effects on the local environment in terms of local emissions such as NOx, particulate matter, noise and safety.

2.1.5 Conclusion

The Bremen Rytle trial was successful in achieving two of its three objectives and partially successful in its third objective.

1. Reducing the number of polluting vehicles entering the city centre
2. Improving space management thanks to last-mile delivery by cargo bikes
3. Increasing the efficiency in the interaction between long distance freight transport and urban freight transport

Shifting pallets to cargo bikes allowed large, diesel trucks to avoid movements within the city centre. In particular, the use of space was greatly improved, as the hub and bike combination allows the space used to be localized differently, with transloading operations occurring at the edge of the city centre so that a smaller footprint is needed for logistic activities in areas with more pedestrian activity.

Table 8: Assessment of trial objectives. O1= Objective nr.1, 02= Objective nr.2 etc. - see list of objectives above

<table>
<tr><th>Trial objective</th><th>KPI</th><th colspan="2">Assessment</th></tr>
<tr><td colspan="4">LAND AND SPACE USE</td></tr>
<tr><td rowspan="4">Improving space management thanks to last-mile delivery by cargo bikes (O2)</td><td>Space use efficiency</td><td colspan="2">p</td></tr>
<tr><td>Land use efficiency</td><td>p</td><td>n</td></tr>
<tr><td>Area occupied by vehicle in traffic</td><td colspan="2">p</td></tr>
<tr><td>Land use of hub</td><td colspan="2">p</td></tr>
<tr><td colspan="4">LOGISTICS EFFICIENCY</td></tr>
<tr><td>Increasing the efficiency in the interaction between long distance freight transport and urban freight transport (O3)</td><td>Time per delivery</td><td colspan="2">n</td></tr>
<tr><td></td><td>Vehicle load factor</td><td>p</td><td>n</td></tr>
<tr><td colspan="4">ENVIRONMENT</td></tr>
<tr><td rowspan="3">Reducing the number of polluting vehicles entering the city (O1)</td><td>CO_2 eq. emissions</td><td colspan="2">p</td></tr>
<tr><td>NOx and particulate matter emissions</td><td colspan="2">p</td></tr>
<tr><td>Cargo bikes replacing diesel vehicles</td><td colspan="2">p</td></tr>
</table>

The success in achieving the third objective is more mixed, as operations improved over the course of the trial but freight volumes were not high enough to justify preloading the entire micro hub and transporting it to the city centre. This would have led to large gains in terms of time saved for the cargo bikes but was not in effect at the time of writing this assessment. The lack of freight volumes also meant that it was difficult to get a sense of the maximum potential for the bikes. Higher freight volumes within 2 kilometres of the hub would have given more insight into the feasibility of this solution from the perspective of logistics efficiency. Theoretically, the bikes should be able to deliver far higher volumes if they are able to secure access to enough goods.

We also saw instances when multiple pallets needed to be delivered to the same customer. Unless the customer was extremely close to the hub, occasions in which a customer orders multiple pallets would likely be more efficiently carried out using a truck.

2.2 Trial 2 Private micro-logistics

2.2.1 Description of trial

This trial relies on a cargo bike sharing system for private micro-logistics called Fietje, corresponding to ULaaDS solution and scheme as presented in Table 9. In Bremen, Fietje has 12 cargo bikes among which 5 are part of the ULaaDs trial. The bikes are located in different areas of the city (cf. Figure 7) where they are hosted by shops, organisations or coffee shops, preferably open 6 days/week. There, users can pick up and drop off the rented cargo bikes during opening hours (all hosts are closed on Sundays). To rent a cargo-bike, users can book one of them online for 1, 2 or 3 days. Rental is free of charge and the bikes can be loaded with a maximum of 80 kilos.

Table 9: ULaaDS solution and scheme - Bremen trial 2

Solution	Scheme
2) Effective integration of passenger and urban freight mobility services and networks	4. Location and infrastructure capacity sharing 5. Transport vehicle capacity sharing

The trials aims and objectives are defined as followed:

First aim defined: City-wide sharing network of cargo bikes to be offered for little monetary compensation focusing on private logistics.

Objectives (as deliverable 5.2 ULaaDS factsheets baseline and city profiles):

1. Avoid car trips for private logistics, thus reducing pollution and congestion.
2. Offer users the possibility to familiarize with cargo bikes without having to invest in purchasing a privately owned one.

Final aim trialed: as defined but without monetary compensation and a greater focus on objective Nº 2.

This deliverable will assess the trial based on the first objective, which looks at three elements:

- avoiding car trips for private logistics
- reducing pollution
- reducing congestion

As the second objective is related to users' awareness and economic impacts, it is assessed in deliverable 5.4.

Figure 7: Locations of Fietje cargo-bikes

2.2.2 Relevant projects

In recent years, cargo bikes have been introduced in many European cities. In order to raise awareness on cargo bikes and accelerate their diffusion, City Changer Cargo Bike (CCCB - Horizon2020 programme) reviewed many projects across Europe, identified multiple “try out” schemes and assessed best practices (see deliverable 2.1 (Cioloca 2019)).

Becker and Rudolf (2018a) have studied a specific free cargo-bike sharing system in Germany and Austria. It is based on a cooperative network of 46 Free Cargo-Bikesharing operators (Freie Lastenräder) with 9,750 registered users. The paper provides insights on different topics, such as:

- user characteristics
- usage behaviour
- intentions for future cargo-bike use and purchase
- impact on car use.

As our analysis will also focus on these different subjects, the paper will provide us with a baseline to discuss our results.

A more recent survey has been conducted among Freie Lastenräder users in 2022, collecting around 2500 responses. The results are not (yet) published but some figures were communicated during the conference Cargo Bike Sharing Europe that happened in Cologne in 2023 (Bissel 2023). These preliminary findings will also be used to discuss our results.

Becker and Rudolf (2018b) also wrote a paper that analyses cargo bike sharing systems in Germany, Austria and Switzerland around five aspects: operators, sharing systems, cargo-bike technology, users, and impacts. In terms of environmental impact, they identify the high potential of cargo-bike sharing for reducing car trips by offering people the possibility to transport goods without a car. Thanks to the sharing system, people do not need to purchase a cargo-bike themselves and can still perform load carrying trips using them. It reduces their need (actual and perceived) to own a car. Becker and Rudolf (2018b) also highlight social impacts. One of them concerns the dissemination of information and knowledge on cargo-bikes among users and passers-by, which is critical for their diffusion. And it also has a positive effect on social justice since it provides a cheap/free transportation mode in areas where less privileged persons live. Based on the Bremen trial, we will discuss further the potential impacts of cargo-bikesharing.

2.2.3 Available data

The data available to assess the trial are described in Table 10.

Table 10: Data sources to assess Bremen trial 2

Data source	Provider	Type of variables	Period
ADFC survey	ADFC	Users characteristics Trip characteristics and use description	2021 & 2022 surveys
Reservation system (Buchungen 2022 final)	ADFC	Booked days	2022
Emissions estimations	ADFC	Emissions estimations (CO_2, NOx, particles)	Based on 2022 survey

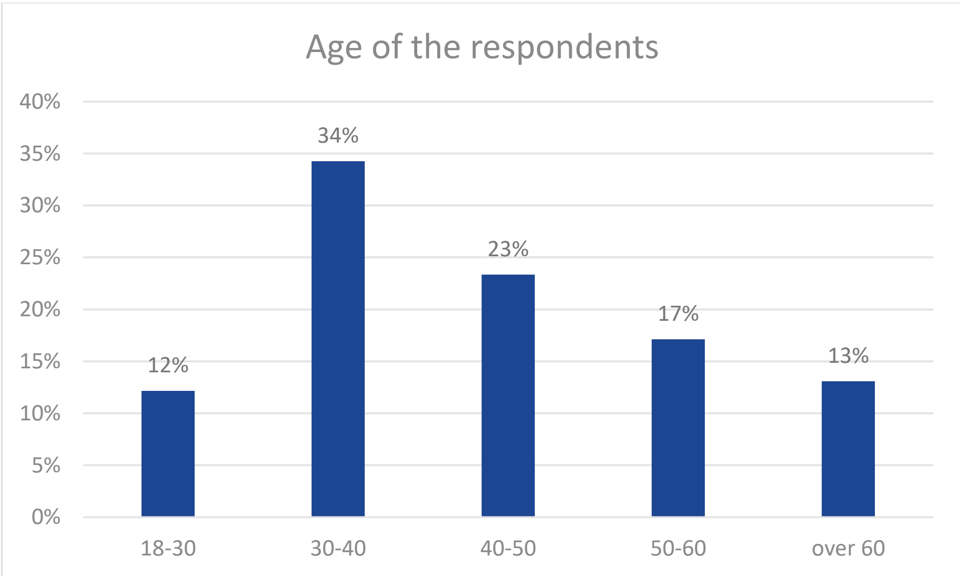
The analysis (mostly) relies on the survey provided by ADFC. This survey has been conducted among people registered on their website. They collected 351 answers. But among them, 30 respondents reported never having used a Fietje cargo-bike. We decided to remove them from the database as the survey questions were intended for actual users of the bike. The database we used was then composed of 321 respondents. As a consequence, our results often show differences when compared with figures used by ADFC. The largest difference between our figures and ADFC's concerns the average distance driven by the cargo bikes, as explained in section 2.2.3.2.

An important limitation to this survey concerns the fact that questions do not differentiate between a specific trip, the most recent trip, or the entire booking period (usually surveys use the most recent transaction). Instead, the questions are more general, as if they intended to cover all uses people made with the bikes. This results in difficulties in interpreting the answers since it is not stated whether they refer to the most recent trip or to an average non existing trip. For example, regarding the distance, we can imagine that some people answered based on their most recent trip and others tried to answer what distance they travelled on average. Moreover, the survey does not cover the fact that users might have used the cargo bikes for several purposes and several trips during one booking period (especially since it is not possible to book the bikes for less than a day).

2.2.3.1 User characteristics

In terms of user characteristics, the ADFC survey asked two questions regarding gender and age. A lower percentage of women were registered (45% to 51%)[2], but this proportion is higher compared to the Free Cargo-bikesharing users, among whom only 35% were women (Becker and Rudolf 2018a). In the more recent survey, 43% of users were female (Bissel 2023), indicating a diffusion of this transportation option among women. In terms of age, users appear to be quite spread among age categories, with more users aged between 30 and 40 years old (cf. Figure 8). This is consistent with the results from (Becker and Rudolf 2018a), according to which the mean age is 38 years old with a high standard deviation.

Figure 8: Age of respondents (source: ADFC survey, 2023)

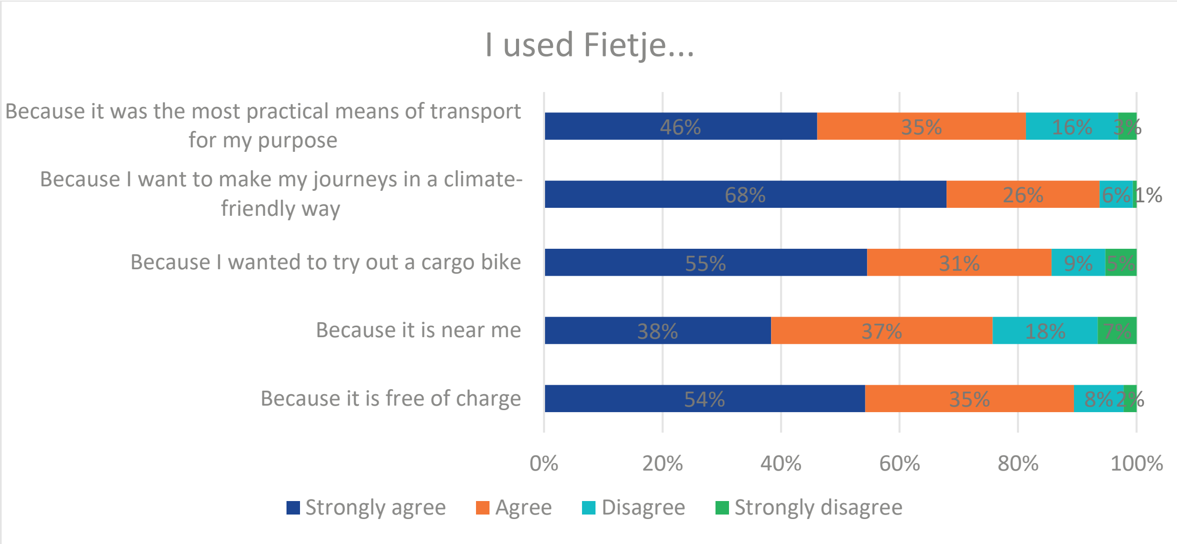


Becker and Rudolf (2018) show that Free cargo-bikesharing users are very concerned by climate change (92%) and air quality (84%). Most of them are cyclists: 71% use a bicycle as their daily means of transport. Nonetheless, they are not well experienced with cargo bikes, since 69% have used them for the first to third time. When it comes to Fietje users, they also seem to be very much concerned by climate change (cf. Figure 9). Indeed, their main motivation to borrow cargo-bikes appears to be “because I want to make my journeys in a climate-friendly way”, with 96% of respondents agreeing to it. Among motivations, convenience is also high for Fietje users since they value:

- the fact that it is the most practical means of transport for their purpose (81%)
- the location is close to them (75%)
- the fact that it is a free service (89%).

[2] 4% of respondents answered «Other».

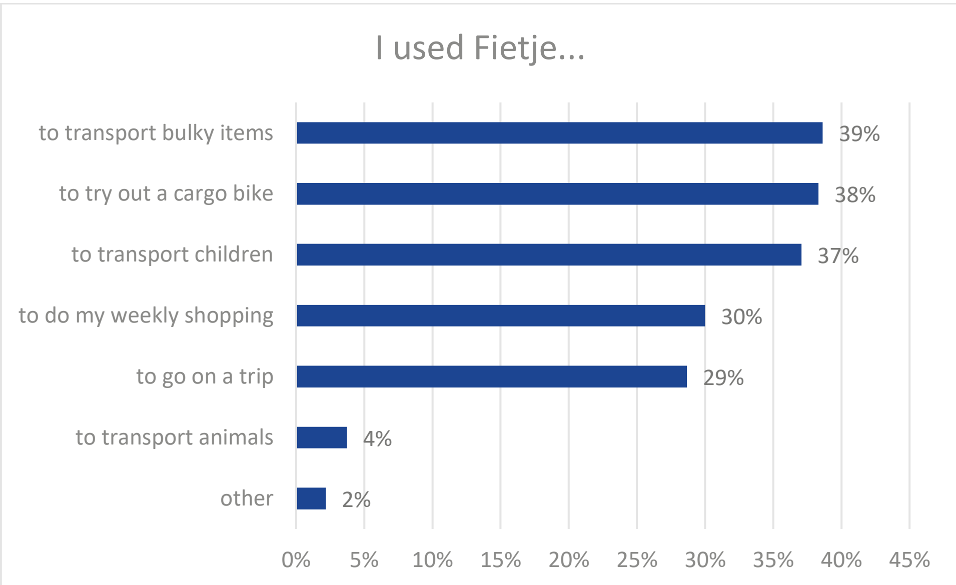
Figure 9: Motivations to use Fietje cargo-bikes (source: ADFC survey, 2023)



2.2.3.2 User behaviour

ADFC survey also enables us to understand better the cargo-bikes uses and users' behaviours with a cargo-bike. Respondents were asked about the trips' purposes when borrowing the cargo-bikes (cf. Figure 10).

Figure 10: Purpose of the trip (source: ADFC survey, 2023; several answers possible)



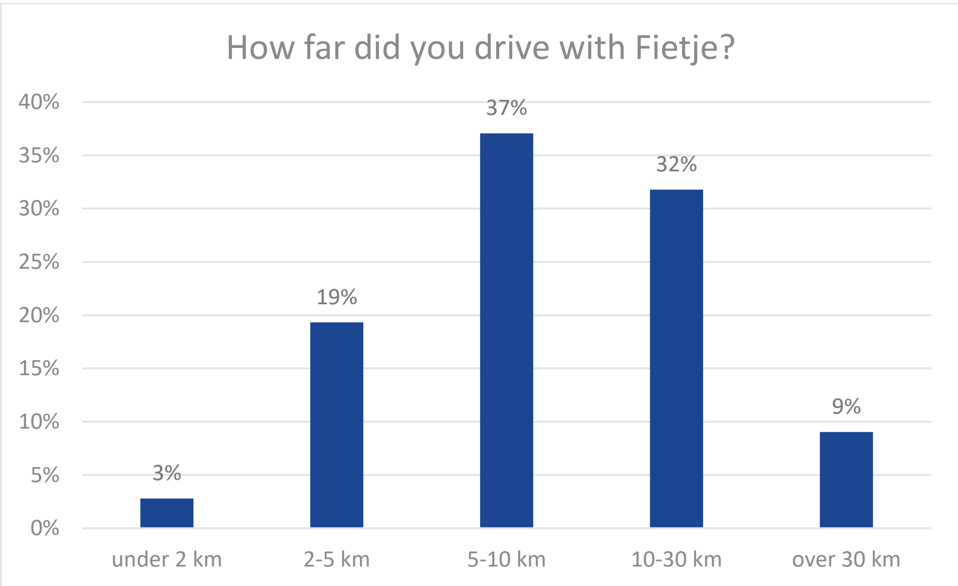
Several answers were possible to this question, and we see multiple purposes indicated by the users (n=572), which means that most respondents borrowed a bike for more than one reason. Moreover, several purposes could be associated with one booking, since it was possible to keep the bikes up to three days. This is consistent with what Becker and Rudolf (2018) found in their study.

In the ADFC survey, one of the main purposes for using Fietje is to try out a cargo-bike. This was the second highest purpose, mentioned by 38% of the sample. This was quite different from the results found by Becker and Rudolf (2018), where it is the least chosen purpose. Similarly, in the more recent survey conducted among that Free cargo-bikesharing users, only 12% mention that the purpose of the trip was to test cargo bikes (Bissel 2023). It is probably due to the fact that ADFC survey does not ask only about the most recent trip. Respondents are probably answering the question by thinking of all their different rentals, including the first one when trying cargo-bikes was one of the purposes. They probably also include this purpose among others, even if it is not the main reason for booking the cargo bike.

Other important reasons to borrow a cargo-bike are to transport persons or things. Indeed, transporting bulky items is the first reason to borrow a Fietje bike, with 39% of answers. They are also often used to transport children, with 37% of answers. Transporting animals is a less common reason, with only 4% of answers. In addition, cargo-bikes are often borrowed to do weekly shopping and for leisure trips.

Regarding the distance travelled, the question asked was "How far did you ride with Fietje?". Once again, it does not refer to a specific borrowing and it also assumes that the bike has been used for only one trip, even if the users kept the bike for several days. We assume the survey participants interpreted the question as meaning distance per day. The majority of respondents travelled between 5 and 10 km (cf. Figure 11). Cargo bikes are rarely borrowed to travel very short distances, i.e. less than 2 km, and only 9% of respondents travelled more than 30 km.

Figure 11: Distance driven with the cargo-bike (source: ADFC survey, 2023)



In order to estimate the average distance travelled with the cargo bikes, we used the barycentre of each distance category (under 2 km, 2-5 km, 5-10 km, 10-30 km, over 30 km) and calculated a weighted average (cf. Table 11). According to our calculation, the average distance travelled by the respondents is 13,5 km. This means that our result is almost 2 km over ADFC's. This is mainly due to the fact that ADFC did not limit the database to persons that had actually used the cargo bikes, so they include non-cargo bike users answering «under 2 km», which lowers their average distance. Data on kilometres travelled was collected from two e-bikes in the fleet using their onboard computers. This gives an average of 18 km per day for one of the bikes and 16 km per day for the second bike. These numbers are slightly higher than the average distance from the survey which is unsurprising since non-electric cargo bikes were also included in the survey. Electric bikes have been shown to encourage more biking for longer distances (Fyhri and Sundfør 2020). According to Fyhri and Sundfør (2020), the "e-bike effect" is 6,1 km, suggesting that the estimates given by survey participants are a relatively accurate representation of the distance covered per day by the bikes (electric and non-electric) during a booking.

Table 11: Base for calculation of the average distance travelled with the cargo-bikes

Distance range	Repartition of answers	Barycentre	
Under 2 km	2,80%	1	(ADFC used 1,5)
2-5 km	19,31%	3,5	
5-10 km	37,07%	7,5	
10-30 km	31,78%	20	(ADFC used 17)
Over 30 km	9,03%	40	(ADFC used 40)
Average distance	**13,5 km**		ADFC found 11,6 km

It would have been interesting to have results on the frequency of borrowings, but the question includes answers for both frequency of use and pickup location in the same question. Therefore, some respondents did not select an answer on frequency but just answered regarding pickup place and vice versa. So unfortunately, this question cannot be used in our analysis.

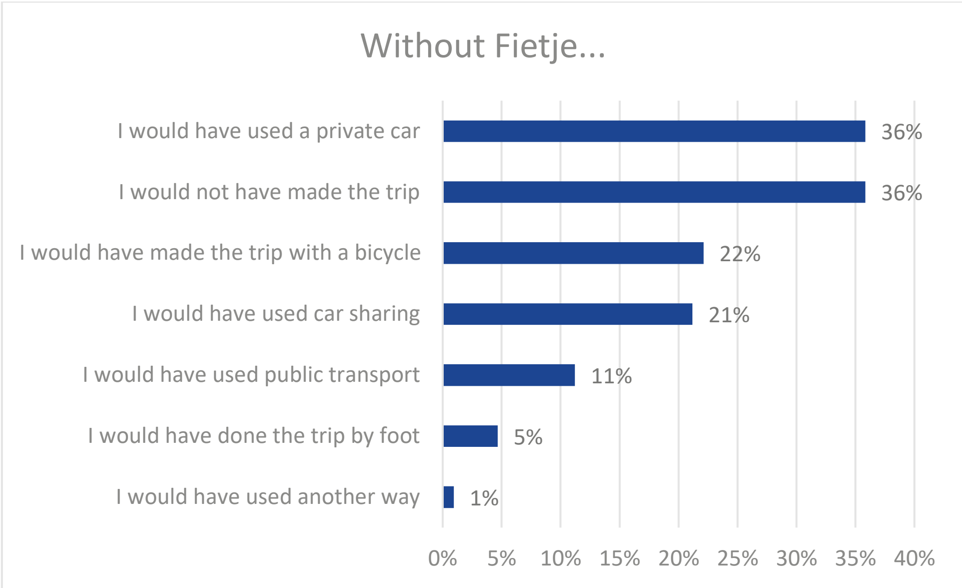
When it comes to the transportation mode that would have been used if the cargo bike was not borrowed, respondents could choose several answers. 36% could have answered they would have used a private car and 21% could have used car sharing, some of them answering both and some other answering other reasons in addition. This means that we obtain a range of car trips avoided for between:

- 38% of respondents who answered that they would have used the car and do not answer any other possible alternative.

- 55% of respondents choosing "private car" or "car sharing" and possibly other reasons (meaning that among them, some would not have necessarily used a car if they had not used the cargo-bike, because they might have answered another possible alternative they also have).

So this means that between 38-55% of cargo bikes trips have replaced car. This is in line with what Becker and Rudolf (2018) find (45,6%) with a survey where only one answer was possible.

Figure 12: Alternative transportation if not cargo-bike (source: ADFC survey, 2023; several answers possible)



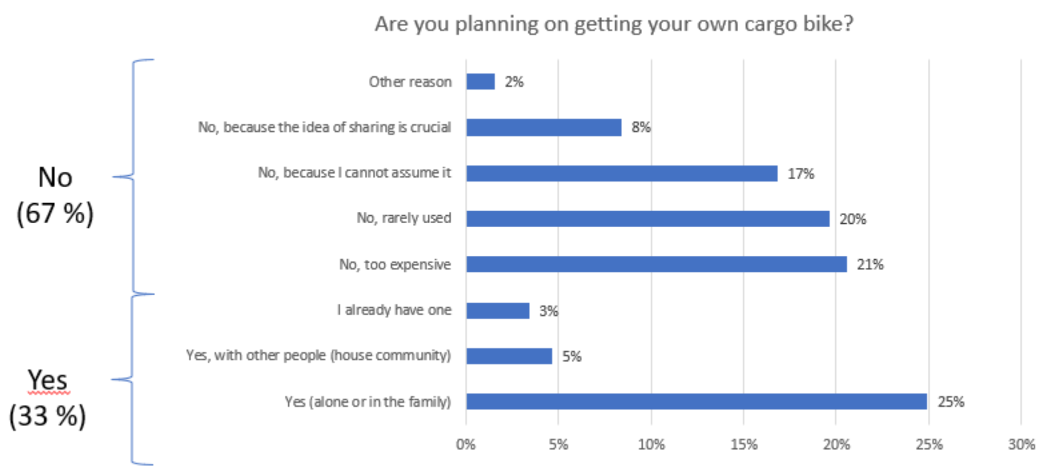
We can also see that for 36% of respondents, not making the trip would have been an alternative if they would not have borrowed the cargo bike. Thus, Fietje cargo-bike sharing system makes possible trips that would not have been made otherwise. It increases the travelling possibilities for users.

2.2.4 Impacts

2.2.4.1 Land and space use

The solution tested in the ADFC trial relied on a sharing principle. In total, 67% of users do not intend to buy a cargo bike, for different reasons (cf. Figure 13). This means that the trial fulfils its second objective by offering users the possibility to familiarize themselves with cargo bikes without having to invest in purchasing a privately owned one. In terms of land use, sharing cargo bikes is more effective than privately owned ones because it results in fewer vehicles in total.

Figure 13: Users' intention to buy a cargo bike (source: ADFC survey, 2023)



When compared 1:1 to other vehicles that would have been used as alternatives, cargo bikes have a smaller footprint. In particular, if we focus on the cases where cargo bikes have replaced cars (between 36 and 55% of the trips), cargo bikes use less space on the roads (5,4 m^2 are freed up) and consequently contribute less to congestion. We can also compare land and space use efficiency indicators for cargo bikes and a medium car, when in traffic.

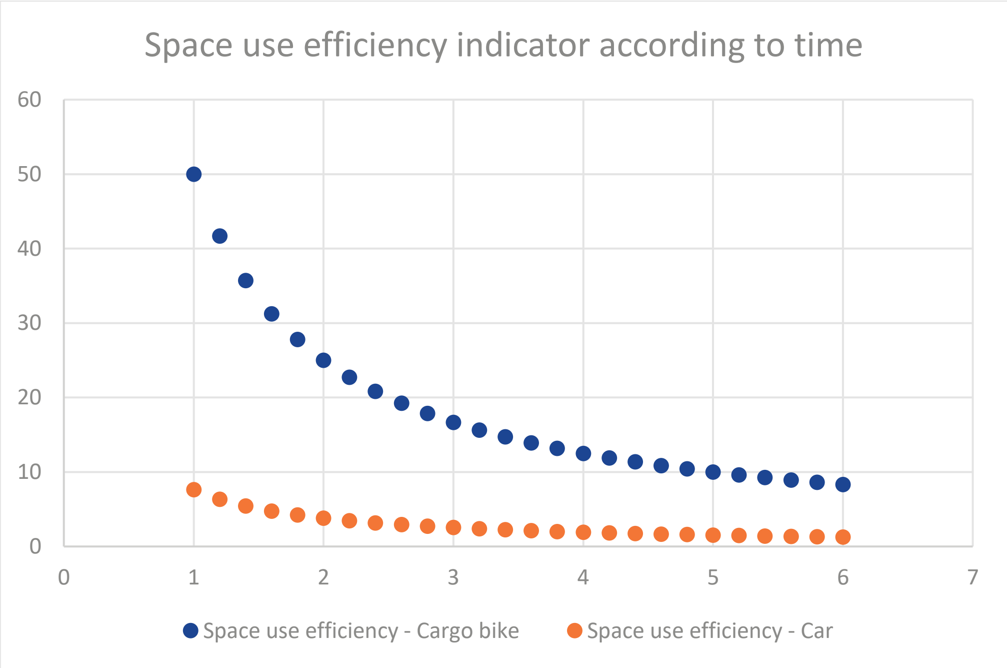
As bikes travelled 13,5 km on average and considering an average speed of 15 km/h in the city centre (Carracedo and Mostofi 2022), it means that cargo bikes were in traffic during 54 minutes on average. If we assume that users would have travelled the same distance if they had used a car and considering an average speed of 30 km/h for cars in city centres, it means that cars would have been in traffic for 27 minutes on average.

If we consider the transportation of 80 kg of cargo, we can see below (cf. Table 12 and Figure 14) that the space use efficiency of cargo bikes is far higher than for the cars, even if it were to take significantly longer to perform the same trip with the cargo-bike. As discussed earlier in section 1.3.2, space use efficiency shows the amount of cargo delivered per hour per cubic meter occupied by the vehicle. A higher value for the land or space use efficiency indicator means that the vehicle is delivering more cargo relative to its size. The difference could be even larger if we accounted for a buffer zone in front of the vehicles to account for the minimum safe distance required to travel in traffic at a given speed.

Table 12: Land and space use comparison

Vehicle	Footprint/space occupancy (m^2)	Volume occupancy (m^3)	Time in traffic to travel 13,5 km (min)	Land use efficiency indicator (cargo = 80 kg)	Space use efficiency indicator (cargo = 80 kg)
Fietje cargo bike	1,6	1,6	54	55,6	55,6
Medium car	7	10,5	27	12,7	16,9

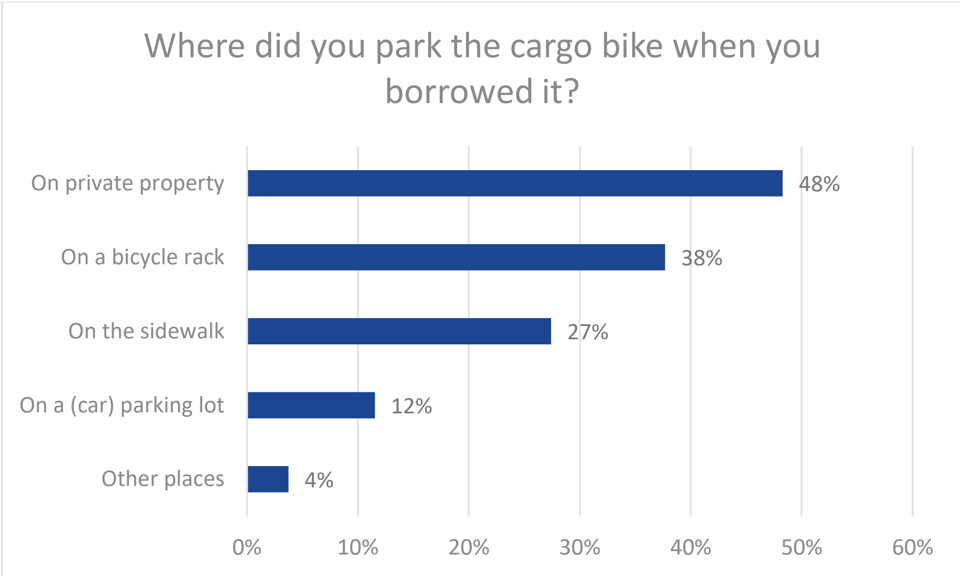
Figure 14: Comparison of space use efficiency for cargo bikes and cars



We have no indication on whether the respondents own a car or have the intention to get rid of their car. We know that 21% of them mention car sharing as an alternative they could have used instead of borrowing a cargo bike. We can see here the potential of the solution if largely and lastingly implemented: users could get rid of their private car and rely on shared cargo-bikes in addition to a car sharing system when needed which would then result in fewer vehicles and have an overall positive impact on land use.

For the 33% of users who own or will buy a cargo bike, parking location is crucial. Almost half of the users park (at least part of the time) the cargo bike on private property (cf. Figure 15). Bicycle racks and sidewalks are also popular parking locations among users. These parking locations could be problematic since cargo bikes are much larger than regular bikes. Fietje cargo bikes measure 2.53 m long and 63 cm wide, which means a footprint of 1.6 m^2. The diffusion of cargo bikes may require adaptations when it comes to public parking infrastructure and bike lanes.

Figure 15: Parking location for the cargo bikes (source: ADFC survey, 2023; several answers possible)

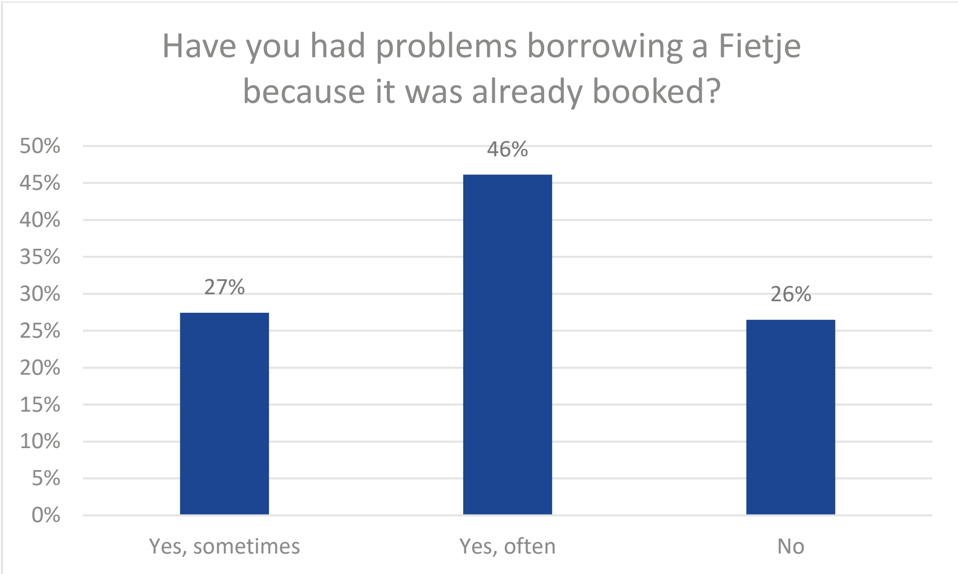


2.2.4.2 Logistics efficiency

This trial concerns private logistics, which covers goods transportation made by private individuals. Since KPIs in the logistics efficiency category do not always apply for this trial, it is difficult to assess the logistics efficiency in the same way as in the other trials. For that reason, the assessment conducted here is more concerned with the efficiency of the booking system.

Most users mention the lack of availability of Fietje cargo bikes: 46% of respondents reported that they often couldn't borrow a bike and 27% at they sometimes couldn't because they were already booked (cf. Figure 16). This is a strong limitation to the cargo bike sharing system efficiency. It could be avoided by enabling shorter bookings (a half day or even hour by hour), as for now it is only possible to book for 1, 2 or 3 days. Especially given that during the trial, users travel on average 13,5 km per day, meaning that the bikes are in use for approximately one hour and parked for the rest of the borrowing period. Efficiency could be significantly improved by enabling shorter borrowing periods more suited to the actual time in use, though it would be important to ensure that a system was in place that did not require significantly more effort from staff.

Figure 16: Lack of availability of the cargo bikes (source: ADFC survey, 2023)



Motor support is also an important option that can increase efficiency for users. 45% of users consider motor support to be important for them. As shown on Figure 17, this opinion is correlated with the distance travelled by users when borrowing a cargo bike, indicating that in order to replace carbonised transportation modes used for longer distances, cargo bikes with motor support are needed. This is consistent with results from Fyhri and Sundfør (2020), showing that purchasing an e-bike makes people increase their bicycle use from 2.1 to 9.2 km on average. On the other hand, when asked about their preferred cargo bike model, users are equally spread between bikes with electric support and without (cf. Figure 18). This indicates that there is not necessarily a need to increase the share of e-cargo bikes but only to maintain a diversified fleet of cargo bikes. The low request for e-cargo bikes is likely due to the fact that Bremen is relatively flat.

Figure 17: Correlation between the need for motor support and the distance travelled

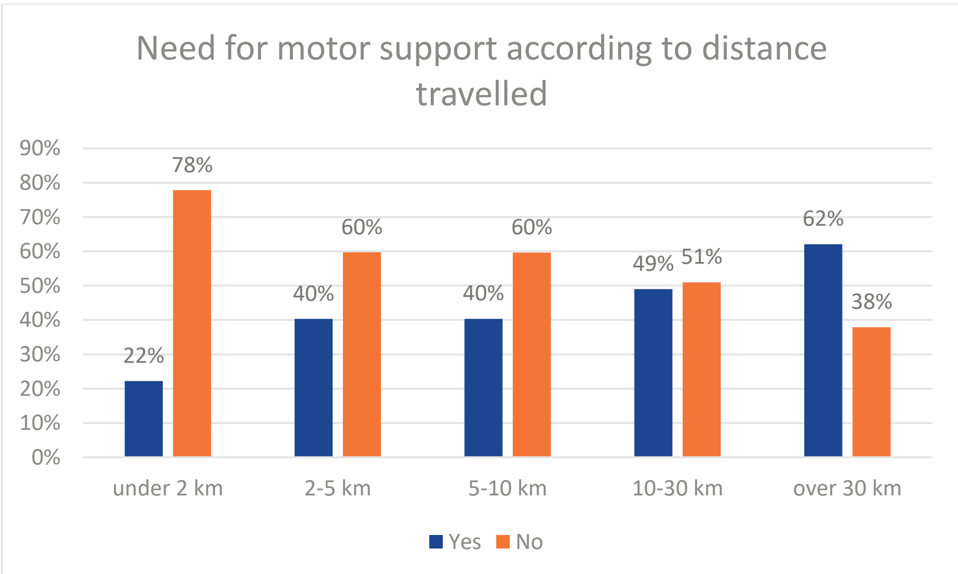
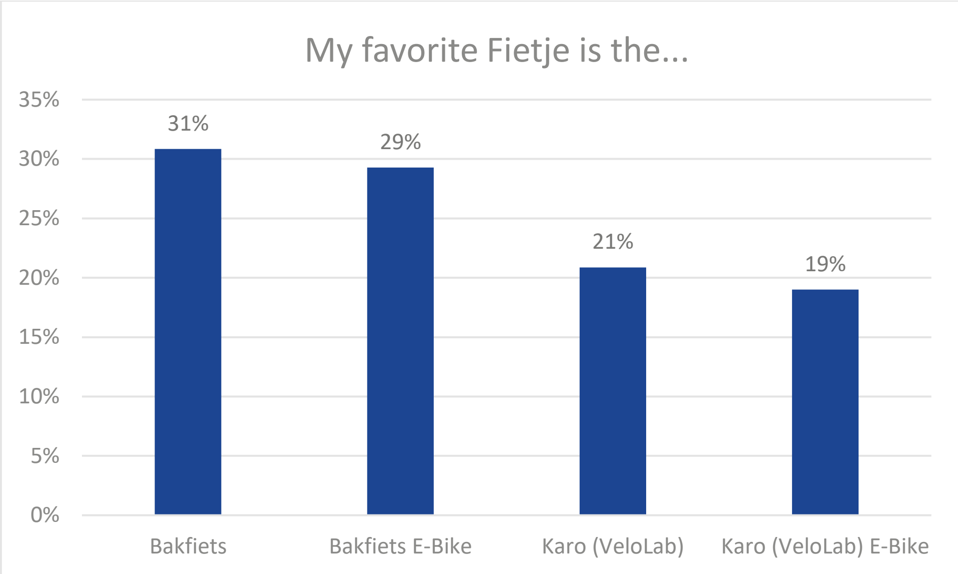


Figure 18: Comparison between preferences for bikes with and without motor support



2.2.4.3 Environmental

Based on the proportion of respondents who could have used a car as an alternative to a cargo bike, we estimate CO_2 emissions that have been avoided during the trial. This estimation considers that:

- Fietje registered 1385 bookings during the trial period[3]

- respondents who could have used a car instead represent between 38% (minimum estimate-users for whom car is the only alternative) and 55% of the users (maximum estimate - users for whom car is one of the possible alternatives)

- on average, bookings are made for 2,16 days

- on average, respondents travelled 13,5 km/day

- a medium car's emissions are estimated to be 135 g/km[4].

$$1385 \times 0{,}38 \times 2{,}16 \times 13{,}5 \times 135 = 2071832{,}58 \text{ g} = 2{,}07 \text{ t}$$

$$1385 \times 0{,}55 \times 2{,}16 \times 13{,}5 \times 135 = 2998705{,}05 \text{ g} = 3{,}00 \text{ t}$$

This means that the trial has avoided between 2,07 t and 3,00 t of CO_2 emissions. Though this can be considered a rough estimate, it shows that the ADFC trial has had a positive impact on CO_2 emissions.

[3] This number of bookings corresponds to all Fietje bikes in Bremen (not only the 5 ones included in ULaaDS).
[4] We consider the CO_2 emissions from a medium car to be 135 g/km (Krause et al. 2020).

2.2.5 Conclusion

Table 13 presents a summary of the trial's assessment, according to the trial objectives and the corresponding KPIs. We also added a KPI correlated to the system efficiency area of impact, as it is also an important aspect of the solution tested in the trial.

Table 13: Assessment of trial objectives. O1= Objective nr.1, 02= Objective nr.2 etc. - see list of objectives above (in 2.2.1).

Trial objective	KPI	Assessment
LAND-USE		
Reduce congestion (O1)	Space use efficiency	p
	Area occupied by vehicle in traffic	p
LOGISTICS EFFICIENCY		
More efficient use of vehicle fleet	Time in operation per vehicle	n
ENVIRONMENT		
Avoid car trips for private logistics (O1)	Cargo bikes replacing fossil fuel cars	p
	CO_2 eq. emissions	p
Reduce pollution (O1)	NOx and Particle matter emissions	p

The ADFC trial was successful in achieving its first objective: avoid car trips for private logistics, thus reducing pollution and congestion. Offering a city-wide sharing network of cargo bikes for no monetary compensation allowed individuals to avoid car trips to perform their private logistics. In that sense, the trial has not only contributed to a reduction in CO_2 emissions, but also participates in a reduction of local air pollution, noise and congestion. Nonetheless, the booking system could be more efficient as the vehicles are used for relatively short amounts of time considering the length of the bookings. Shorting booking periods could create a larger impact as the bikes would be available for other users more frequently.

2.3 Trial 2B Cargo-hitching simulation

2.3.1 Description of trial

This trial aims to develop an offer combining on-demand passenger and freight transport, while addressing the second ULaaDS solution, based on the fifth scheme (cf. Table 14). The trial was initially planned to be done in cooperation with Daimler, relying on the existing operation of the shuttle they used for employees ("WerkShuttle"). ULaaDS partner Via would adapt the WerkShuttle app for on-demand mobility to include the cargo-hitching functionalities. Ongoing analysis determined that freight movements within the office park were extremely optimized and there was little opportunity to enact a cargo hitching model that would result in efficiency gains which required adjustments to the trial.

It was instead decided that a simulation of a cargo hitching service would be the best solution, which Via conducted using a combination of generated data, data from their other services in similar sized cities, and data collected from conversations with ULaaDs partners and logistic actors in Bremen. More can be read about the trial in deliverable 4.7.

Via initially considered four different cargo hitching scenarios to simulate. Through interviews, experience, and internal discussions, it was determined that two cargo-hitching scenarios should be simulated in two cities and compared against a baseline simulation of only passengers (scenario 1) and only cargo service (scenario 2). The two cargo hitching services were a commingled service, with one to fulfilling all the passenger and cargo requests (scenario 3) and the second using only the vehicles available in the passenger only service to utilize extra capacity during low demand periods to deliver packages (scenario 4). In scenario 3 and 4, cargo and passengers were not permitted to be in the vehicles at the same time. The simulated services ran for 21 hours, from 04:00 to 1:00 the following day.

Table 14: ULaaDS solution and scheme - Bremen trial 3

Solution	Scheme
2) Effective integration of passenger and urban freight mobility services and networks (Cargo hitching)	5. Transport vehicle capacity sharing

The objectives of the trial are the following:

Objectives (as deliverable 5.2 ULaaDS factsheets baseline and city profiles):

1. Increasing network efficiency because of higher load factors
2. Increasing synergies with other spatial developments
3. Limiting environmental emissions
4. Increase flexibility and service availability.
5. Keeping people transportation and freight transportation at socially acceptable levels in an economically viable way

2.3.2 Relevant projects

While cargo-hitching is a viable solution for long distance transport, especially air travel, it is far less common in the world of urban logistics (Zhu et al. 2023). Previous studies have often focused on fixed lines in more rural areas as well as last mile options at fixed points, for example TKI DINALOG's cargo hitching project (van Duin et al., 2019).

Cargo hitching is being explored in other EU funded projects such as SPROUT and MOVE21. In MOVE21, a subsidized-on demand public transport service that provides free rides to the elderly in

Oslo, Norway, looks for ways to utilize its unused capacity to transport freight. For this project, business and governance innovation is considered as important as technological innovation. As an example, one barrier for the project is that the driver is not allowed to leave the vehicle unattended while passengers are on board due to prior contract structures that had not considered the transport of goods.

In the SPROUT project, the Next system was trialed in Padua, Italy, using modular autonomous vehicles traveling in a platoon that can include both freight and passengers. It was assessed positively for its potential to reduce emissions and pollution and increase efficiency, but experienced regulatory and administrative barriers related to the use of experimental vehicles and autonomous technologies.

These projects have shown that the combination of passengers and freight offers many potential benefits but can be challenging to realize the gains due to existing regulatory frameworks, business models and operational challenges. While not unreasonable, such restrictions can add a layer of complexity to route optimisation and make establishing an efficient route more challenging and there is valuable knowledge to be gained by better understanding and revealing barriers related to cargo hitching.

Of particular interest for the ULaaDS Via trial as an on-demand service, considerations for passenger service level must be considered. When combining person and freight transport, the needs of the passenger must be prioritised as significant declines in service quality due to package pickup/drop-off would not be accepted by passengers (Mourad et al. 2021). It can also be challenging to pull multiple distinct actors together as a cargo hitching scheme requires a large number of stakeholders working in cooperation. Policymakers could facilitate this process by defining a set of principles through which they operate that encourages cooperation and makes clear their goals, a so-called «normative framework” (Cavellaro & Nocera, 2022).

2.3.3 Available data

While a simulation provides no tangible impacts, the potential of such a service can still be considered and discussed. Our assessment is therefore limited to information provided by Via's report and any potential impacts are based solely on these findings. We therefore consider this trial to be in tier 2, where we have some insight into the solution based on the available data, but our conclusions are limited.

Table 15 presents data from various scenarios simulated for Bremen. Scenarios 1 and 2 are considered the baseline, and scenarios 3 and 4 simulate cargo-hitching. Scenario 3 was allowed to use as many vehicles as necessary in order to complete the combined package and passenger requests whereas scenario 4 was given the same resources as the passenger only scenario and any package deliveries had to be carried out using extra capacity throughout the day due to lower passenger numbers. For the purpose of the simulation, a passenger and a unit of cargo were assumed to each occupy one "space" in the vehicle and they were not allowed to occupy the vehicle at the same time. A passenger request needed to be fulfilled before a cargo request could be fulfilled.

Table 15: Data from simulation of Via cargo hitching service trial in Bremen

Bremen	Scenario 1 Passenger only	Scenario 2 Cargo only	Scenario 3 Passenger and cargo	Scenario 4 Passenger and cargo
Passengers (# per day)	100	0	100	100
Cargo (# of package per day)	0	200	200	52
Vehicles required	2	4	5	2
Avg utilization (# of passengers + packages)	2,35[5]	2,35	2,85	3,55
Avg wait person (min)	12	n/a	21	26
Avg wait cargo (min)	n/a	15	19	35
Avg trip duration person (min)	17	n/a	12	13
Avg trip duration cargo (min)	n/a	19	20	19
Avg trip length (km)	2,4	2,4	2,9	2,5
Avg walk person (m)	75	n/a	105	105
Percent shared trips (%)	26	34	33	38
Avg passengers/packages	0,66	0,69	0,71	0,76
Avg daily vehicle drive distance (km)	240	265	295	370
Annual passengers (# of boardings per year)	26200	0	26200	26200
Annual packages (# of deliveries per year)	0	52400	52400	13600
Annual revenue hours (total hours of vehicle driving time)	11000	22000	27500	11000

In addition to providing information on kilometres travelled, vehicle occupancy and trip duration, Via also provided estimations for CO_2 emissions and reductions as compared to the baseline scenarios. To do this they used a value of 2,345 grams of CO_2 emitted per litre and calculated expectations based on the baseline scenarios vs the results of the simulation. The results showed

[5] These values correspond to the bayrcentre of the ranges presented in VIA report.

that cargo-hitching scenarios emit slightly less CO_2 compared to both the passenger only and the cargo only scenarios.

2.3.4 Impacts

2.3.4.1 Land and space use

The simulation data suggests clear benefits for land use with cargo hitching by reducing the number of vehicles necessary to transport a given number of passengers and cargo. Via frequently uses a Mercedes Vito van for its services in other cities than Bremen, the dimensions of which we can use to look more closely at the land and space use of this solution (cf. Table 16). We assume the same type of vehicle is used in all scenarios, whether transporting passengers only, cargo only, or a combination of the two.

Table 16: Vehicle dimensions Vito van

Vehicle	Dimensions (L x W x H cm)	Footprint/area occupancy (m^2)	Volume occupancy (m^3)
Mercedes Vito	514 x 225 x 191	11.6	22.1

In scenario 3, the cargo-hitching service uses 5 vehicles to fulfil the demand of 100 passenger trips and 200 package deliveries. To fulfil the same demand separately requires a total of six vehicles - two vehicles for passenger only (scenario 1) and four vehicles for cargo only (scenario 2). Similarly, scenario 4 can fulfil all the passenger requests and 26% of the cargo requests using two vehicles. This would require at least three vehicles to accomplish if the services were separated – two vehicles for passenger only (scenario 1) and at least one vehicle for cargo only (based on scenario 4, where delivery of 200 cargo units requires four vehicles). In summary, the cargo hitching service in both scenario 3 and 4 uses at least one vehicle less than in the scenarios without cargo hitching. Cargo hitching will therefore potentially save the area and volume occupied by one vehicle (11.6 m^2 and 22.1 m^3 respectively) during the 21 hours[6] the service is in operation.

2.3.4.2 Logistics efficiency

Based on the simulation results, the impacts of cargo-hitching on logistics efficiency are limited. However, different scenarios might be able to achieve higher levels of efficiency than simulated. The feasible service level identified in Bremen by using data from other cities similar in size suggested that two vehicles would be enough for estimated passenger service and four vehicles for a potential cargo service.

[6] In the simulation, service hours are set from 4 a.m. to 1 a.m. on weekdays, i.e. 21 hours of daily operation.

Table 17: Distance travelled per passenger and/or cargo estimates

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Average daily vehicle drive distance (km)	240	265	295	370
Vehicles required (# of vehicles)	2	4	5	2
Total daily distance (km)	480	1060	1475	740
Number of entities (# of passengers + packages)	100 + 0	0 + 200	100 + 200	100 + 52
Distance per passenger and package (km per passenger and/or package)	4,80	5,30	4,92	4,87

When looking at the average distance travelled per passenger and packages, the incorporation of packages in scenarios 3 and 4 leads to a slight increase in distance travelled per delivery/drop-off: 4,92 km in scenario 3 and 4,87 km in scenario 4, compared to 4,80 km in scenario 1 (cf. Table 17). At the same time, the cargo-hitching scenarios provide a noticeable improvement over the cargo only service (scenario 2) where the average distance per delivery/drop-off is 5,30 km.

In scenario 4, which sees just the utilization of extra capacity in the passenger service to deliver packages, we see that an extra 260 km of driving is needed to deliver the 52 packages which is 68,9 km more than would be expected based on the kilometres driven in the freight only service (scenario 2). This is due to the higher priority given passenger trips which can lead to a lest optimal route being taken in order to reduce passenger wait times.

2.3.4.3 Environment

Based on the estimates made by Via and presented in their report, scenario 3 would enable a reduction of 2 tons of CO_2 per year, while scenario 4 would enable a reduction of 400 kg CO_2. The report argues that the low emission reduction enabled in scenario 4 is due to the low volume of packages delivered (26% of the volume delivered in scenario 3).

Table 18: Estimated greenhouse gas reduction in the simulation trial (from VIA report)

Greenhouse Gas Emissions	Estimated tons of CO_2 emitted annually			
Demand scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Bremen	16	36	Expected: 51 Actual: 49 Reduction: 2 (4%)	Expected: 25 Actual: 25 Reduction: 0,4 (1%)

These emissions reductions are due to the increased efficiency enabled by the cargo-hitching principle. As the simulation trials were calculated with fossil fuel vehicles, an important improvement would be to fully electrify the services.

2.3.5 Conclusion

The Via simulation for Bremen provides a number of useful insights for the potential use of an on-demand cargo hitching service. The simulation suggests that vehicle load factor can be increased, allowing a greater utilization of vehicles by using cargo hitching when compared with a passenger only or freight only scenario.

However, the on-demand nature of the service makes forecasting of passenger and freight demand critical for correctly deploying resources. In the examined scenarios, both the passenger and freight flows could be on-demand. In real world deployment, the challenges associated with on-demand services could be mitigated by focusing on a more fixed stream for either passenger or freight. For example, developing a cargo-hitching service that offers passenger services on-demand, but with a more predictable freight could be easier to implement. Identifying these possibilities requires significant levels of data sharing and cooperation between multiple actors. It is also important to find ways of balancing the demands of passengers and freight to understand when and how each can occur without reducing service levels.

3. Groningen

3.1 Trial 1 Sharing platform for logistics

Groningen's first trial focused on the development, the implementation and the promotion of a shared platform for zero-emission urban freight vehicles. The platform was intended for shop owners, either to supply their shop or to deliver their customers in Groningen.

3.1.1 Description of trial

Trial 1 addresses the two ULaaDS solutions, based on three schemes (cf. Table 19). The Municipality of Groningen and the Groningen City Club worked together to establish a platform where local shopkeepers and entrepreneurs can access three different zero-emission vehicles:

- A cargo bike (Urban Arrow L), with a top speed of 25 km/h, a loading volume of 400 L, a maximum allowed total weight of 250 kg and a range of 40 km.
- A light electric freight vehicle (Carver cargo), with a top speed of 45 km/h, a loading volume of 500 L, a maximum allowed total weight of 500 kg and a range of 100 km.
- An electric van (Volkswagen ID Buzz cargo), with a top speed of 145 km/h, a loading volume of 3.9 m^3, a maximum allowed total weight of 650 kg and a range of 424 km.

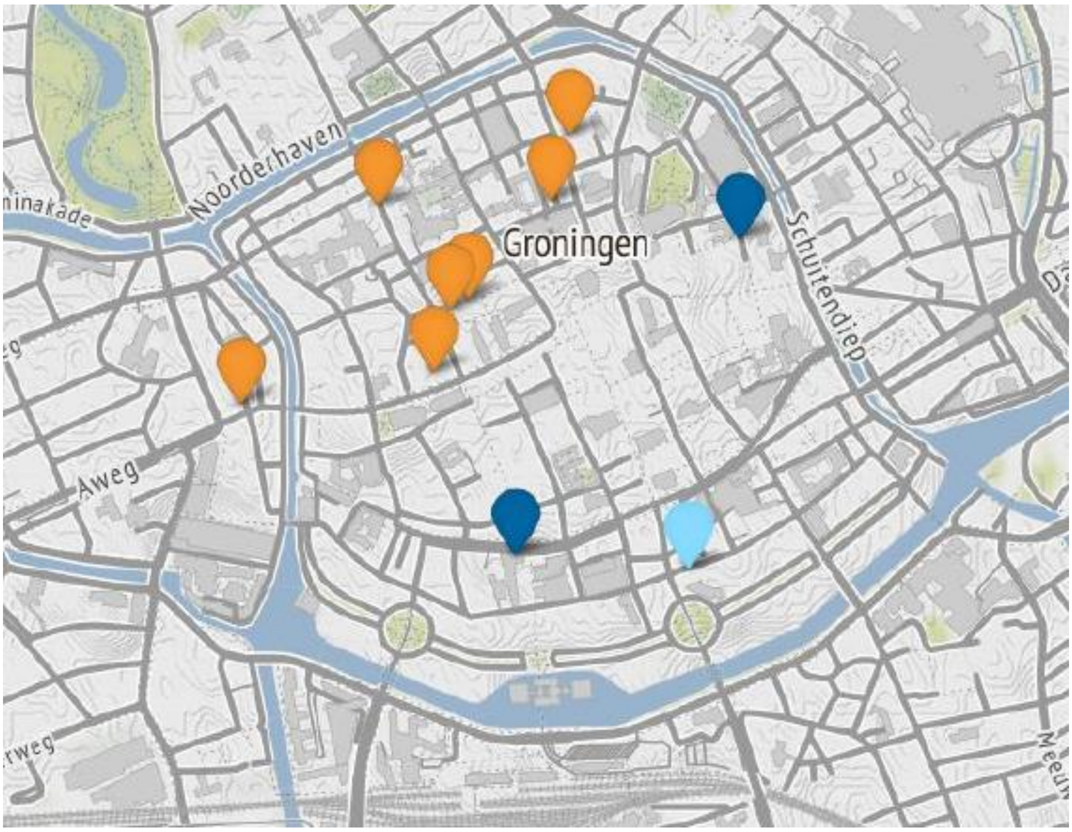
The available vehicles are located in or close to the city centre and users have to return them at the same location they were picked up from. Figure 19 shows locations of the different vehicles. The cargo bike was located in the East of the city centre in an underground bicycle parking lot. The LEFV was in the South of the city centre at a Groningen municipality office. The van was initially located at the leasing company (15 minutes by car or bike from the city centre), then at the East of the city centre in a garage next to the cargo bike location. Since June 2023 the van is located in the South of the city centre, on Herebinnensingel.

Seven shop owners have been renting the shared vehicles. Their shop location is also mapped in Figure 19. Eight more shop owners were involved in the trial but have not (yet) used the vehicles.

Table 19: ULaaDS solutions and schemes - Groningen trial 1

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

Figure 19: Location of trial 1 stakeholders (the LEFV and the cargo bike are in dark blue, the location of the van (since June 2023) is in light blue, shops involved in the trial are in orange) (Source: deliverable 3.5)



The aim and objectives of the trial are the following:

First aim defined: Develop and promote a platform for shared (zero-emission) vehicles to enable collaborative delivery models for shopkeepers and other entrepreneurs in the city. The main goal is to stimulate a platform that:

- can organize the delivery of orders from multiple shops in the city centre to consumers in the city and its neighbouring peri-urban and rural areas. The deliveries may include possibilities to deliver via mobihubs/parcel lockers, parking garages, offices, hotels etc.

- provides access to multiple zero-emission vehicles for shared use by local shopkeepers and entrepreneurs.

Objectives (as deliverable 5.2 ULaaDS factsheets baseline and city profiles):

1. Increasing the use of cargo bikes and other zero emission vehicles (and decreasing the use of polluting vehicles)
2. Increasing the efficiency/use of transport vehicles
3. Increasing liveability and safety because of the use of smaller, silent, and clean vehicles
4. Giving more target groups the opportunity to use electric vehicles.
5. Reducing CO_2 emissions

Trialed aim: as defined

In this deliverable, the trial is assessed according to the objectives 1, 2, 3 and 5. The fourth objective relates to users experience and costs and is assessed in deliverable 5.4.

3.1.2 Relevant projects

As car-sharing systems have developed in European cities, research has extensively studied its spread and implications in terms of user behaviour and mobility demand. For example, the EU project STARS explored the diffusion of car sharing in Europe, identifying five car sharing business models (Rodenbach et al., 2018):

- Free-floating within an operational area (customers can park the car wherever they want, as long as it is within the operational zone)

- Free-floating with pool stations (customers don't need to return the car to the same location, but they have to park on one of the numerous fixed pool-station)

- Round trip, home zone based (customers need to return the car to the area where they found it)

- Round trip, pool station based (customers need to return the car to the same parking place it was found)

- Peer-to-peer and community schemes (cars are not owned by a company but by users).

The STARS project, as well as most research on car-sharing, focuses on platforms aimed at individual customers. We could not find previous research on inter-business car-sharing, which shows that the solution tested in this trial is innovative in terms of organisation. However, different initiatives have happened outside of research projects. For example, in France, the *SQY Share*[7] project in Saint-Quentin-en-Yvelines was launched in September 2020 and consisted of a car-sharing system between three different companies (Banque Populaire Val de France, Leoni and Enedis).

It is more frequent to see businesses with their own internal car-sharing system. Sharing cars with other companies must solve several additional obstacles, such as insurance issues in case of damage, the reluctance of employees to share professional vehicles with other businesses, the need for a neutral partner to lead the project and the need for a close geographical proximity between the businesses involved (Mouly, 2018). According to the CEO of Ubeeqo (a car-sharing solution provider), there is a strong need for a project leader at the heart of the system's organization in order for an inter-company car-sharing system to work.

3.1.3 Available data

The three shared vehicles show very different use rates during the trial period. The most used vehicle is by far the van (ID Buzz) and our assessment will mostly consider its use. From the day it became available, on the 14th February 2023, until the end of data collection on the 17th June 2023, the van was rented 76 times[8], for a total of 9695 km. The light electric freight vehicle (Carver) was only used by three shop owners and had fewer than 200km driven. The cargo bike (Urban Arrow L) was not used.

Our analysis relies on different data sources summarized in Table 20. The quantitative data only concern the electric van since data concerning the light electric freight vehicle (LEFV) were not sharable and the cargo bike was not used.

Table 20: Data source to analyse Groningen trial 1

Data source	Provider	Type of variables	Period
GPS installed in vehicles	Century	Location data (not sharable for the LEFV)	14.02.2023 – 17.06.2023
Reservation system	Century	Quantitative data (not sharable for the LEFV)	14.02.2023 – 17.06.2023
Interviews with users	RUG	Qualitative data (reasons for use, replaced trip, user satisfaction, discussion on potential)	End of February 2023 - Beginning of May 2023[9]

[7] More information on the project: Inauguration de SQY Share | SQY (saint-quentin-en-yvelines.fr)
[8] These numbers are higher than those presented in deliverable 3.5 which is based on data from 14/02/2023 to the 01/05/2023. The trial was still running when the deliverable was written.
[9] One round at the end of February 2023 (before using it) and one round at the end of April/beginning of May 2023 (after some usage).

The van was rented by six different users (cf. Table 21). Among them, we can observe very different behaviours depending on the shop. First of all, there are discrepancies in terms of rental frequency. Two shop owners rented the ID Buzz especially frequently. The first one is the furniture and interior design shop who rented the van 28 times (cf. Table 21). The second one is the cheese and luxury food shop owner who rented it every Wednesday morning (20 times in total) in order to visit local dairy farms in the countryside and bring back the products back in their shop[10]. On the other hand, the children's apparel shop rented it only 2 times.

Table 21: Van users' description

User	Business description	ID Buzz rental times
Children's apparel	Sells clothing for kids, owns a private vehicle. Location inside the city centre in a car-restricted area.	2
Cheese and Luxury Foods	Sells cheese and luxury foods. Owns a private vehicle. Located in the city centre in a car-restricted area and has an additional location in a neighbouring town.	20
Furniture & Interior design shop	Sells furniture and interior items. Own a diesel van which is used for deliveries. Located in the city centre in a location that is accessible by car.	28
Wine Merchant	Sells a broad range of quality wines to cafés and restaurants. Also hosts tastings on location. Had a shop, now has a small storage location close to the city centre	8
Garden Boutique	Sells items related to gardening ranging from crops to tools and seeds to decoration. Has a field in a neighbouring town where crops are grown. Shop is located in the city centre. Owns a light electric vehicle and a cargo bike	10
Art Gallery	Sells supplies for painting and other forms of art. Located in the city centre, do not own any vehicle.	8
TOTAL		**76**

As we can see in Table 22 the standard deviations are quite high, which means that there is a striking diversity of duration and distance travelled among the different rentals. This can be attributed to very different usage patterns during the rental period for users (cf. Table 23). In addition, we see

[10] This shop owner also occasionally rented the Carver to deliver companies within Groningen.

that even for the same user, different rental periods can be very different in terms of both duration and distance. The result show that users are renting the ID Buzz for different kinds of trips, probably covering different types of needs.

Table 22: Average and standard deviation values for rental duration and distance covered (on the whole sample N=76 rentals)

	Rental duration (hours)	Distance covered (km)
Average	15:45	125 km
Standard deviation	17:19	147 km

3.1.4 Impacts

3.1.4.1 Land and space use

As a shared vehicle platform, this trial has the potential to reduce space needed for parked vehicles by allowing multiple people to share the benefits (making trips) of a smaller number of parked vehicles. As carried out, only the ID Buzz saw significant usage during the trial meaning the other two vehicles sat mostly unused occupying space.

When considered in traffic, the impact of the ID Buzz in terms of land use is either neutral or negative, depending on what the alternative transportation mode used by the shop owner would have been. Often, the use of the ID Buzz replaced the use of a smaller vehicle. For example, if we focus on the two major users:

- the Cheese & Luxury Foods shop owner uses the ID Buzz as a replacement of their personal car. So for them, using the ID Buzz results in using more space in traffic

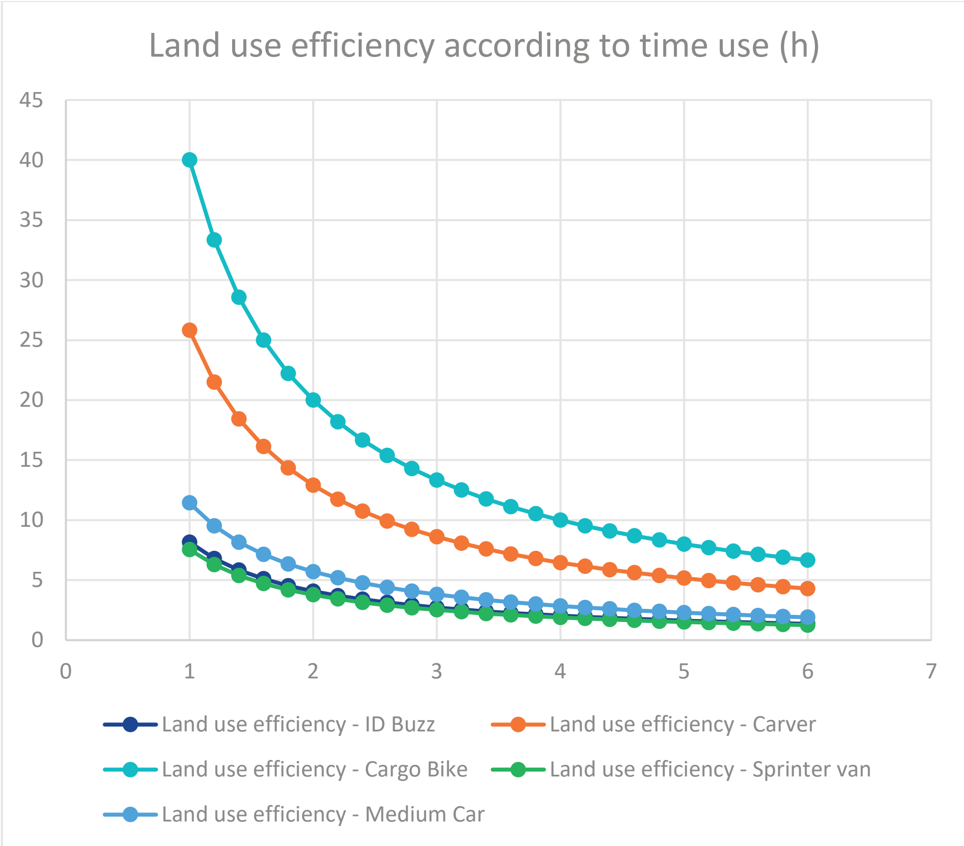
- the Furniture & Interior design shop owner has their own diesel van as an alternative. So for them, using the ID Buzz means using slightly less space in traffic.

Given the data we have, we are unable to determine if a shared platform would contribute to overall fewer trips in the long run (and less land use in traffic per person). This could be true if a pricing mechanism was put into place which makes the costs of an individual trip more obvious and pushes users to take fewer unnecessary trips than they would have with their own private vehicle. Given that this trial incurred no costs on the users and there was a general excitement about using and testing the ID Buzz, in the limited period of the trial the opposite effect is more likely- people drove more frequently to experience the novelty of the vehicle.

If the two other vehicles from the trial (the cargo bike and the Carver) would have been used, the impact in terms of land use would have been more positive since they are much smaller than the ID Buzz, (cf. Figure 20).

The lower use of the two other vehicles is partially due to the fact that the cargo bike and the Carver could not be booked nor unlocked using the mobile app, which was only meant for the ID Buzz. In addition, the cargo bike was vandalised at the beginning of the trial and the battery was stolen. The lock was also difficult to open, and the placement of the cargo bike was comparatively far away from the other vehicles, making it a less attractive choice. Additionally, some shops already had either a light electric freight vehicle or a cargo bike available for use, so the Carver and the cargo bike offered less utility when compared with the ID Buzz.

Figure 20: Land use efficiency comparison for Groningen trial 1 vehicles (cargo = 80 kg)



When not in use, the cargo bike is parked in an underground bicycle parking lot and the LEFV at an office location for the Municipality of Groningen. Only the ID Buzz has been parked on the street since June 2023. We don't have information on where the vehicles are parked while in use. Since parking for loading/unloading is allowed anywhere, users most likely park the rented vehicles in the area near their shop, their supplier, or at their customers. Whether the vehicle is engaged in collection or delivery activities can also have implications on where, when and for how long it is parked in different areas. Collection routes involve stops at suppliers in the surrounding area with a longer stop at the shop to unload the collected goods. Delivery routes involve a long initial stop to load the vehicle and then multiple shorter stops at customers around the city.

During the trial, shop owners adapted their business operations and investments, taking into account the possibility to rent different vehicles. The cheese & luxury foods shop owner chose to buy an electric personal vehicle that can also be used for small deliveries and will potentially not need to buy a diesel van thanks to the trial. The garden boutique owner made a similar decision and used the trial as inspiration to consider their own vehicles and decided to get rid of their diesel van and invested instead in a light electric freight vehicle. The LEFV is usually big enough for their operations and when they need a vehicle with more capacity, they can rent the ID Buzz. With that in mind, the solution trialed here would, if scaled up, have the potential of reducing the shop owners' private fleet, both in terms of vehicle size and number. Shop owners would buy less and/or smaller vehicles. A consequence could be fewer cars parked on streets around shops, which would result in less land used for parking in central areas.

3.1.4.2 Logistics efficiency

Shop owners involved in the trial do not perform many deliveries in their business activity. As a consequence, the logistics efficiency expected by shop owners is not as demanding as for other types of businesses. For some shops (like the children apparel shop), deliveries are not really part of their business model. It is rather seen as a nice supplement they can offer from time to time.

When deliveries become an important part of their business model, shop owners turn to another solution that is more efficient from a logistics point of view. For example, the wine merchant actively used both the ID Buzz and the Carver for delivering wine to their customers from the shop located in the city centre. But then the physical shop closed to become only an online shop. Since then, the shop owner no longer uses the trial vehicles and completely outsources deliveries to a cycling courier delivering from a warehouse.

On the other hand, the art gallery prefers to deliver themselves over pure logistics efficiency because they can more easily guarantee that their fragile products are delivered safely. Their customers also value the fact that deliveries are more personal when performed directly by them instead of a courier.

When it comes to consolidation, almost all shop owners rent a vehicle to perform just one delivery, which is not very efficient. Only the cheese and luxury foods shop organises a round on Wednesdays to pick up products from different suppliers.

The size of the different vehicles can also be a limitation for shop owners, depending on their activity. For example, the van can be too small for certain types of furniture or large orders. In that case, the furniture and design shop must deliver with their own diesel van. For the same reason, the art gallery only rents the ID Buzz because the other two vehicles are too small for their products. The location where the shared vehicles are parked can also be critical and influences the efficiency of deliveries, as it takes shop owners more time to deliver if they need a longer time to go pick up and drop off the vehicle at a distant location. When up-scaling the solution it could be interesting to spread the vehicles more widely through the city centre. That way, shop owners would never need to go far in order to rent them.

Even if some shop owners rarely used the vehicles, they are globally very satisfied with the service as it brings them an additional possibility. In that sense, the shared vehicle platform improves delivery conditions for shop owners since they have more options. But the high satisfaction level can also be explained by the fact that renting the vehicles was free during the trial period. When asked about their willingness to pay for such a service, all shop owners answered that they would agree on paying a fee, but frequency of use would of course depend on the amount they need to pay.

As developed in deliverable 3.5, implementing a usage fee would also reduce "comfort use" and increase availability. Indeed, as vehicles can be rented free of charge, many rentals started the day before the actual use for deliveries. This results in less availability for other users, a similar issue to the one discussed in the cargo bike sharing trial in section 2.2.4.2 above. If paying a fee, shop owners would adjust the rental duration to their actual needs and thus increase the overall availability of the vehicles. As mentioned in interviews, several shop owners experienced that the vehicle was not available when they needed it.

3.1.4.3 Environmental

The pilot has definitely increased awareness on electric vehicles and has enabled shop owners to test and familiarize themselves with them. Now at least two shop owners (Cheese and luxury foods & Garden boutique) have decided to invest in a new electric passenger car and a LEFV. This indicates that the shared platform contributes to more people adopting electric vehicles. If scaled up, the trialed solution would probably result in an increased penetration of electric vehicles in Groningen, at least among shop owners and companies.

As biking is very popular in the Netherlands, cargo-bikes already have a good penetration rate. Shop owners generally have their own bike or cargo-bike or have the possibility to borrow one from someone. That is part of the explanation as to why the shared cargo-bike has not been used in this trial. It can also be explained by the fact that the cargo-bike was vandalized at the beginning of the trial and the battery was stolen. When it became available again, the lock was not simple to open and the location was perceived as inconvenient.

The location of the shared vehicles is also an important factor when it comes to the environmental impact. They should be located close to the users so they can pick up or drop off the vehicle without using another motorized vehicle. As mentioned by one of the shop owners during a meeting, the willingness to travel to/from a vehicle's parking location depends on the perceived value of use. As the ID Buzz provides a lot of carrying capacity, it has a higher value of use and hence it is worthwhile to travel to even if it is located further away. On the opposite end of the spectrum, the willingness to travel is lower for the Carver and even lower for the cargo bike which are more limited in the types of goods they can carry. A denser network of LEFVs and cargo bikes would be needed for a broader use.

Table 23 shows the total kilometres travelled by each shop owner with the ID Buzz and the alternative transportation modes they have. Based on this, we have estimated the CO_2 emissions spared, based on the worst-case scenario[11]. In total, the trial might have spared up to 1,8 t CO_2. But this estimate should be put in perspective as it only takes into consideration emissions while in use, ignoring the emissions due to production and transportation to and from the production place to Groningen.

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[11] It means that when shop owners had several alternative transportation modes, we estimated the CO_2 emissions as if they would have used the most emitting one. For example, for the children's apparel shop, we assume that without the trial ID Buzz, they would have travelled 468 km by car. We made an exception for the Cheese and Luxury Foods shop, because we know they would have used their car once a week to do the Wednesday round, except for 6 or 7 weeks where they would have rented a van. So we estimated that 7/52= 13% of the kilometers would have been done by a van and the rest by car.

Table 23: Use comparison between shop owners

Company name	**Total rental duration (hours)**	**Total distance covered (km)**	**Alternative transport mode**
Children's apparel	12:03	468	- private car - private bicycle for smaller deliveries
Cheese and Luxury Foods	457:47	3931	- private car for their Wednesday visit - a rented van 6 or 7 times a year - their neighbours' cargo bike or car
Furniture & Interior design shop	405:36	2933	- own diesel van
Wine merchant	125:07	522	- cycling courier
Garden boutique	171:34	1428	- owned a diesel van but got rid of it - got their own LEFV - rented diesel van when they cannot use it
Art gallery	24:59	205	- a courier (who probably use a van)
TOTAL	**1197:06**	**9695**	

3.1.5 Conclusion

As developed in this section and summarised in Table 24, the GCC trial was partially successful in achieving the four objectives assessed in this deliverable:

1. Increasing the use of cargo bikes and other zero emission vehicles (and decreasing the use of polluting vehicles)
2. Increasing the efficiency/use of transport vehicles
3. Increasing liveability and safety because of the use of smaller, silent, and clean vehicles
5. Reducing CO_2 emissions

Table 24: Assessment of trial objectives. O1= Objective nr.1, O2= Objective nr.2 etc.

Trial objective	**KPI**	**Assessment**

LAND AND SPACE USE			
Increasing the efficiency/use of transport vehicles (O2)	Land use efficiency	–	n
LOGISTICS EFFICIENCY			
Increasing the efficiency/use of transport vehicles (O2)	Deliveries per tour per vehicle	p	–
	Days in operation per vehicle	n	
ENVIRONMENT			
Increasing the use of cargo bikes & other zero emission vehicles (O1)	Cargo bikes & other ZE vehicles replacing diesel vans	p	–
Decreasing the use of polluting vehicles (O1)	Days in operation per fossil fuel vehicle	p	
Increase liveability and safety because of the use of smaller, silent, and clean vehicles (O3)	NOx emissions	p	
	Particle matter emissions	–	
	Noise emissions	p	
Reducing CO_2 emissions (O5)	CO_2 eq. emissions	p	

When it comes to increasing the use of zero emission vehicles, the trial was partially successful regarding electric vehicles. On the one hand, the ID Buzz has been substantially used, but on the other hand, it was only borrowed by half the shop owners involved in the pilot and the other available vehicles were used either infrequently or not at all. On a longer-term perspective, the trial has also brought important learnings for future upscaling.

In terms of efficiency per use, the trial is difficult to assess as shops have diverse activities and offer very different delivery services. Most of the deliveries are not consolidated (the vehicle is borrowed to achieve only one delivery) so the number of deliveries per tour per vehicle is only one for the large majority of the rentals. In that sense, the trial has probably not worsened the previous situation. However, if looking at the days in operation per vehicle, the trial was not successful:

- the cargo bike was never used,
- the Carver was used infrequently,
- the ID Buzz was often borrowed, but with a lot of comfort use, meaning few operations per day.

When it comes to land and space use, the trial either provides the same efficiency as their alternative transportation modes, or has a negative impact, depending on what alternative the shop owners could have used. So the second objective is partially fulfilled.

The third objective of the trial is not easy to assess as there is no available data concerning the trial's impact on liveability and safety. But we can assess the impact in terms of emissions. As the trial vehicles are electric and have most of the time replaced vehicles with combustion engine, noise and NOx emissions are reduced on a local perspective. It is more difficult to assess the impact on particle matter emissions without measurements. Particulate matter not only comes from combustion but also from road, brake and tire wear, as well as resuspension of particles already on the road. As electric and combustion engine vehicles behave differently and are both responsible for particle matter emissions, there is no clear impact of the trial.

In terms of reducing CO_2 emissions, the trial has an overall positive results since zero emission vehicles have been used instead of combustion engine vehicles so less CO_2 has been emitted while using these vehicles. In that sense, the carbon footprint and the fifth objective of the trial are positive.

3.2 Trial 2 Parcel Lockers

3.2.1 Description of trial

Trial 2 in Groningen was intended to test the addition of a white label parcel locker system to a multi-modal mobility hub (cf. solutions and schemes in Table 25). The municipality of Groningen (GRO) and the public transport organisation of the provinces Groningen and Drenthe (OVB) have worked together and chosen to locate it at the Park and Ride (P&R) in Hoogkerk. The implementation has been challenging and as of the time of writing, Groningen Trial 2 has not yet implemented the white label parcel locker. Nonetheless, the process has resulted in two positive outcomes:

- learnings from an operating and business model perspective (documented and discussed in deliverable 4.5)

- an overarching policy framework for parcel locker placement on public spaces in the city that also considers other forms of out of home delivery pick-up/drop-off points (documented and discussed in deliverable 6.6).

Table 25: ULaaDS solution and scheme - Groningen trial 2

Solution	Scheme
1) Collaborative delivery models to enhance logistics efficiency and multimodal mobility in cities	3. City-wide platform for integrated management of urban logistics
2) Effective integration of passenger and urban freight mobility services and networks	4. Location and infrastructure capacity sharing

The trial's aim and objectives are the following:

First aim defined: Offer two logistics services:

- Parcel lockers at the hubs in the peri urban region

- A collective service for delivery of goods for inner-city entrepreneurs who will no longer be allowed to enter the inner city with their own car (2025).

Objectives (as deliverable 5.2 ULaaDS factsheets baseline and city profiles):

1. Increasing the use of existing multimodal hubs by adding logistics services
2. Increasing the satisfaction of people using the multimodal hubs
3. Increasing liveability and safety in neighbourhoods by decreasing of the amount of delivery vans in neighbourhoods
4. Reducing of CO_2 emissions

Final aim trialed: At the time of publishing this deliverable, the parcel locker has not yet been deployed. Groningen and OVB are in the process of determining a location and have developed a framework for implementation.

The deliverable will focus on the objectives 1, 3 and 4 while the second objective is addressed in deliverable 5.4 as it relates to users' satisfaction.

3.2.2 Relevant projects

White label parcel lockers, also called open or actor neutral parcel lockers, consist of parcel lockers open to different suppliers at the same time. In the literature, this solution is presented as beneficial for customers and the environment by enabling more efficient distribution, less traffic and environmental emissions, denser networks, increased customer satisfaction and better utilization of space. And at the same time, it is also difficult to implement because of various competitive, legal, practical and operational challenges (Carotenuto et al., 2018; Hofer et al., 2020; Rohmer and Gendron, 2020; Schodl et al., 2020; Strauß et al, 2022; Caspersen et al, 2023). Hovi et al (2023) analyse the example of Nærboks, whose challenges concern the allocation of capacity between the various actors and the establishment of technological solutions that are used by all actors.

In addition to the implementation of a white label parcel locker, the trial also intended to test a location on a P&R site. As many commuters pass by the P&R site every day, they could easily pick up their parcels with their own car, without adding more car traffic. Previous research shows that location strongly affects how consumers travel to pick-up their parcel (Caspersen, Jordbakke, and Knapskog 2023).

3.2.3 Available data

Since the parcel locker has not yet been deployed, no data has been collected. Instead, scenarios have been analysed in deliverable 3.5, to assess the operating model implications of deliveries in different types of pick-up points (e.g., parcel lockers, in-shop pick-up/drop-off points or crowd-sourced neighbourhood hubs), also called out of home deliveries. These scenarios are based on different percentages of deliveries (0% to 100% with increments of 5%) operated via out of home locations for one of the two larger logistics service providers operating in the inner-city of Groningen. This area has around 2000 parcel deliveries per day, which corresponds to 700 deliveries for each of the two larger logistics service providers operating (PostNL and DHL), according to their relative market share. They each have about five out of home delivery locations in the concerned area. All locations will receive parcels, with an estimated stop time of 20 minutes for each out of home delivery. In comparison, the stop time for home delivery is 2.25 minutes on average (based on observations in Groningen). Vans are considered to have a capacity for 250 home deliveries and the working time is 8 h. The methodology developed is explained in detail in a scientific working paper (Niemeijer et al., 2023).

Table 26 shows a selection of three scenarios taken from deliverable 3.5:

- 0% of packages are delivered out of home (i.e., 700 packages are delivered to individual addresses)
- 30% of packages are delivered out of home (i.e., 210 packages are delivered in pick-up points and 490 packages are delivered at individual addresses)
- 100% of packages are delivered out of home (i.e., 700 packages are delivered to pick-up points)

In the intermediate scenario (30% of deliveries are performed out of home), the number of stops is 495 (490 individual addresses + 5 pick-up points). When increasing the share of out of home deliveries by increments of 5%, it is the first scenario where the full effective capacity of the van (5 m^3) is used on its first trip. This scenario implies a total distance of 134.86 km, travelled by 2.71 vans. When compared with the scenario with 0% of deliveries performed out of home, the total distance travelled is shorter and the number of vans needed smaller (cf. Table 26).

Table 26: Operating model implications of out of home delivery in Groningen (from deliverable 3.3)

Adoption rate out of home	Number of stops	Total working hours	Total km	Vans needed	Trips per van	Volume per van
0%	700	36,18	195,55	4,52	1,00	3,10
30%	495	21,71	134,86	2,71	1,03	*
100%	5	2,85	87,98	0,36	7,87	*

* At this adoption rate, the full effective capacity of the van is used on its first trip

3.2.4 Impacts

As the parcel locker is not installed at the time of writing, it is not possible to assess the actual impacts of the solution in terms of logistics efficiency, land use and environment. But based on the scenarios developed in deliverable 3.5 and on the literature review, this section will consider the potential implications of white parcel lockers placed in mobility hubs and more generally of out of home delivery solutions.

In addition, the trial brought important learnings concerning the implementation challenges which are analysed in deliverable 4.5. The policy framework implications are discussed in deliverable 6.6.

3.2.4.1 Land and space use

In the scenarios developed in deliverable 3.5, there are five out of home delivery locations which can be either parcel lockers, in-shop pick-up points or crowd-sourced neighbourhood hubs. In these scenarios, the pick-up points' capacity is not taken into consideration. Nonetheless, pick-up points have a limited capacity and compared to an in-shop pick-up point, parcel lockers occupy more space to store the same amount and volume of parcels (in a shop, parcels can be stored in a compact way whereas in a parcel locker there is only one parcel per locker with some/a lot of air around).

In order to assess the impact of the parcel locker in terms of land use, their capacity is an important factor to consider. For example, in the scenario where 30% of parcels are delivered to pick-up points, 205 parcels are delivered to five pick-up points. The considered parcel locker (cf. Figure 21) has around 48 boxes. When the van delivers to the parcel locker, some of the boxes are not available because customers have not yet collected their previously delivered parcels. For a large share of customers, it takes more than one day to collect their parcel. Hovi et al. (2023) found that only 55% of parcels are collected within 24 hours and that a parcel stays on average 31.6 hours in a locker. This means that five parcel lockers do not have enough capacity to store 205 parcels. In order to implement this scenario, it is then needed to have in-shop or crowd sourced pick-up points (with more capacity) and/or to install several parcel lockers next to each other. In terms of occupancy, we estimate that the considered parcel locker has the following footprint[12]:

- 1,8 m^2 in space
- 3,6 m^3 in volume

In addition to their footprint, parcel lockers also require manoeuvring space and parking space for the delivering vans. Given the fact that the parcel locker was going to be placed on a P&R, there should be available space for the van to deliver. It is also important that the logistics operations do not hinder P&R users' mobility.

[12] As we don't know the parcel locker's exact size, we estimate it based on the number of boxes. The considered parcel locker has 48 boxes, which corresponds to three Swipbox put next to each other (Akdeniz et al. 2022). So the estimated dimensions are: 600 x 3000 = 1.8 m^2 or 600 x 3000 x 2000 = 3.6 m^3.

Figure 21: Parcel locker considered in Groningen trial 2

When it comes to the location of the lockers, it must not obstruct other traffic, including pedestrians. Placing them against a wall can be a solution. The location of parcel lockers is further discussed in section 2.3.4.3 since it also has impacts on the environment.

Delivering to pick-up points also has impacts on the number of vans used and on the time they spend driving in the city. The scenarios developed in deliverable 3.5 show that with an increased share of out of home deliveries, less vans are used and less time is needed to deliver the parcel: from 4,52 vans working for a total of 36,18 hours, the needs go down to 0,36 vans working for 2,85 hours. This means that there are fewer vans in traffic and for shorter periods of time.

As far as white label parcel lockers are concerned, there are of course important gains linked to land use, but based on Groningen trial 2, it is difficult to assess to what extent. As stressed by Akdeniz et al. (2022), the logistic operators have no reason to deliberately overinvest in capacity. So, a white label network distributed over several actors could have approximately the same capacity as the addition of the actors' own networks.

3.2.4.2 Logistics efficiency

Based on the scenarios developed in deliverable 3.5, we can say that a higher share of out of home deliveries has a positive impact in terms of logistics efficiency. If 30% of deliveries performed at out of home in pick-up points, then the full capacity of the van (5 m^3) would be used on its first trip. Delivering out of home would also enable shorter routes and consequently require fewer vans and drivers.

The scenarios also underline the fact that white label parcel lockers have the same operating consequences in terms of logistics as other forms of out of home delivery solutions (e.g., in-shop pick-up/drop-off points or crowd-sourced neighbourhood hubs). This is also the conclusion from Hovi et al. (2023): compared to another type of pick-up point, a white parcel locker network where each distributor delivers their own parcels will have relatively limited efficiency gains for distribution. Using consolidation terminals could potentially reduce traffic to the lockers but the effect would be marginal with possibly increased costs due to the additional transhipment at the consolidation terminal (Hovi et al. 2019). More than any benefits from the use of white label networks, it is the direct effect of the use of parcel lockers rather than home delivery that provides a gain in distance travelled and logistic efficiency (Hovi et al. 2023).

3.2.4.3 Environmental

As discussed previously, deliveries to pick-up points are more efficient than home deliveries, resulting in fewer kilometres driven for the delivery vehicle. In the scenarios developed in deliverable 3.5, kilometres driven are more than halved if we compare the situation where all parcels are delivered to the customer's home address versus all parcels delivered to pick-up points. However, when looking at the environmental impact, we must also consider customers travelling to the pick-up point to collect their parcel. As previously demonstrated, location strongly affects how consumers travel to pick-up their parcel (Caspersen, Jordbakke, and Knapskog 2023). The less a customer needs to travel, the more likely the customer is to not use a car, emphasizing the need of a dense network of pick-up points where every customer lives within walking or cycling distance from one of them (Niemeijer and Buijs 2023). In that sense, implementing parcel lockers can be an efficient way to densify the network and not encourage customers to drive, as they can be more flexibly located than other types of pick-up points.

In addition to the distance, Niemeijer and Buijs (2023) also show that the urbanisation level has a strong influence on the transport mode choice, regardless of the distance. Customers can choose a transportation mode for other reasons than the distance. For example, people living in urban areas often do not own a car so will walk longer distances to collect their parcels. Looking at carbon emissions, Niemeijer and Buijs (2023) show that the potential for a reduction is greater in urban areas than it is in rural areas where the benefits derived from more efficient deliveries in pick-up points are quickly negated by the carbon emissions from customer travel. An important lever is to encourage customers' trip chaining so they can pick up their parcel during an existing trip. For example, supermarkets are shown to be consumers' preferred location, as they travel there often (Kedia, Kusumastuti, and Nicholson 2019). In that perspective, the chosen location for the parcel locker in Groningen trial, a park & ride zone in Hoogkerk, seems an interesting option.

3.2.5 Conclusion

As the parcel locker has not yet been deployed yet, the trial objectives are not fulfilled. But nonetheless, the process has brought many important learnings, as more knowledge on the implementation challenges (cf. Deliverable 4.5), as well as the policy framework (cf. Deliverable 6.6).

In this deliverable we have discussed the potential impact of the white label parcel locker if implemented. This solution has the potential to have positive impacts in terms of logistics efficiency and land use (objectives 1 and 3). When it comes to reducing CO_2 emissions (objective 4), the impact is very dependent on how customers would travel to collect their parcel. The chosen location could favour trip chaining and avoid situations where customers drive their car on a dedicated trip, only to collect their parcel.

4. Mechelen

4.1 Trial 1 Last mile solutions

Originally intended as a collaborative delivery model using cargo bikes, this trial was not carried out and its impacts were not assessed. As of this writing, parties in Mechelen are still actively looking to increase the share of small vehicles making deliveries. More can be read about this trial in deliverable 4.7.

4.2 Trial 2 Cargo-hitching

4.2.1 Description of trial

Table 27: ULaaDS solution and scheme - Mechelen trial 2

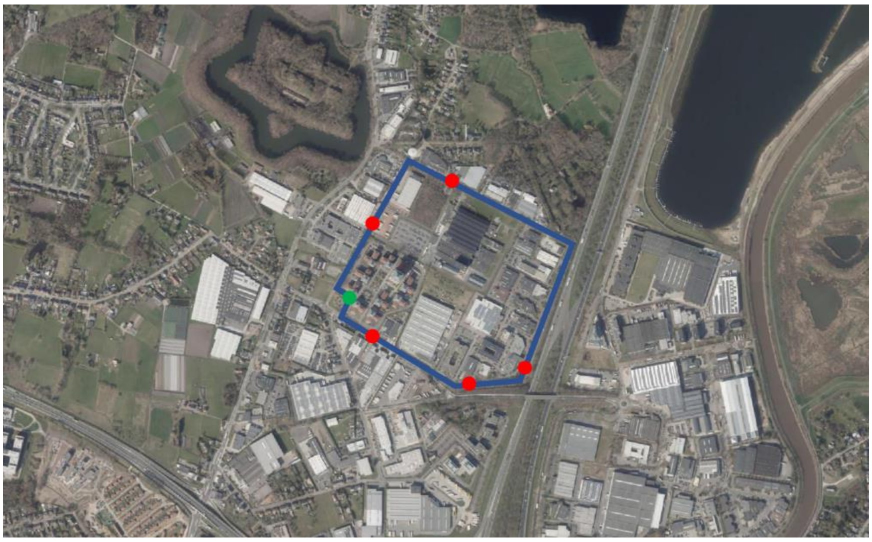
Solution	Scheme
2) Effective integration of passenger and urban freight mobility services and networks	5. Transport vehicle capacity sharing

This solution trialed an autonomous vehicle with an on-board parcel locker (also called a dynamic parcel locker) to combine freight and passenger transport. It was tested in the outer city in a business park (Mechelen-Noord) where about 20 companies are located with around 2500 employees in total. The location was chosen because of its relatively low traffic and mobility complexity which would make it easier for the autonomous vehicle to drive without intervention by human operators. The vehicle travelled a 2.1 km route at a maximum speed of 15 km/h which took 17 minutes without considering stop time. For safety reasons, the shuttle was limited to a maximum speed of 15 km/h (instead of 25 km/h) which limited its utility for passengers.

This trial was the result of a theoretical inquiry where 5 possible scenarios were considered by relevant stakeholders and trial partners. Of the five developed scenarios, scenario 4: cargo-hitching was selected as the most likely to produce positive results considering non-negotiable requirements (such as the need to operate an autonomous vehicle safely).

In addition to the transport of passengers, there were two specific freight use cases investigated during this trial using the parcel locker as 1) a first mile drop-off point and 2) a collection point for the last mile. During the trial, a static parcel locker was installed by BPost adjacent to the start of the autonomous vehicle route.

Figure 22 Route of the autonomous shuttle (blue line), stops (red dots) and main stop (green dot). From deliverable 4.7



4.2.2 Relevant projects

While relatively little research has gone into cargo hitching compared with other urban logistics innovations, projects such as SPROUT, MOVE21 and TKI DINALOG have all looked at various strategies to combine the transport of people and goods (these projects are discussed in greater detail in 2.1.2).

The combination of an autonomous vehicle, an on-board parcel locker and passenger transport in ULaaDs offers a unique perspective on cargo hitching that gives valuable insights for future projects and has not been trialed in other contexts that we are aware of.

4.2.3 Available data

The trial ran during the summer from 13.6.22 to 5.8.22, though the onboard parcel locker did not come into operation until 4.7.22. Quantitative data was collected from both the vehicle and the parcel locker and qualitative data was collected through stakeholder fora and an online survey. An overview can be seen in figure 28.

Table 28: Overview of data collected from trial

Data providers	Type of variables	Period

Mechelen, VIL, EasyMile, BPost	Energy consumption [kWh] Traveled distance [km] Number of passengers per day/hour Vehicle characteristics Total number of locker reservations Days of operation Qualitative data in Dutch from the stakeholder forum and an online survey	13/06/22-05/08/22

4.2.4 Impacts

Given the goals of the trial and the limited testing phase, the trial's impacts on land and space use, logistics efficiency and the environment are limited. We discuss them below from a conceptual and theoretical standpoint but given that this trial was intentionally isolated from more complex traffic situations and was focused on testing and combining new technologies, the potential impacts and the case for upscaling are not clear. We go more in depth about why it is challenging to assess the different impact areas below. These discussions provide useful insights into barriers and success factors for implementing this type of solution.

4.2.4.1 Land and space use

Cargo hitching has the potential to reduce vehicle movements related to logistics which could have significant implications for land and space use, though this was not in evidence in this trial. In the case of an onboard parcel locker, the potential land and space use savings are related to the removal of vehicle movements necessary for servicing the parcel locker as it is instead combined into an already running transport system as well as space required for the physical installation of a parcel locker.

The Mechelen trial showed that the on-board parcel locker was not properly dimensioned for the vehicle. A more purpose-built locker could have made better use of the available space on the vehicle which would have increased the potential number of logistic operations that this solution could displace.

4.2.4.2 Logistics efficiency

Contrary to expectations, loading and unloading the locker went smoothly. The trial leaders assumed that it would be challenging to manage the locker on a moving vehicle, but the postal employees were able to load and empty it within seconds due to their experience and the short, fixed route which made it easy to locate the vehicle. However, customers reported preferring a static parcel locker. The familiarity of use, lack of waiting times for the vehicle, predictability of location, greater capacity, more flexible operating hours and not needing to interface with multiple apps all contributed to this preference.

The dynamic parcel locker on board the vehicle had seven available slots to hold packages (4 medium, 3 large). By comparison, the static parcel locker that was installed nearby had 26 slots (8 small, 14 medium, 4 large). During the trial period, the static locker processed 102 shipments, 54 first mile and 48 last mile. The dynamic locker had just 3 first mile shipments, only one of which was successfully completed, and 12 last mile, of which 6 were picked up. The rest failed due to the locker being too small or no slots being available.

The vehicle's use as passenger transport was somewhat limited. The reduced speed combined with a short circular route in a location in which many employees already drove their own vehicle reduced the number of potential users. In total, 299 passengers used the vehicle during the trial period, for an average of 8 per day of operation. A maximum of 38 passengers used the vehicle during a promotional family day.

It is also relevant to consider this trial in light of the simulations that occurred in the Via simulation in Bremen (section 2.3 above). One of the major constraints in the simulation was the inability to transport people and parcels at the same time as passengers are less likely to tolerate delays while in the vehicle. This can lead to less efficient routes and extra driven kilometres for both passengers and parcels.

The Mechelen trial explores the potential to remove some barriers related to the transport of people and freight simultaneously. Using a parcel locker that is quickly and easily serviced by postal employees minimizes delays and detours related to freight transport and effectively separates passengers and freight in a secure manner. However, it is important to find a balance that maximizes freight capacity while minimizing discomfort for passengers in the form of displaced seating and standing space in the vehicle.

4.2.4.3 Environmental

By using a zero-emission vehicle, the trial offers the potential to significantly reduce emissions related to transport if it replaces a fossil fuel vehicle. Although the trial period was relatively short, kWh and vehicle km were recorded, allowing insight into the emissions and energy use over time. The EasyMile vehicle travelled 1555 km using 36 kWh per 100km on average, which is similar to listed specifications of an electric sprinter van: 35.8-40.9 kWh/100km (Mercedes, 2023). However, if compared to a diesel van of similar size using 8.2 liters of fuel per 100 km, the converted kWh/100km is 87.4.

Given the experimental nature of this trial, there is little in the way of concrete impacts that can be extrapolated for environmental impacts as it was not shown to displace or reduce other forms of transport during this period. The potential for this type of concept to displace or reduce other forms of transport is also uncertain.

4.2.5 Conclusion

<u>Trial objectives:</u>

1. Test cargo-hitching with passengers and freight to optimize vehicle use
2. Test the use of an on-board parcel locker
3. Test the ability of an autonomous vehicle to increase service levels

While the trial provided valuable insights into both cargo hitching and the use of autonomous vehicles, its objectives were only partially achieved. The impacts of the trial were hindered by regulatory constraints, a relatively short test period, operational and technical challenges and competition from a static locker that was installed during the testing phase.

Operating an autonomous vehicle with an onboard parcel locker has not been trialed previously, and the experimental nature of the trial did not lend itself to assessing the wider impacts related to land and space use, logistics efficiency, or the environment.

On the other hand, the trial provided powerful insights into more specific operational details related to the human machine interface (HMI) of the vehicle, the parcel locker and the combination of the two. Data was also collected on the acceptance of autonomous vehicles in society and the need for regulatory innovations to keep pace with technological advancements was highlighted.

Through the trial in Mechelen, ULaaDs was able to reveal many of the operational considerations necessary for enacting cargo hitching. Contrary to expectations, loading and unloading the locker went smoothly and was carried out in a matter of seconds. However, the nature of the autonomous vehicle's route (short, low speed) and the trial's location at a business park limited its usefulness as a passenger service. Customers also stated a preference for a static locker and that the need to use two separate apps to follow the bus and operate the locker impacted the convenience of the solution.

5. Conclusions

5.1 Adapting to change

While it is clear that the ULaaDs trials have produced positive impacts, many of the impacts were more intangible and related to the cooperation and learnings borne out of the very act of conducting the trials. As with many other projects, ULaaDs was impacted heavily by the pandemic which led to some activities being limited and others being changed or adapted on the fly, hindering data collection. Rapid shifts in trials due to regulatory limitations or financial issues with project partners also impacted data collection. Priority was placed on carrying out the trials which sometimes came at the cost of collecting a clear baseline from which to assess their impacts.

In assessing the impacts of the trials, we focused a great deal on how, when and where land and space are used. In dense urban cores where space is at a premium, finding ways to more effectively utilize space is extremely valuable. In this regard, the use of smaller vehicles such as cargo bikes to replace much larger vehicles offers tremendous potential. The shared cargo bike trial especially showed clear potential to reduce the number of vehicles occupying space in traffic by providing a more efficient and environmentally friendly option. Solutions such as parcel lockers also provide opportunities to reallocate when and where logistics activities occur and can reduce the number of vehicles needed to make deliveries by giving customers easier access to a network of pick-up points that they can walk or cycle to.

However, the value of freeing up urban space is not always captured by companies like LSPs which can make more space efficient solutions challenging to implement from a business perspective. Developing a clearer understanding of the positive impacts provided by using land and space efficient logistic solutions can allow cities to more confidently advocate for their use by developing innovative tools of policy and governance. There is a need and potential for developing tools and knowledge on land and space efficiency in urban logistics.

The logistics efficiency of the trials was the most difficult impact area to assess. As they consisted universally of small pilots and test cases, the ULaaDs trials were not fully integrated into logistic systems and did not have the full support of these systems. It was often difficult to determine the maximum potential of a specific solution due to limited operating areas, organizational issues or lack of freight volumes. To achieve full (or near full) integration of innovative solutions into logistic systems would require larger scale pilots or demonstrations, which was outside the scope of ULaaDS.

The ULaaDs trials have contributed positively to reducing GHG emissions and improving the local environment, either by avoiding trips or replacing them altogether with an electric option. Using smaller vehicles offers additional benefits for local air quality and energy efficiency. As fleets are electrified and renewable energy sources grow increasingly prevalent, more focus needs to be paid to energy efficiency and production related emissions as opposed to point source emissions from vehicles. The majority of innovative transport solutions being trialed in cities across Europe are zero emission. Focusing on the improvements in GHG emissions as a result of shifting from fossil to electric does little to describe the benefits of a specific trial given that the likely alternative would also be electric. The choice is less and less about fossil fuel vs electric but rather which kind of electric vehicle will be used and determining how the system will be organized and scaled.

Future projects involving small pilots should focus on the critical factors and potential for scaling up a trial. Identifying which barriers are solvable and which are not is key to understanding a trial's potential impacts. Determining whether a pilot is limited by technological, policy, co-operational, organizational or operational barriers can allow a targeted use of resources and also provide a better understanding as to its future potential and impacts. The ULaaDs trials strike a balance between using existing solutions in novel ways and really pushing the boundaries of what is possible with today's technologies and regulatory frameworks to consider how urban logistics might take place in the near future.

Acronyms

Acronym	Meaning
AI	Artificial Intelligence
AV	Autonomous Vehicles
D	Deliverable
EC	European Commission
GA	Grant Agreement
ICT	Information and Communication Technology
LEFV	Light Electric Freight Vehicle
LF	Load Factor
LSP	Logistics Service Provider
O	Objective
ODD	On-demand Delivery
P	Product
PPP	Public Private Partnership
PM	Person Month
SUMP	Sustainable Urban Mobility Plan
SULP	Sustainable Urban Logistics Plan
T	Task
UC	Use Case
UCC	Urban Consolidation centre
UFT	Urban Freight Transport
ULaaDS	Urban Logistics as an on-Demand Service
WBS	Work Breakdown Structure
WP	Work Package
VUR	Vehicle Utilisation Rate
ZEV	Zero Emission Vehicle

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Annexes

ULaaDs Vehicle dimensions and characteristics	Length (mm)	Width (mm)	Height(mm)	Space occupancy/Footprint (m^2)	Volume occupancy (m^3)
Euro Pallet	1200	800	_	1,0	
Rytle bike (model 1)	2700	1300	1980	3,5	6,9
Rytle Hub (container 20foot)	6050	2440	2600	14,8	38,4
Medium car	4100	1700	1500	7,0	10,5
7.5 ton truck	8350	2500	3500	20,9	73,1
Fietje cargo bike	2530	630	1000	1,6	1,6
Mercedes Vito	5140	2249	1910	11,6	22,1
Sprinter van	5267	2020	2356	10,6	25,1
Century carver (3 wheel moped)	2890	1080	1490	3,1	4,7
ID Buzz	4942	1976	1963	9,8	19,2
Cargo bike Groningen	2100	950	1000	2,0	2,0
EZ.Mile autonomous vehicle	4050	1892	2871	7,7	22,0