Case Study

Data-driven Evaluation of Cargo Bike Delivery Performance in Brussels

Assessing operational advantages of cargo bikes over vans in the Brussels urban centre

Nov 2023

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Executive Summary

- Urban last-mile deliveries are a major source of emissions and congestion. Cargo bikes offer a sustainable alternative to vans and trucks.

- This case study provides rigorous data-driven analysis of cargo bike performance based on GPS traces from Urbike's fleet of eBullitts in Brussels.

- Our analyses find that cargo bikes have **30% shorter routes**, and travel at 16km/h vs 11.3km/h for vans constrained by congestion.

- **Cargo bikes park within 30 meters of delivery points** on average, minimising walking time. Meanwhile, previous studies have shown that **vans can spend up to 25 min per stop** searching for parking.

- Modelling real Urbike routes using simulations of cargo bikes and vans shows that cargo bikes are over **2x faster than vans** (48 min vs 99 min per route).

- Cargo bikes have **1/5 the total vehicle cost per parcel** compared to diesel and electric vans when factoring in purchase costs, maintenance, insurance, etc.

- Life cycle analysis shows cargo bikes cut **GHG emissions by 96-98%** relative to both diesel and electric vans.

- Widespread adoption of cargo bikes could help decongest cities, improve air quality, and promote sustainable urban transport overall.

Introduction

Today, transport accounts for around 30% of a city's carbon emissions and is expected to grow at a faster rate than any other sector in the coming decade.[1] One of the primary drivers behind this acceleration is the surging demand for swift logistics, stimulated by the e-commerce boom. By 2025, global package deliveries are projected to hit 200 billion, a significant jump from the fewer than 90 billion in 2018.[2]

With these prevailing trends, CO2 emissions and traffic congestion resulting from urban last-mile deliveries are expected to surge by 30% by 2030 in the world's top 100 cities. This equates to an alarming additional 6 million tonnes of CO2 emitted compared to 2019 figures.[3]

A predominant challenge for logistics operators grappling with this unprecedented surge centres on the last mile of the delivery process.[4] It is reported to constitute a hefty 40

1 Creutzig, F., Jochem, P., Edelenbosch, O. Y., Mattauch, L., van Vuuren, D. P., McCollum, D., & Minx, J. (2015). Transport: A roadblock to climate change mitigation? Science.

2 Statista. (2021). eCommerce report. Statista Digital Market Outlook.

3 Deloison, T., Hannon, E., Huber, A., Heid, B., Klink, C. H., Sahay, R., & Wolff, C. (2020). The future of the last-mile ecosystem. In World Economic Forum (Vol. 1).

4 Savelsbergh, M., & Van Woensel, T. (2016). 50th anniversary invited article—City logistics: Challenges and opportunities. Transportation Science.

to 60% of the total delivery cost of a parcel.[5][6] In recent times, cargo bike logistics has risen to prominence as an environmentally friendly and economically viable alternative to traditional LGV fleets in urban settings.

Their merits, such as improved efficiency in dense urban areas, are increasingly recognised and supported by a growing number of studies.[7][8][9][10][11]

In fact, experts predict that cargo bikes could potentially replace over half of urban van deliveries, thanks to their faster speeds on congested roads, minimal time spent looking for parking, and shorter routes across cities. A case in point: a recent study in Paris showed that 67% of daily van operations by a prominent logistics operator could be seamlessly transitioned to cargo bikes without incurring additional costs.[12]

5 Bachofner, M., Lemardelé, C., Estrada, M., & Pagès, L. (2022). City logistics: Challenges and opportunities for technology providers. Journal of Urban Mobility.

6 Statista. (2023). Share of total supply costs worldwide in 2018, by type of cost. Retrieved September 22, 2023.

7 Gruber, J., Kihm, A., & Lenz, B. (2014). A new vehicle for urban freight? An ex-ante evaluation of electric cargo bikes in courier services. Research in Transportation Business & Management.

8 Sheth, M., Butrina, P., Goodchild, A., & McCormack, E. (2019). Measuring delivery route cost trade-offs between electric-assist cargo bicycles and delivery trucks in dense urban areas. European Transport Research Review.

9 Ploos van Amstel, W., Balm, S., Warmerdam, J., Boerema, M., Altenburg, M., Rieck, F., & Peters, T. (2018). City logistics: Light and electric. Amsterdam University of Applied Sciences.

10 Wrighton, S., & Reiter, K. (2016). Cycle-logistics—moving Europe forward! Transportation Research Record.

11 Verlinghieri, E., Itova, I., Collignon, N., & Aldred, R. (2021). The promise of low-carbon freight: Benefits of cargo bikes in London. Possible.

12 Robichet, A., Nierat, P., & Combes, F. (2022). First and last miles by cargo bikes: Ecological commitment or economically feasible? The case of a parcel service company in Paris. Transportation Research Record.

Aim of the Case Study

The need for a broad evidence base

There exists today a number of reports that have highlighted the strong benefits and potential of cargo bike logistics, both commercial and environmental. However, to accelerate a large-scale adoption of cargo bikes and garner the necessary support from stakeholders, including logistics operators and policy-makers, we need a robust repository of evidence from multiple cities. From experience, we have seen that London-based data may not convince policymakers in other cities like Berlin, Copenhagen or Sydney (and vice versa). Collecting robust evidence across urban environments is important in that regards. This case study is a pursuit in that direction.

The need for rigorous methodology

With the increasing number of pilot studies being run to trial cargo bikes across the world, a downfall has been the lack of rigorous methodology when conducting the performance analyses.

Some analyses bundle the performance of a vehicle across their whole day, failing to take into account the areas in which they operated, including the stem distance from the initial depot for vans, or reporting misleading statistics by including the stop times when calculating the average speed of a vehicle. This leads to misunderstandings in the potential for a shift, and can slow down the process of a transition by years within an organisation.

Here we introduce a framework to guide the analysis of vehicle performance. We segment the delivery process into different steps that can be studied separately, to refine the understanding of disparities in performance between vehicle types. Given the strong influence of urban areas (e.g. city centre, residential areas, suburbs), we also focus on discerning the performance of vehicles across different regions. Our objective is not just to advocate for the replacement of vans with cargo bikes, but to understand the zones within cities where each vehicle type performs at its best.

Urbike, a pioneering cargo bike logistics operator in Brussels

Our case study focuses on the operations of Urbike, a Brussels-based cooperative that specializes in last-mile delivery of goods by cargo bike. Their goal is to gradually replace vans and light trucks for deliveries in urban areas. The goods they deliver range from parcels, dry and refrigerated food, medicines, flowers, and other essential urban goods for both business (B2B) and residential (B2C) customers. Urbike works with larger clients, and most of their activities involve multi-drop deliveries.

Urbike was created in 2018, originating from the “BCklet” pilot project supported by Innoviris, the Brussels regional innovation agency. During this project, Urbike was able to deploy its cargo bike delivery models with key partners like the Belgian postal service bpost, the retailer Delhaize, and the pharmaceutical company Multipharma. Beyond their day-to-day last-mile operations, Urbike has actively participated in key initiatives shaping the future of cargo bike logistics in Brussels and beyond. They have provided consulting and design for sustainable logistics transitions by businesses and local authorities, most notably through the Cairgo bike project where they assisted over 300 companies and 650 professionals in adopting cargo bikes (2020-2023).

Urbike has shared its learnings and operational expertise at national and European conferences including Velo-City and POLIS. Their contributions have been recognized with awards like the Ashoka social impact prize, the 2020 Belgian Logistics Project of the Year, and the Brussels Hub Start Award for their innovative structure and disruptive approach to urban logistics. Urbike is also a signatory to the Green Deal for low-emission logistics in the Brussels region and a member of the Belgian Cycle Logistics Federation (BCLF).

In early 2023, Urbike had traveled 250,000 km and delivered 350,000 packages, avoiding an estimated 84 tons of CO_2 emissions. As of late 2022, Urbike had 43 employees, including 22 permanent staff and others engaged through a wage portage scheme via the social enterprise Smart. They are on an ambitious path to expand operations, including launching a new operational entity in the city of Leuven in October 2023.

The urban context of Brussels

Brussels has a unique logistics landscape due to its rich history and location at the heart of Europe. Its historic city centre features narrow, winding streets and limited parking options, making vehicle-based logistics challenging.

As the capital of the European Union, Brussels is home to a large number of international institutions, multinational corporations, and economic actors, contributing to a high volume of freight traffic in the city. Vans make up a significant proportion of vehicle traffic in Brussels, to the extent that Belgians have even invented a word for it - "la camionnettisation". In 2012, vans accounted for 8% of traffic, according to Bruxelles Mobilité.[13] By 2021, the share of small vans in vehicle traffic had grown to 11%.[14].

Additionally, light van sales increased 33% between 2005 and 2015 based on the regional mobility plan Good Move.[15] The growth in van traffic contributes to Brussels' notorious heavy congestion levels. INRIX ranked Brussels as the 3rd European city with the most hours lost in congestion per driver in 2021 (134 hours per year on average).

> **In Brussels, "the freight traffic accounts for about 8% of the local traffic, the vast majority of which is handled by vans, the environmental and mobility impact of which is concerning," notes the regional mobility plan project Good Move.**

13 Bruxelles Mobilité. (2019). Chiffres clés sur le transport de marchandises à Bruxelles: Édition 2019.

14 Bruxelles Mobilité. Les véhicules de transport de marchandises. Bruxelles Mobilité. Retrieved June, 2023.

15 Bruxelles Mobilité. (2020). Plan régional de mobilité Good Move 2020-2030.

To tackle this, the city of Brussels has very recently (August 2022) introduced aggressive policies to curb congestion (and particularly through-traffic) in the city centre.

Following the example of cities like Amsterdam, motor traffic can now only move between neighbourhoods by using main axes. The city is also cutting down on parking spaces.[16] This is likely to further reinforce the advantage of cargo bike logistics when compared with vans.

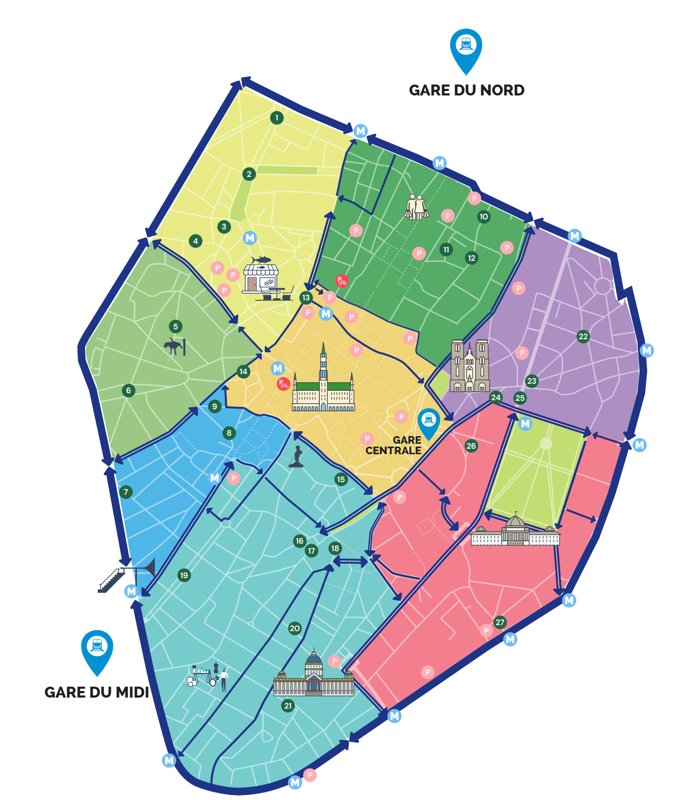


Figure 1 Good Move Map in Brussels: points on the map represent traffic control measures

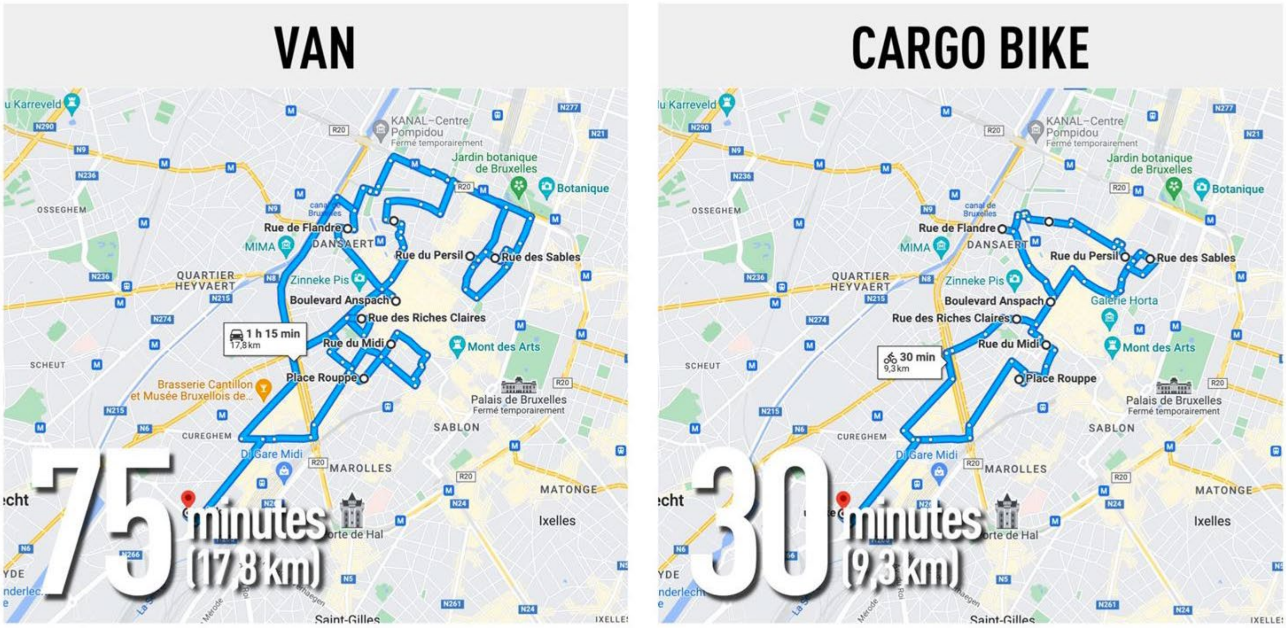


Figure 2 Illustrative example of Brussels' new traffic plan "GoodMove". Time estimate generated by Urbike with 9 sample stops showing the difference between vans and cargo bikes.

16 Delaney, C. (2022). Good move Brussels takes another step in the right direction. Retrieved from https://ecf.com/news-and-events/news/good-move-brussels-takes-another-step-right-direction.

Related Research and Studies

We review in this section relevant research on urban deliveries, before delving into the methodology we followed to analyse cargo bike performance.

An important part of our analyses focus on service time as it is an often disregarded component of route optimisation and a major performance indicator, that is also heavily dependent on the type of vehicle used. For example, a van may be delayed by traffic congestion before potentially needing extended cruising for available parking, in turn leading to a longer distance on foot to the delivery point. This can represent a significant part of a delivery driver's day. In contrast, a cargo bike, due to its size and maneuverability, can move through traffic more effectively and often finds parking closer to the final delivery location.

A 2018 study in London highlighted that walking can account for 62% of the total van round time[17] due to limited suitable kerbside parking space in urban centres. Similarly, studies found that delivery drivers spend on average 5.8 minutes and 24 minutes searching for each parking spot in Seattle and New York City, respectively.[18 19]

Despite the significant amount of time currently spent looking for parking, optimisation tools largely ignore the search time for parking in route planning.[20] Choosing when and where to park remains a decision made by the driver[21], which can have significant

17 Allen, J., Piecyk, M., Piotrowska, M., McLeod, F., Cherrett, T., Ghali, K., Bektas, T., Bates, O. & Friday, A., et al. (2018). Understanding the impact of e-commerce on last-mile light goods vehicle activity in urban areas: The case of London. Transportation Research Part D: Transport and Environment.

18 Dalla Chiara, G., & Goodchild, A. (2020). Do commercial vehicles cruise for parking? Empirical evidence from Seattle. Transport Policy, 97, 26-36.

19 Holguín-Veras, J., Amaya, J., Encarnacion, T., Kyle, S., & Wojtowicz, J. (2016). Impacts of freight parking policies in urban areas: The case of New York City.

20 Reed, S., Campbell, A. M., & Thomas, B. W. (2021). Does parking matter? The impact of search time for parking on last-mile delivery optimization. arXiv preprint arXiv:2107.06788.

21 Boysen, N., Fedtke, S., & Schwerdfeger, S. (2021). Last-mile delivery concepts: A survey from an operational research perspective. OR Spectrum, 43(1), 1-58.

impact on their performance.[22] The nimbleness of cargo bikes presents a competitive advantage by allowing riders to find parking much quicker, and closer to the final destination. We study this in detail in the next section when looking at the different datasets.

Amazon recently open-sourced a large dataset of van-deliveries for their Last Mile Routing Research Challenge, organised in 2021.[23] The aim of the challenge was to model sequences of delivery stops to predict the actual delivery routes conducted by experienced drivers, to "reflect the tacit knowledge of seasoned drivers gleaned through years of experience".

The Amazon dataset is one of the largest and most up-to-date van delivery datasets openly available, spanning five U.S. cities, namely Austin, Boston, Chicago, Los Angeles and Seattle.

The analysis of the Amazon dataset shows that the service time is highly dependent on where the delivery occurs for vans. In Boston's city centre, many areas have a high probability of having deliveries that take longer than 5 minutes, or even 10 minutes[24]. On average, across all five cities, delivery drivers spend 25% of the time driving and 75% of their time walking to the stop and doing the delivery (when excluding the stem distance from the depot).

In this case study, one of our contributions lies in evaluating to what extent cargo bikes are affected by the urban context in which the delivery happens.

22 Bates, O., Friday, A., Allen, J., Cherrett, T., McLeod, F., Bektas, T., ... & Wise, S., et al. (2018). Transforming last-mile logistics: Opportunities for more sustainable deliveries. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems.

23 Merchan, D., Pachon, J., Arora, J., Konduri, K., Winkenbach, M., Parks, S., & Noszek, J. (2022). 2021 Amazon Last Mile Routing Research Challenge Dataset.

24 Schrader, M. C., Kumar, N., Collignon, N., Astefanoaei, M. S., Sørig, E., Yoon, S., Xu, K., & Srivastava, A. (2022). Modelling the performance of delivery vehicles across urban micro-regions to accelerate the transition to cargo-bike logistics. In NeurIPS 2022 Workshop on Tackling Climate Change with Machine Learning.

Methodology

Collecting cargo bike data

Through in-person interviews, we gathered a better understanding of data collection and operational processes as well as limitations in the data by discussing with dispatchers, CTO and riders. In the end, we created our dataset by collecting GPS data and stop information from the TMS software.

Figure 3 Map of Urbike's operation in Brussels between Oct and Dec 2022. Covers approx. 10,000km of GPS data.

GPS Data

In order to collect data about the movement of the cargo bikes, we installed GPS trackers on 9 of Urbike’s eBullitt cargo bikes. Data collection started in October 2022 and was carried out over a period of 1.5 months. We tracked 7,340 deliveries on 907 delivery routes. We used PowUnity trackers due to their Shimano compatible system, the robustness of their data tracking and the ease of use of their data extraction API.

TMS Data

Additionally, we extracted data from Urbike's dispatch software, used to optimise routes and send out tasks to riders throughout the day. We extracted stop details such as parcel information and stop address to analyse service time and distance to address. The TMS dataset does not include a `completed at` time for each delivery. We thus approximate service time based on the GPS traces in our study.

In alignment with GDPR, all collected data was anonymised and processed to ensure the privacy and security of individuals involved. Our primary focus was on the operational metrics of the cargo bikes and not on individual user data.

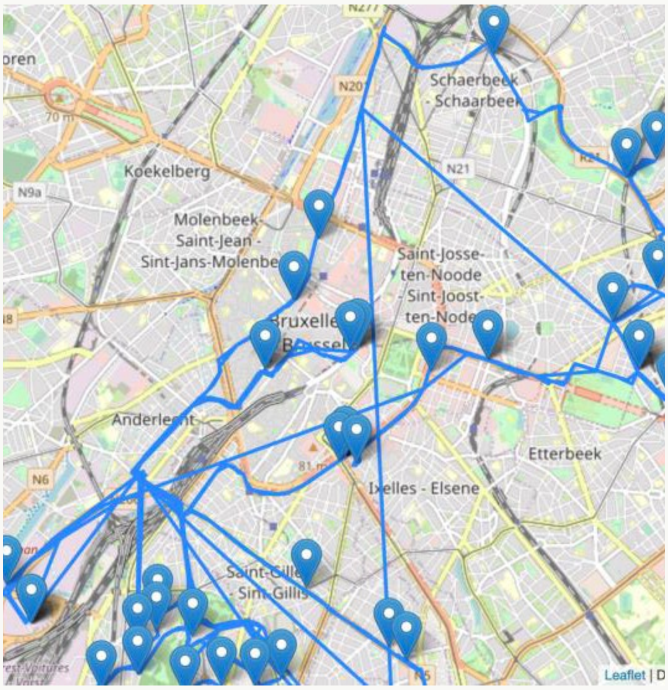


Figure 4 Map of delivery addresses without GPS matching

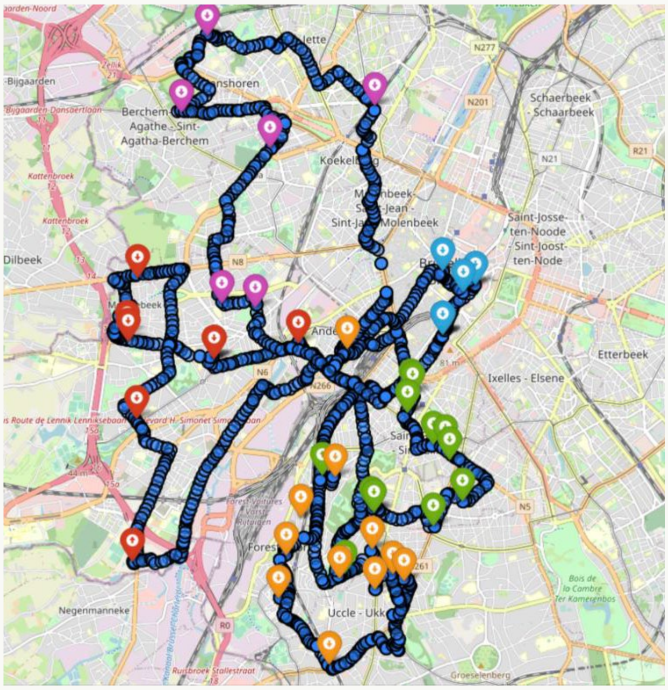


Figure 5 Map of delivery addresses with GPS matching

Matching datasets

To create a rich dataset, we designed a matching algorithm to pair the GPS traces with the tasks dataset. This allows us to study each journey segment between stops, time looking for parking and the walking distance from the vehicle to the address.

Defining a framework to analyse cargo bike performance

In order to compare the performance of delivery vehicles (e.g. cargo bikes and vans), we define a framework that segments the delivery process in multiple steps.

In previous studies, vehicle performance is often modelled with a single statistic (either average speed or parcel per hour), without taking account the different factors that might impact a vehicle across different urban areas. This can lead to misleading statistics. For example, a van might have a long drive into the city from the depot (the so-called "stem distance"), which can be driven at much higher speed than in a congested zone.

When averaging this without separating the stem distance from the inter-stop trips inside the city region, this can significantly bias the results of the van in simulated comparisons. Indeed, a 30km/h statistic for van speed is not uncommon in studies, even if 10 km/h might be a more accurate statistic inside the city centre.

For example, Lee et al.[25] assume a cargo bike capacity of 350 kg and an average speed of 10 km/h (while admitting this is not based on any data), compared to a speed of 30 km/h for an LGV. Conversely, Elbert et al.[26] ignore the speed of the vehicle, deciding instead to focus on service time, with 2 min for the cargo bike vs up to 8 min for the LGV, while assuming a cargo bike capacity of 125 kg. In Arnold et al.[27], a cargo bike moves at 12 km/h vs 17 km/h for an LGV, but no differentiation is made for service time.

25 Lee, K., Chae, J., & Kim, J. (2019). A courier service with electric bicycles in an urban area: The case in Seoul. Sustainability, 11(5), 1255. Lee, K., Chae, J., & Kim, J. (2019). A courier service with electric bicycles in an urban area: The case in Seoul. Sustainability, 11(5), 1255.

26 Elbert, R., & Friedrich, C. (2020). Urban consolidation and cargo bikes: A simulation study. Transportation Research Procedia, 48, 439-451.

27 Arnold, F., Cardenas, I., Sörensen, K., & Dewulf, W. (2018). Simulation of B2C e-commerce distribution in Antwerp using cargo bikes and delivery points. European Transport Research Review, 10(1), 1-13.

This variation in assumptions can be attributed to the scarcity of reliable data and the complexities of modelling fine-grained delivery scenarios, which ultimately points to a significant gap in our understanding. The importance of accurate, data-driven decision-making is paramount in an industry known for high pressure and tight margins.

To avoid these scenarios and capture the delivery process accurately, we introduce our framework that segments the delivery process into the following five steps.

Travelling to the destination

This includes the navigation of the vehicle between A and B. Vehicles might have different speed profiles (e.g. maximum speed), different ways of being affected by congestion, or different routes due to different infrastructure (e.g. bike lanes, bus lanes), or restricted access in certain areas (modal filters, one-way street, Low Traffic Neighbourhood).

Cruising for parking

This refers to the time driving around the delivery address while looking for a place to park the vehicle. Vehicles might have different parking access, or difficulty in finding parking depending on their type / size, and on where they are in the city. For vans, this can sometimes mean relatively long periods of time, and longer distances from the final address as suitable parking can be sparse.

Unloading parcel

Different vehicles and parcels might have different profiles that affect the time it takes to find and unload the parcel. In our study, we assume that the vehicle type does not affect unloading times significantly.

Walking to the address

This refers to the time spent walking between the vehicle and the final address. This is tightly linked to cruising for parking behaviour, as the longer a vehicle needs to cruise, the more likely they are to park further away from the address, and the longer the deliverer will need to walk. There is strong evidence that van drivers spend a considerable amount of time walking, as they sometimes prefer to leave their vehicle parked and walk between locations to avoid spending time looking for further parking. Our (simplified) model does not take this into account and assumes the vehicle will move between every stop. This is a reasonable assumption with the Urbike data, as the average distance between stops is quite long (more than 500m).

Delivering to the door

The final part of the delivery process occurs in the building complex of a delivery. The type of customer, or the type and complexity of a building, the need for special access, the presence of a loading bay, the floor of the address, as well as the size and number of parcels, can all influence how long servicing a stop might take. Consider a package requiring a sign off from the customer, and the customer is on their way home. The deliverer might decide to wait, which could take a significant amount of time. Similarly, if a parcel needs to be delivered to the 15th floor and wait for someone at reception to let them through, a deliverer might spend considerable time when compared to a suburban delivery where a parcel can simply be left at the front door.

Modelling urban context

Earlier, we discussed the importance of urban context on the efficiency of urban deliveries. By urban context, we refer to the impact that the characteristics of an the place in which the delivery occurs has on the different aspects of service time described above. The size of the street, parking availability, vehicle accessibility, the number of shops, the presence of bicycle infrastructure, loading bays, the height of the buildings, the function of buildings are all things that will impact the service time of deliverer and will do so differently based on the type of vehicle they are using. In this section, we explain how we approach the problem of representing urban context using computational methods.

Dividing cities in micro-regions

Understanding the layout and dynamics of urban spaces is essential for efficient deliveries. Historically, analysts have relied on divisions like zip codes, census zones, or neighbourhood boundaries. However, these divisions can vary significantly from one city or country to another, making consistent analysis a challenge. To address this limitation, we use a hexagonal tessellation to divide urban terrain into consistent spatial units with equivalent sizes and shapes. This facilitates comparative analysis across cities.

We do this for two reasons. First, we study how urban context affects the performance of cargo bike deliveries in the context of Urbike in Brussels. Second, we hope that our framework can be used to estimate the areas where using cargo bikes would have the most impact in other cities.

In our study, we use the Uber Hexagonal Hierarchical Spatial Index (H3).[28] Instead of relying on predefined boundaries, the H3 system divides the world into consistent hexagonal cells. This method offers a standardised approach, akin to overlaying a grid on a map. The beauty of this system is its adaptability; it can provide both macro and micro views of the terrain by adjusting the size of the hexagons.

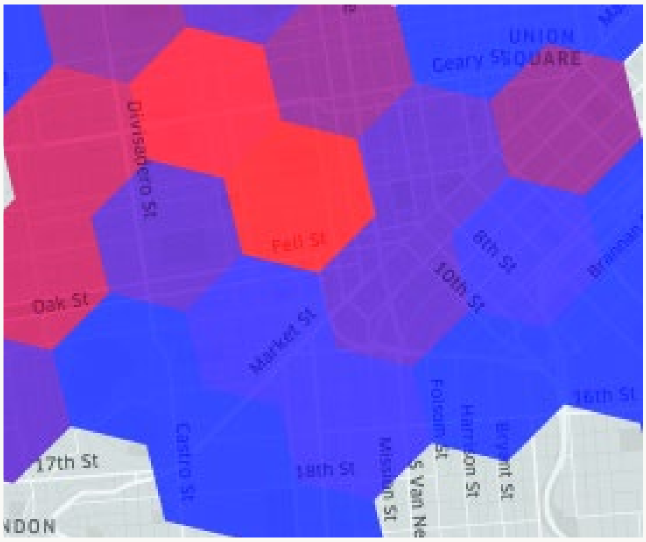


Figure 6 Example micro-region map created using H3

We enrich our hexagonal segmentation by incorporating OpenStreetMap tags that annotate fine-grained details of infrastructure and land use. This allows us to model the urban fabric at a resolution conducive to studying how built environment factors like density and road patterns influence delivery productivity. In contrast to coarse administrative units, our approach provides a flexible yet standardised framework to study how local urban contexts relate to vehicle performance.

Using OpenStreetMap tags as urban descriptors

For our analysis, we selected a resolution where each hexagon covers an area equivalent to several city blocks (we use hexagons with an edge length of 174m). This size allows for a detailed yet manageable view of urban spaces, facilitating efficient and standardized analysis across various cities and countries.

To capture the characteristics of urban micro-regions, we use OpenStreetMap (OSM), an open-source mapping project. OSM is considered a leading example of volunteered geographic information[29], having over 9 million users and approximately 4 million daily map edits as of December 2022.

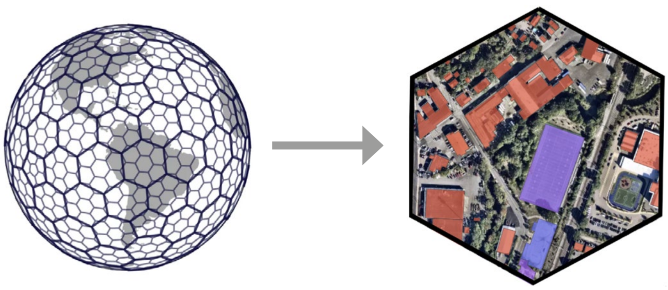
28 H3: Uber's hexagonal hierarchical spatial index. (2018, June).

29 Mashhadi, A., Quattrone, G., & Capra, L. (2015). The impact of society on volunteered geographic information: The case of OpenStreetMap. In OpenStreetMap in GIScience.

In our work, the urban context for each micro-region is based on the types of buildings, plots, and roads annotated in OSM in that region. Each object in OSM is annotated with tags in the form of a `key=value` pair, where the `key` represents the category of the object and the `value` specifies the type within that category.

Our approach provides a flexible yet standardised framework for evidencing how local urban contexts relate to vehicle performance.

Categorising types of urban areas by clustering micro-regions



# of buildings	39
# of sports pitches	1
# of parking	1

To be able to draw comparisons across vehicles and cities, we choose to go up in the hierarchy of scale, following the assumption that cities share a common high-level structure, namely that they can broadly be divided into an urban core, dense residential areas, commercial or industrial regions, and suburban zones.

To study vehicle performance within and cities we leverage our models of micro-regions to discover different types urban zones that make up Brussels.

We follow the methods introduced by Hex2Vec[30] to create machine representations of urban micro-regions based on the OSM tag descriptions. We then use agglomerative clustering to group hexagons with similar characteristics. Finally, we use these urban regions to analyse the performance of cargo bikes and evaluate the influence of urban context.

In the next section, we present our results from analysing the performance of the eBullitt cargo bikes in the Urbike fleet.

30 Wozniak, S., & Szymanski, P. (2021). Hex2vec - Context-Aware Embedding H3 Hexagons with OpenStreetMap Tags. In Proceedings of the 4th ACM SIGSPATIAL International Workshop on AI for Geographic Knowledge Discovery.

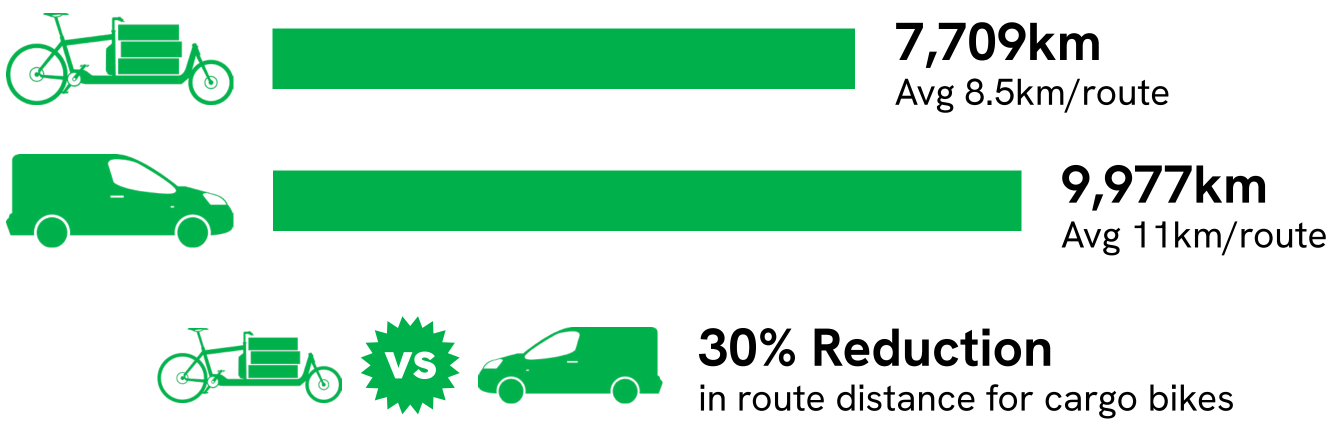
Results

Travelling to the destination

We begin by comparing the time cargo bikes and vans take to travel between stops. We separate this in two parts, first estimating the difference in distance travelled by the two different vehicle types, and second their travelling speeds.

Comparing route lengths for vans and cargo bikes in Brussels

Total Driving Distance to the Same Addresses
Using Urbike's 907 historical routes



We first compare the driving distances between stops of vans and cargo bikes in Brussels, grounding our analysis in the Urbike route dataset. Bicycles are known to benefit from shorter routes than motor vehicles for multiple advantages. They benefit from bike and bus lanes, can navigate through modal filters, and are often allowed through access on one-way roads. A study in London showed that bikes had on average 8% shorter trips for journeys under 5km. In 2017, a a pilot project in Sydney reported that bikes travelled a third less than vans in the city.[31]

Due to our lack of access to van data, we decided to compare van and bike routes using the Google Maps API. In case strong distortion between Google Maps distances and true distances exist, we decided to use the same method for both vehicle types to reduce the chances of being biased towards one vehicle.

The results are based on our analysis for all 907 delivery routes. We find that the bicycle routes summed up to 7,709 km. For a car, this was 9,977 km. The average cargo bike route length was of 8.5 km, while the equivalent route took 11 km for a motor vehicle. This amounts to 30% shorter routes for cargo bikes.

31 Parr, A.T. (2017). RIPPL #23: Consolidation Down Under: Sydney's CBD cycle logistics hub. Retrieved from https://www.rippl.bike/en/rippl-23-consolidation-down-under-sydneys-cbd-cycle-logistics-hub.

Analysing cargo bikes speed across urban regions in Brussels

Next, we look at the speed of Urbike cargo bikes using the GPS traces.

In Modelling urban context, we used a machine learning method called **clustering**, applied to all the H3 hexagons and the OpenStreetMap data within each hexagon, to divide Brussels into three different urban zones. We study the speed of cargo bikes across these three different urban regions, that we name **Core Area**, **Urban Area** and **Suburban Area**. This is motivated by the fact that vans are strongly penalised by congestion in urban centres.

We compare the average speed of cargo bikes across these urban regions to evaluate if their performance is affected by where they are in the city.

We find an average speed of 16.3km/h in the Core Area, 15.4km/h in the Urban Area, and 16.1km/h in the Suburban Area.

Overall, we find that the moving speed of the Bullitt cargo bikes have a consistent speed across all urban regions, and we find no strong evidence that urban context affect their movement. We note that most Urbike runs (80%+) are conducted with trailers, and this might result in slightly slower speeds than if the cargo bikes did not use a trailer. Across all regions, **we find an average speed of 16km/h that we use going forward in our analysis.**

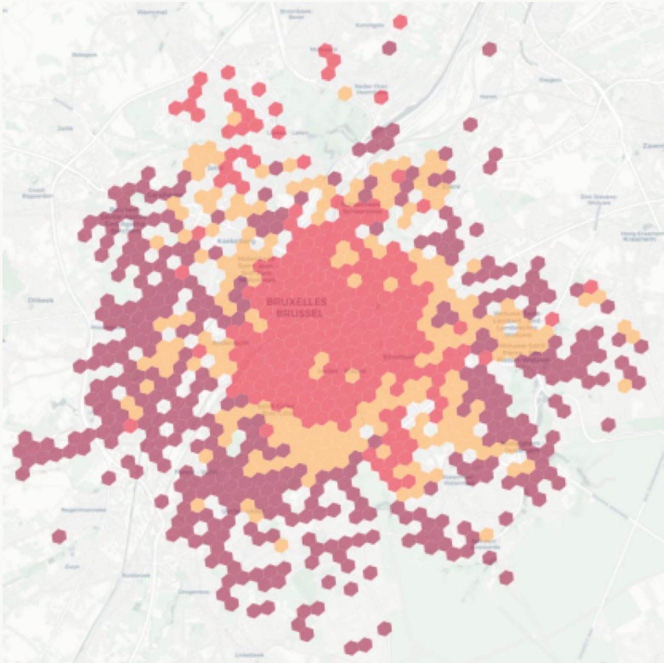
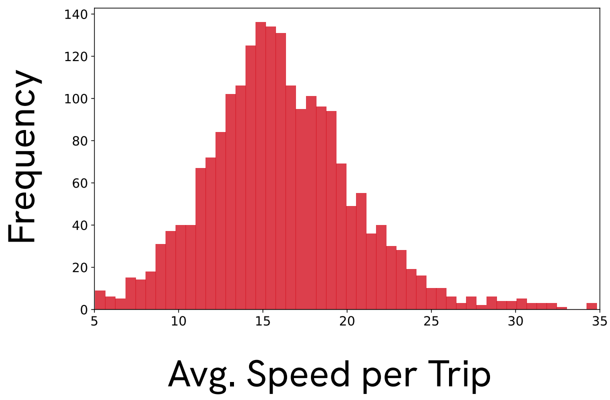
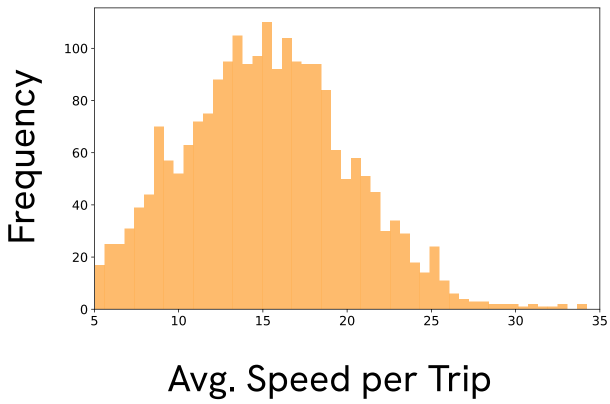


Figure 7 Map of Brussels divided into 3 types of region: Core Area, Urban Area and Suburban Area using H3



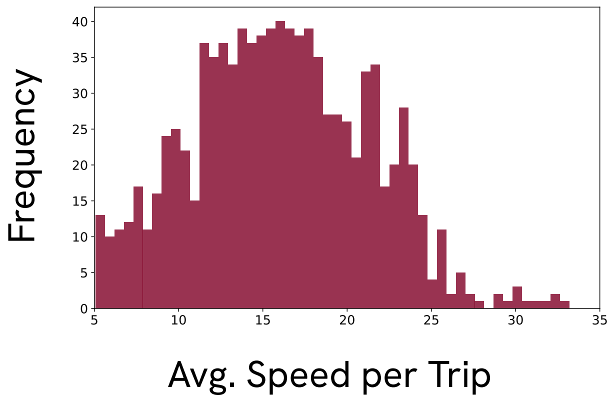
Core Area

16.3km/h avg.



Urban Area

15.4km/h avg.



Suburban Area

16.1km/h avg

Estimating van speeds in Brussels

Finding reliable data on vehicle speed from logistics operators is particularly difficult. Here we resort to estimates from the best data sources we were able to find. We hope our work inspires more data sharing across journey times, and in the domain of last mile logistics generally. Looking at the GPS traces, we estimate that 87% of the time is spent within the Core Area (53%) and Urban Area (34%).

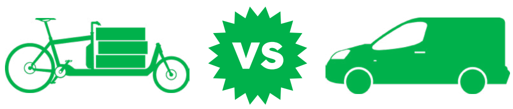
According to the 2022 INRIX Global Traffic Scorecard, the average last-mile delivery speed in Brussels is 10mph (16km/h). However, this includes driving in the wider metro region.

The average last-mile delivery speed in Brussels' inner city is 7mph (11.3km/h), according to the INRIX 2018 report, which is the speed considered for Urbike's operational area[32].

Estimated Driving Speed
in central Brussels area

16km/h

11.3km/h

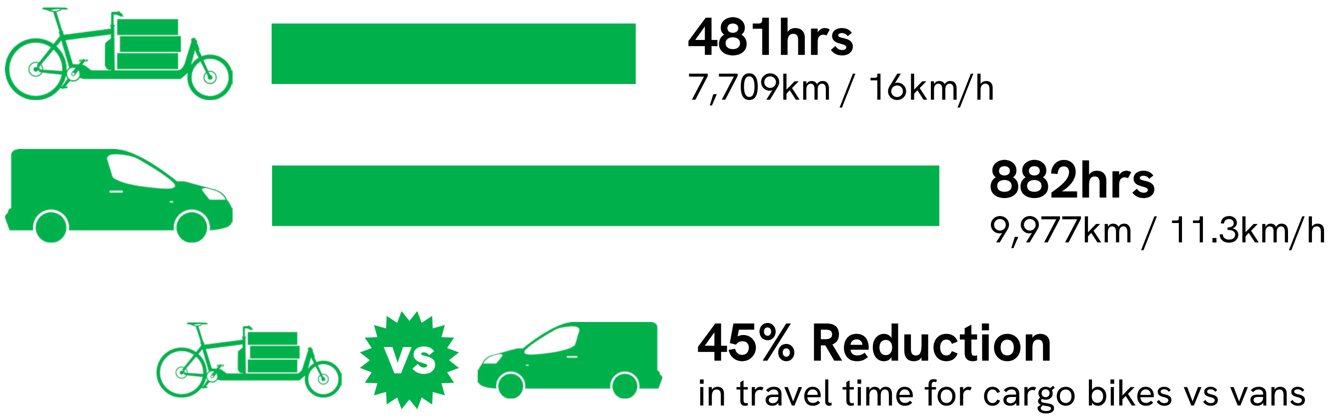


42% faster
cargo bikes driving speed vs vans

32 INRIX 2018 Global Traffic Scorecard. "Inner City Last-Mile Travel Time: The time it takes to travel one mile into the central business district during peak hours." Retrieved from https://web.archive.org/web/20190808033409/https://inrix.com/scorecard/.

INRIX reports do not use consistent measures across different years, and the zone limits are not explicitly defined, which complicate the comparison and reliability of data. An average speed of 11.3 km/h is consistent with the reported speed in the Central London area in 2018 (https://www.london.gov.uk/who-we-are/what-london-assembly-does/questions-mayor/find-an-answer/average-traffic-speeds-1).

Estimated Total Driving Time
using distance and speed estimates



Taken together, these figures indicate significantly slower speeds for vans compared to the 16km/h average speed we observed for Urbike's cargo bikes, especially within the downtown core. **We thus estimate 11.3 km/h as the average van speed for our subsequent analysis when comparing the two vehicle types.**

Analysing service time and distance to door

A key advantage of cargo bikes over vans is their ability to park closer to the final delivery address and spend less time servicing stops. To analyse these factors for Urbike, we measure the distance to door to estimate the service time per stop. Distance to door captures how close cargo bikes park to the actual delivery point. Short distances minimise walking time. Service time encompasses the total time spent at each stop, including parking, unloading parcels, and walking to the door. Faster service times enable more deliveries per hour. In the following sections, we present the analysis of these metrics based on Urbike's GPS traces and delivery data.

Distance to door for cargo bikes

To estimate service time, we use the matched GPS traces to the TMS stop location data. For distance to door, we measure the distance between the parking spot in the GPS trace and the actual delivery address. This is done using the Bing Maps API to geocode addresses and compute the Haversine distance between latitude/longitude points. By linking traced GPS coordinates to delivery addresses, we can precisely quantify the walking distance from parking spot to door for thousands of Urbike's stops.

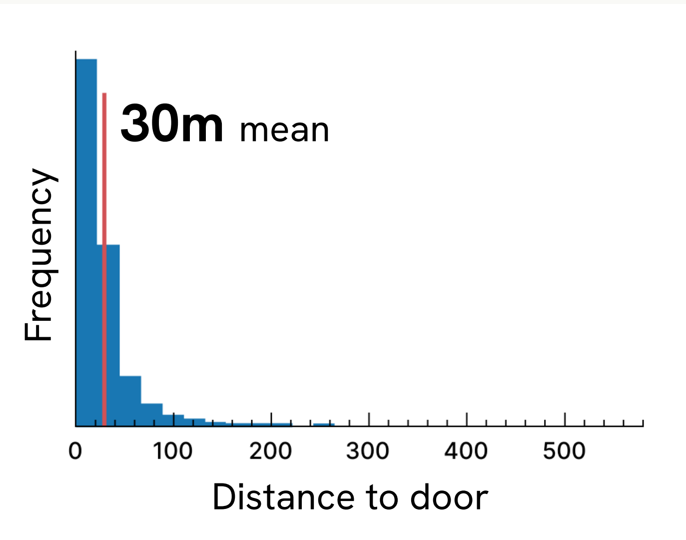


Figure 8 Frequency distribution of distance to door from Urbike's GPS history

Our analysis of over 3,895 Urbike delivery stops shows that cargo bikes park incredibly close to the final delivery address. Across all urban regions, we find an average parking distance of just 30 meters from the door.

The nimble nature and smaller size of cargo bikes allows them to park virtually at the point of delivery, implying that they also waste no time searching for parking. At a walking pace of 3km/h, the average 30m distance for Urbike bikes equates to just 35 seconds - virtually no time wasted. The consistency of this result across urban zones, from city centre to suburbs, highlights a major advantage of cargo bikes compared to vans, which often struggle to find legal parking near the final address. For comparison, studies show that vans in cities like London and New York can spend 5-25 minutes searching for parking per stop[18 19].

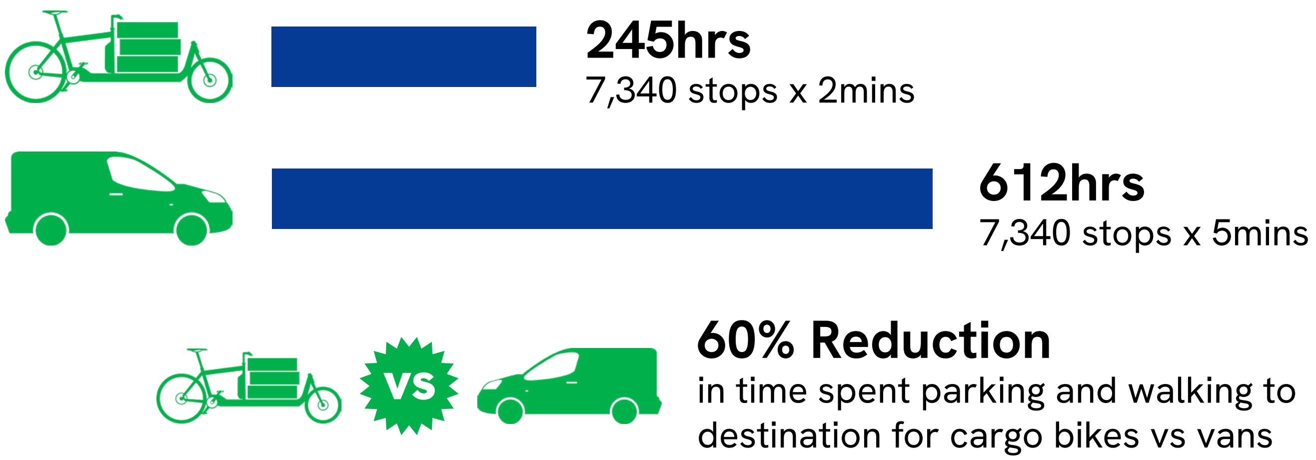
By parking directly at the door, cargo bikes avoid both wasted time walking from van to delivery point.

In this analysis, we decide to ignore the time spent at the door (cf. step 5, p. 14), assuming it is the same for any vehicle. We use the approximation of 2 minutes for cargo bike service time (steps 2, 3, 4) in the rest of our comparison.

Estimating service time for vans

Precise data on van service time in Brussels is limited. However, studies in other cities provide useful benchmarks. Analysis of over 6,000 Amazon delivery routes across 5 US cities found drivers spend 75% of time looking for parking or walking to the door[23]. In London, a study showed walking accounts for 62% of total round time[22].

Estimated Total Time Spent Parking and Walking to Destination



On average, vans take 5.8 minutes to find parking in Seattle[18] and 24 minutes in NYC[19]. While no definitive statistics exist for Brussels, its city center with narrow streets and limited parking point to similarly lengthy search times.

Given Brussels' reputation for extreme congestion, we assume a conservative estimate of 5 minutes average for van service time, encompassing parking search and walking distance. This aligns with the lower end of van service times reported in academic literature (e.g. a study comparing cargo bikes and vans in London used 8 minutes in their model)[11]. More fine-grained data will be necessary to get a better understanding of where vans are particularly penalised in the city.

For Urbike's cargo bikes, we estimate service time as just 2 minutes given their ability to park immediately at the destination. While generous for vans, this 3 minute gap still highlights a major advantage of cargo bikes over vans trawling congested streets for parking.

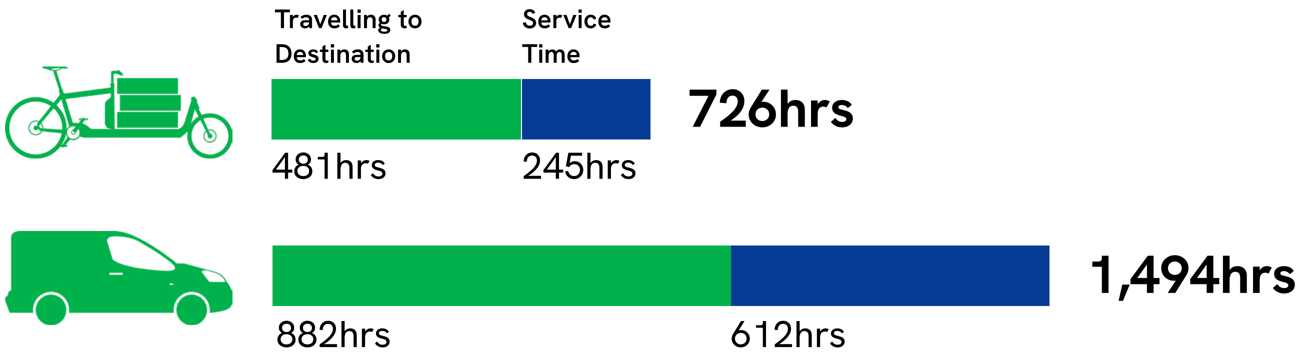
Comparing models of vans and cargo bikes on Urbike deliveries

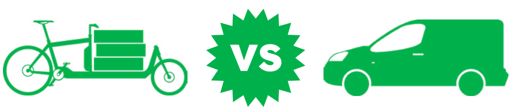
By combining our analysis on driving distances, vehicle speeds, and service times, we can now model total delivery time for vans versus cargo bikes on Urbike's real-world routes.

For traveling between stops, our analysis found cargo bikes have 30% shorter routes and travel at 16km/h, while vans average 11.3km/h in congested Brussels. For the 907 Urbike routes totaling 7,709km, this equates to 481 hours of travel time for bikes versus 882 hours for vans.

For service time, we estimate 2 minutes per stop for cargo bikes based on their ability to park at the door, and 5 minutes for vans including search and walking time. Across 7,340 stops, total service time is 245 hours for bikes and 612 for vans.

Estimated Total Delivery Time
combining travelling to destination and service time





51% Reduction
in total delivery time for cargo bikes vs vans

Adding these components, the total time to complete Urbike's deliveries is 726 hours using their eBullitt cargo bikes, versus 1,494 hours with vans - over twice as long. On average, vans would take 99 minutes per route, compared to just 48 minutes for bikes.

This modelling highlights that for real-world routes in a dense city like Brussels, cargo bikes provide over a 2x speed advantage for the last mile. Their combination of agility, access, and efficiency in urban centres make them a superior choice for urban deliveries.

Evaluating the vehicle cost of delivery

To quantify the economic impact of using cargo bikes versus vans, we model total cost of ownership including both fixed and variable expenses.

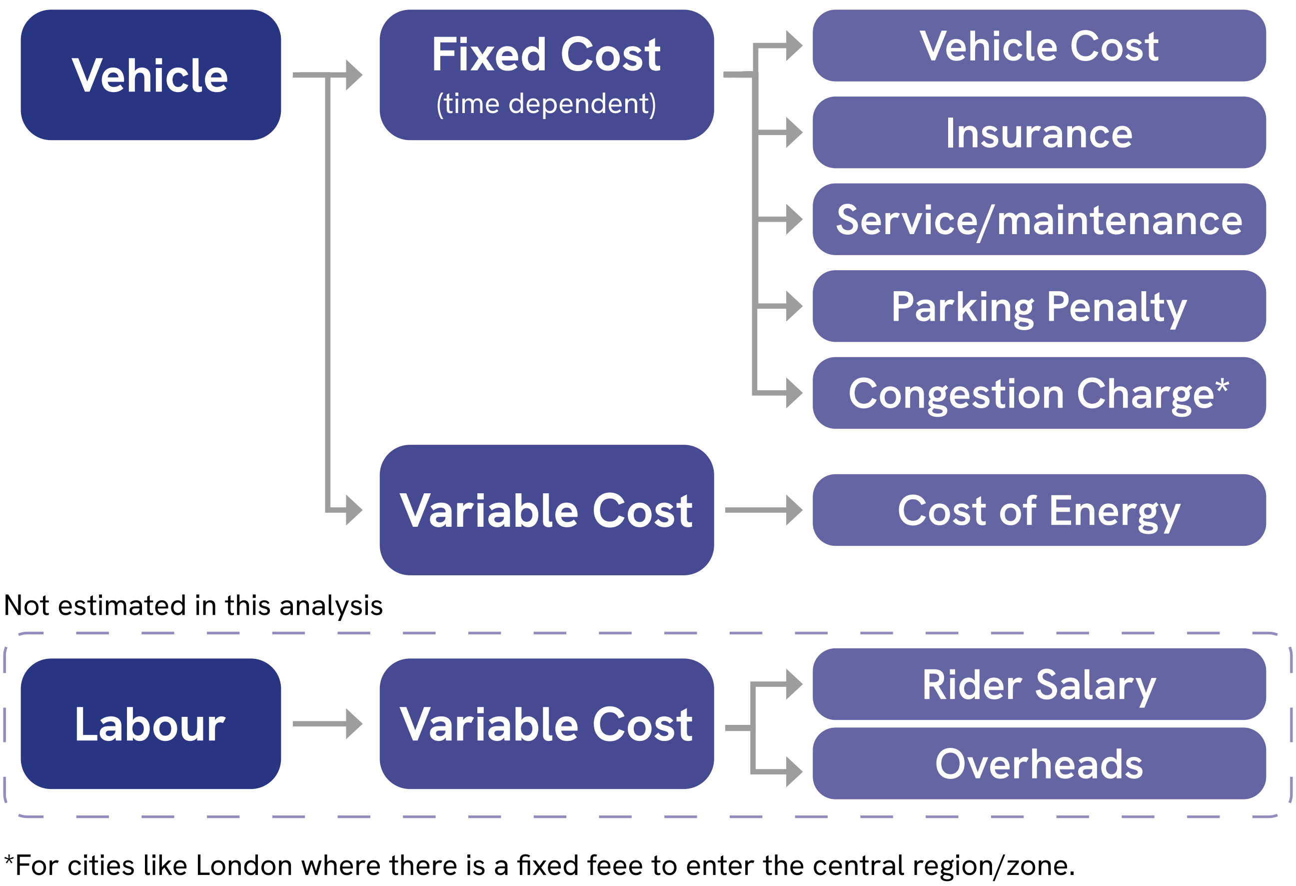


Figure 9 Cost estimation structure for full delivery cost

To evaluate vehicle costs, we compare Urbike's eBullitt cargo bikes against two van models that are commonly used for urban parcel delivery - the diesel Ford Transit Connect and the electric Citroen e-Berlingo. While not exhaustive, these specific vans serve as useful representatives to approximate costs for a typical diesel and electric van fleet.

Yearly cost otherwise stated **Vehicle Type**	**eBullitt**	**Fort Transit Connect**	**Citroen e-Berlingo**
			
Full Price	€6,000	€25,000	€35,000
Depreciate over		5 years	
Yearly Cost	€1,200	€5,000	€7,000
Insurance	€580	€900	€900
Service/Maintenance	€270	€270	€200
Parking Penalty	€0	€1,500	€1,500
Congestion Charge	€0	€1,500	€0
Total Yearly Vehicle Fixed Cost	**€2,050**	**€9,170**	**€9,600**

Figure 10 Estimated yearly vehicle fixed cost breakdown

Looking at fixed costs, the purchase price per e-cargo bike is €6,000 based on Urbike's Bullitt model, while the Ford Transit diesel van is €25,000 and the Citroen e-van is €35,000. With 20% annual depreciation[33], this equals €1,200 per year for bikes, €5,000 for the Ford, and €7,000 for the Citroen. Additionally, insurance[34], maintenance[35], parking fines, and congestion charges add €850 in extra fixed expenses for the cargo bike. For the diesel van, we estimate this adds €4,170 per year, and €2,200 for the e-van[36].

In total, annual fixed costs are €2,050 per e-cargo bike compared to €9,170 for the Ford van and €9,600 for the Citroen e-van.

33 Using the standard vehicle-like asset depreciation rate in Belgium.

34 Approximate using quote from Laka (one of the UK's leading bike insurance providers).

35 Worst-case approximation using van-equivalent estimate according to Energy Saving Trust

36 Energy Saving Trust. (2020). Electrifying last mile deliveries: A guide for businesses.

	eBullitt 	Fort Transit Connect 	Citroen e-Berlingo 
Working days (in 1 year)	250 days (2000hrs)		
# Parcels delivered	20,200 10.1 parcels/hr x 2,000hrs	9,800 4.9 parcels/hr x 2,000hrs	9,800 4.9 parcels/hr x 2,000hrs
Distance driven (km)	16,510km 0.81km/parcel x 20,200	10,365km 1.05km/parcel x 9.800	10,365km 1.05km/parcel x 9,800
€ per kWh or L	€0.3	€1.83	€0.3
kWh or L / 100km	2.146kWh/100km	8.50L/100km	22.37kWh/100km
€ energy / km	€0.004	€0.156	€0.067
Total Yearly Vehicle Variable Cost	**€106**	**€1,612**	**€696**

Figure 11 Estimated yearly vehicle variable cost breakdown

For variable expenses, Urbike's e-cargo bikes deliver 20,200 parcels annually, traveling 0.81km per parcel and consuming 2.146kWh per 100km, costing €0.004 per km. The Ford van delivers 9,800 parcels annually, averaging 8.5L/100km at a diesel cost of €1.83/L, equaling €0.156[37] per km. The Citroen e-van also handles 9,800 parcels yearly, using 22.37kWh/100km at an electricity rate of €0.3/kWh[38], costing €0.067[39] per km. With these distances and volumes, e-cargo bikes incur €106 in energy costs versus €1,612 for the Ford van and €696 for the Citroen e-van.

37 https://statbel.fgov.be/en/themes/energy/petrol-prices

38 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_price_statistics#Electricity_prices_for_household_consumers

39 https://ev-database.org/uk/car/1546/Citroen-e-Berlingo-M-50-kWh

	Fixed Cost	Variable Cost	Total Yearly Cost	Parcels Delivered	€ Cost per Parcel
eBullitt 	€1,960 +	€106 =	**€2,066** ÷	€20,200 =	**€0.10 /parcel**
Ford Transit Connect 	€9,170 +	€1,612 =	**€10,782** ÷	€9,800 =	**€1.10 /parcel**
Citroen e-Berlingo 	€9,600 +	€696 =	**€10,296** ÷	€9,800 =	**€1.05 /parcel**

Figure 12 Estimated yearly vehicle total cost breakdown

Adding fixed and variable costs, total yearly expenses are €2,066 per e-cargo bike, €10,782 for the Ford Transit van, and €10,296 for the Citroen e-van. Despite the same 20,200 parcels delivered, e-cargo bikes cost 1/5 the amount per parcel (€0.10) as the vans (€1.05-€1.10).

Greenhouse Gas (GHG) Emissions: Cargo Bikes vs Vans

While analysing the cost efficiency of cargo bikes compared to vans is important, understanding the full environmental impact of these vehicles is vital. The European Union has regulatory frameworks in development, such as the Corporate Sustainability Due Diligence Directive (CSDDD) and the Corporate Sustainability Reporting Directive (CSRD), to support its greenhouse gas (GHG) emissions reduction target of 55% by 2030.

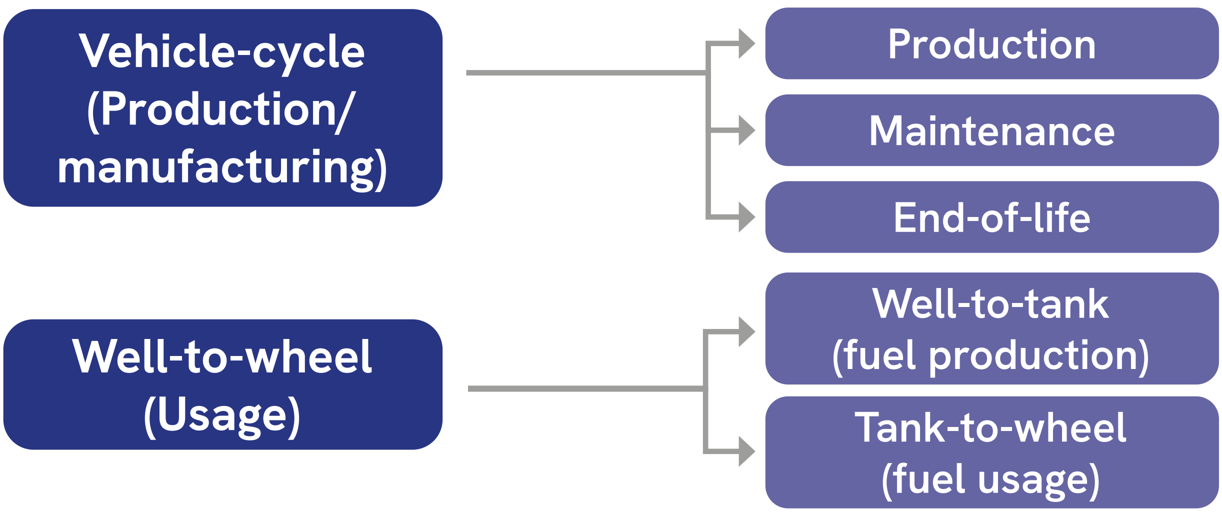


Figure 13 Greenhouse Gas (GHG) estimation structure

As these regulations come into force, quantifying the full lifecycle of GHG emissions will become increasingly important. By using the European Commission's Life Cycle Assessment (LCA) methodology, we provide an indicative end-to-end view of GHG emissions from a vehicle's production to its end-of-life.

The eBullitt's primary sources of emissions come from its production, which considers elements such as frame weight, battery capacity, and tires. This is similar to comprehensive studies undertaken by industry players like Trek in the US.

Over its lifecycle, we consider that the eBullitt's maintenance phase includes one battery and two tire replacements. When considering the end-of-life emissions, we approximate values using data from electric vans, which stand at about 18%. In contrast, the Diesel (N1 Class 3) and Electric Vans (N1 Class 3) have their emission values directly pulled from the European Commission's LCA.

For the energy these vehicles consume, the eBullitt relies on an electricity-based energy source, labeled as BEV. When assessing the emissions due to electricity generation, we focus on the 2020 EU28 fuel source mix, which translates to an energy consumption of about 10.08Wh/km. The Diesel Van uses diesel, referred to as ICEV-D, whereas the Electric Van operates on electricity, termed BEV. Both of these figures are rooted in the European Commission's 2020 data.

From our comparative analysis, we find that the eBullitt emits a minimal 0.0079 kgCO2e/km. When you compare that to the Diesel Van, which emits a substantial 0.3207 kgCO2e/km, and the Electric Van at 0.1561 kgCO2e/km, the difference is stark. If we further break this down for a practical scenario of delivering 500,000 parcels, the eBullitt is responsible for just 3,228 kgCO2e. In comparison, the Diesel Van produces 169,602 kgCO2e and the Electric Van releases 82,553 kgCO2e.

The broader perspective here is that the eBullitt achieves a staggering 98% reduction in emissions when placed beside diesel vans and a 96% reduction against electric vans.

When distilled down, the narrative is clear: The eBullitt cargo bikes significantly diminish the environmental impact in urban deliveries. Their increased usage could lead to monumental reductions in GHG emissions, making them not only pivotal for urban eco-friendliness but also a beacon for global climate change initiatives.

Conclusion

Through this case study we set out to provide rigorous evidence on the logistics performance of e-cargo bikes for urban last mile deliveries. By collecting detailed GPS traces from Urbike's fleet in Brussels, we studied the behaviour of cargo bikes across urban contexts in Brussels. We also introduced our analysis framework to segment each step of the delivery process and refine our understanding of their performance advantages.

We find e-cargo bikes operate with consistent speeds around 16km/h across Brussels' variable urban terrain, unaffected by the congestion that slows vans to just 11.3km/h. Our analyses also showed that e-cargo bikes park within 30 meters of recipients on average, minimising walking time. In contrast, studies show vans can spend up to 25 minutes searching for parking per stop in major cities.

Factoring in real-world distances and speeds, we estimate total delivery time per route is over 2x faster with Urbike's cargo bikes compared to diesel vans constrained by Brussels' narrow streets. On a typical 8.5km route, e-cargo bikes take just 48 minutes while vans require 99 minutes.

Modelling total cost of ownership further proves bikes' economic advantages. Purchase prices for Urbike's Bullitt e-cargo bikes are a fraction of typical diesel and electric vans. Adding insurance, maintenance, depreciation, and energy costs, vans have 5-10x higher expenses per parcel despite moving lower annual volumes. E-cargo bikes also slash greenhouse gas emissions by 96-98% relative to both diesel and electric vans based on comprehensive life cycle assessments.

These insights strengthen the evidence base for cities worldwide to confidently transition substantial portions of urban freight to zero-emission cycling logistics.

We believe widespread cargo bike adoption could catalyse broader improvements to urban life and sustainability. Halting the widespread growth, and even reducing, the number of vans in cities could directly help to decongest roads, lower pollution levels and improve public health. Reclaimed road space could enable more parks, bike lanes, and plazas if citizens advocate for these public amenities. Removing traffic danger could also accelerate getting more citizens cycling, further reducing car use in cities, and helping reach a key tipping point on the way towards sustainable and humane cities.

Founded in 2008 in Copenhagen, Larry vs Harry specialises in the production of cargo bikes, both manual and electric-assisted, gaining recognition in over 30 countries. The introduction of their Bullitt X model in 2022 exemplifies their focus on catering to urban logistics needs.

Their reliability has led to partnerships with esteemed cargo bike fleets across the European Union, including Cycloon in the Netherlands, Coursier in France, and Urbike in Belgium. Strategic alliances with major logistics players like Fedex and DHL have equipped them with deep insights into urban logistics challenges, making them a trusted name in the cargo bike industry.

Kale AI is a London-based startup specialising in AI-driven solutions designed to innovate urban logistics. Their primary focus lies in supporting cargo bike operators scale their business, by developing a dispatch software focused on the needs of the industry.

Their notable collaborations include a sustainable fleet dashboard developed with King's College London and the Mayor of London, aiding transitions to greener transport options. They've worked on a fleet optimisation tool for major van-based logistics operators to make informed decisions about how to integrate cargo bike logistics in their urban operations. In partnership with institutions like MIT and ITU Copenhagen, they've recently led Machine Learning research on estimating vehicle performance across urban micro-regions.