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# Mobility as a Service for Freight and Passenger Transport: identifying a microhubs network to promote crowdshipping service

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**Abstract:** Mobility as a service platform for freight and passenger transport can promote sustainable cities. However, most of the contributions in the literature on mobility as a service platform explicitly focus on passenger mobility only. This article describes the operational characteristics of a mobility as a service platform for freight and passenger transport operated by GoMoov in Joinville, Brazil. In addition, it also explores the setting up of a microhub network for parcel deliveries employing e-shared vehicles and a crowdshipping workforce. Findings indicate that ten microhubs are sufficient to cover the urban area of Joinville (98.96% of the residents and 98.99% of the dwellings). Mobility as a Service platform for freight and people transport generates non-negligible economic and environmental benefits. Appropriate marketing strategies and active engagement of the companies involved are crucial to its success.

**Keywords:** Urban freight transport; Freight and passenger transport; Mobility as a Service; Crowdshipping services; Microhubs

## 1 Introduction

Passenger and goods movements share the same infrastructure in cities; however, they are typically conceived, considered, and treated as separate issues notwithstanding their evident and substantial interactions and, sometimes, conflicting interests (Bruzzone et al., 2021; El Ouali et al., 2021; Maltese et al., 2023; Marcucci et al., 2023; Trentini et al., 2011; Trentini and Malhene, 2012). The integration of passengers and goods is built on a widely accepted vision, aligned with the goal of the European Union of developing a sustainable urban mobility policy. This vision foresees and incorporates the development

of efficient public transport systems with good connectivity that improves the quality of city life.

Connected mobility solutions play a vital role in reducing transport-related negative externalities (Marcucci et al., 2017). Many digital platforms that provide door-to-door services and connect users with transport service providers are progressively emerging and acquiring a central place in the urban mobility panorama (Le Pira et al., 2021; Pangbourne et al., 2020). As for passengers, these platforms go under the name of Mobility as a Service (MaaS) (Pangbourne et al., 2020; Santos and Nikolaev, 2021; Vij and Dühr, 2022). MaaS has become a reality thanks to the ubiquitous development of digital technology and has subsequently generated relevant social changes (Hasselwander et al., 2022). MaaS platforms can potentially alter urban mobility patterns (Pangbourne et al., 2020) and support cities in achieving sustainable development goals.

Recently, some scholars have been investigating how to incorporate urban freight transport (UFT) into MaaS. For example, Casady (2020) illustrates the integration of freight and people in a MaaS framework; Le Pira et al. (2021) identify opportunities and schemes for MaaS for Passengers and Freight (MaaS4PaF) and conceptualize its framework; Brach (2019) discusses the benefits and costs associated to the integration of freight transport in MaaS; Monios and Bergqvist (2020) propose a business model for using autonomous electric vehicles in a sharing system for freight transport. Jittrapirom et al. (2017) discuss the Tuup app as a MaaS platform that includes both passengers (public transportation, bike sharing, car sharing, car rental, taxi and shared taxi, parking rent) and freight services (crowdshipping). The Tuup app was developed in Helsinki (Finland) and represents an example of how MaaS can incorporate different transport-related services.

Although the literature mentions the benefits of integrating freight transport into MaaS, few studies have analysed real data from real case studies or pilots. This article illustrates and discusses the feasibility of integrating UFT into MaaS with respect to a specific case study. It describes the operation of a MaaS platform that integrates people and cargo-oriented services, operated by GoMoov in Joinville, Brazil (Figure 1). In 2021, Joinville had 604,708 inhabitants (Figure 4), being the most populous city in the Santa Catarina state. The population density is 536,1 hab./km<sup>2</sup>. The municipality has a high human development index (0.809) among Brazilian municipalities, occupies the 21st national position, and has one of the highest incomes per capita in the country. Industrial and commercial activity is the basis of the city's economy, which has a per capita GDP of BRL 58,476.90 in 2019 (about 11,457.30 euros).

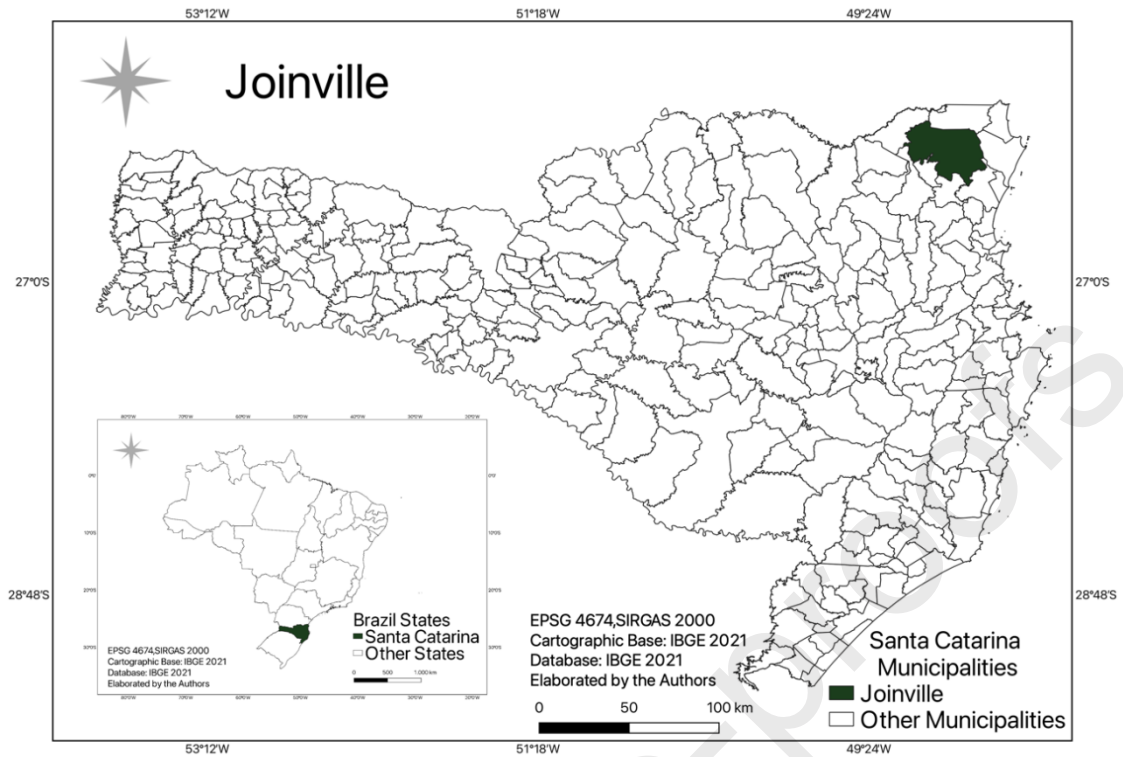


Figure 1 – Location of Joinville in Brazil.

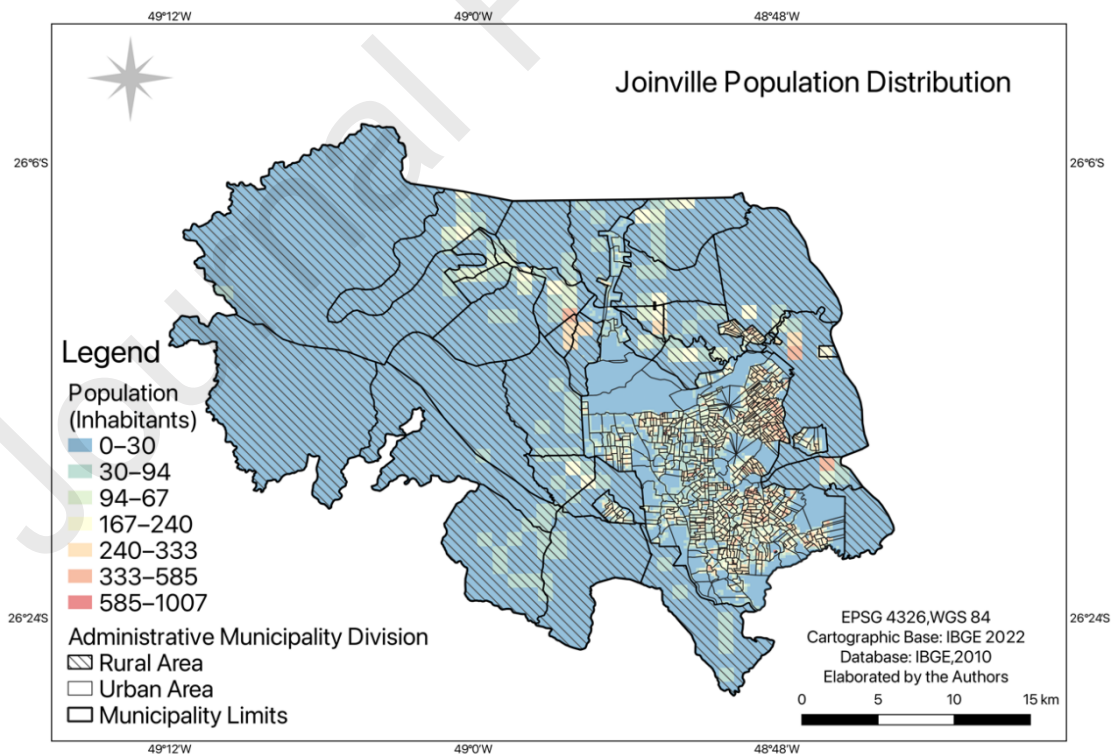


Figure 4 – Spatial distribution of the population.

Beyond being Brazil's third largest industrial area, Joinville also promotes many international cultural events every year, has intense industrial activity, and constitutes an important tourist and commercial destination. The city has a very smooth topography and is well endowed with good cycling infrastructure. On the other hand, the public transportation system and micromobility services supply are not available in the entire city and population. Joinville is characterised by a high motorisation rate (50%) compared to Brazil average (25% proportion car per inhabitants) (IBGE, 2022).

The GoMoov platform is innovative since the application jointly offers: micromobility renting service for people, micromobility renting for cargo delivery, bidding platform for crowdshipping service negotiations. The feasibility is tested by analysing the differences emerging from operational data in the pilot study with and without cargo operations. Additionally, this paper proposes an improvement in cargo operation by implementing microhubs that allow reducing the last mile delivery kilometers driven. The article illustrates how a MaaS platform can also incorporate crowdshipping services. Furthermore, the results indicate that the infrastructure is important to promote commercial viability of cargo operations.

This paper is arranged in 6 sections. Following the introduction section 2 details the literature on crowdshipping and clarifies how the integration of freight delivery services can be fruitfully integrated in a MaaS platform. Section 3 details the case study and the data on which the examination is based, followed by the data analysis in Section 4. The results are presented and discussed in Section 5, followed by the final remarks in Section 6.

## 2 Background

The scientific literature emphasises the potential MaaS can generate in tackling transportation problems (including freight) (Hasselwander et al., 2022), even considering that most contributions explicitly focus on passenger mobility. This implies a limited exploitation of the potential benefits that could materialise when integrating passenger and freight movements whenever this proves technically feasible and financially convenient. Le Pira et al. (2021, p.5) define MaaS for passenger and freight (Maas4PaF) as *"a user-oriented integrator of passenger and freight transport services enabling searching, booking and payment through a single digital platform for customised door-to-door trips. Users are both passengers and shippers, and those who perform the delivery (i.e., MaaS carriers) could be passengers, passenger transport operators, and freight transport operators"*.

Maas4PaF allows the integration of people and passenger transport. This approach to transport, which can also be transferred to planning too, can (i) improve the use of urban infrastructure (Bruzzzone et al., 2021); (ii) promote economic growth and social equity by creating new business opportunities for companies (Vij and Dühr, 2022); and (iii) create new e-consumers markets for transport service operators (Vij and Dühr, 2022). As a consequence, Maas4PaF contributes to creating trip awareness (Butler et al., 2021), increases user travel responsibility (Alyavina et al., 2020), changes in travel behaviour (Alyavina et al., 2020; Butler et al., 2021), and reduces urban space use by decreasing parking areas (Butler et al., 2021). A MaaS platform for freight and passenger transport

can enhance the creation of sustainable cities and create environmental awareness with the increase in sharing schemes (Storme et al., 2021), such as crowdshipping services. Castiglione et al. (2022) discuss the combination of crowdshipping and e-mobility. Using probabilistic behavioural models, the authors assess how commuters can act as crowdshippers, reducing the need for traditional delivery vehicles, and generating sustainable urban delivery solutions.

Crowdshipping represents an emerging trend accelerated by app-based platforms that connect supply with demand (Le et al., 2019). Crowdshipping constitutes a delivery service where a commuter offers its free carrying capacity, with respect to time and/or space, to perform deliveries voluntarily and is compensated accordingly (Buldeo Rai et al., 2017; Nascimento et al., 2023). The selection of couriers to the delivery route is based on the closest voluntary courier, who asks for the lowest delivery fee or the best reputation on the platform (Le et al., 2019). The crowdshipper can use the available transport modes on the MaaS platform to perform deliveries.

Much has been published on crowdshipping in the literature. Most of the articles look at the supply side, i.e., commuters that can choose to act as crowdshippers and investigate under which conditions they might do so (Neudoerfer et al., 2021). Relevant to this paper are operations and service management including sustainable service (Dai et al., 2020) optimizations of facilities (Punel et al., 2019), and supply and demand matching derived problems (Ermagun et al., 2020; Marcucci et al., 2017). The demand side oriented papers investigate consumers' preferences for crowdshipping use (Punel et al., 2018) and their willingness to receive a parcel through a crowdshipping delivery service (Buldeo Rai et al., 2021).

Recently, some authors have focused on a crowdshipping concept based on public transport. Gatta et al. (2019) investigate the potential of using public transit, particularly the Roma metro network that incorporates automated parcel lockers within metro stations, with a combination of crowdshipping as a sustainable last-mile delivery method. The findings support this model as a feasible approach to urban logistics, providing information to policymakers and logistics providers. Fessler et al. (2024) explore motivational drivers and barriers to the participation of commuters in a crowdshipping service that combines automated parcel lockers with public transport. The authors suggest that communication efforts should focus on environmental and public crowdshipping benefits, targeting younger people who value social and environmental contributions most. To sustain engagement, the platform could integrate environmental feedback (e.g., emissions saved per delivery performed) and social tools such as gamification, fostering community building. Fessler et al. (2022) use stated choice experiments to analyse of public transport users' preferences to carry a parcel on their ride, where they are automatically compensated for by travel cost reductions. As a main result, the monetary compensation positively affects the user's decision to participate in the delivery, while the additional time, weight, size, and number of packages negatively affect their willingness to act as a crowdshipper.

Nascimento et al. (2023) assert that pick-up points can play an important role in promoting UFT system efficiency and in improving service quality thanks to better parcel accessibility. This paper analyses a microhub network to serve as a pick-up point, with the

aim of increasing delivery efficiency and crowdshipping options. Microhubs, micro-fulfilment centres, delivery microhubs or micro-distribution hubs are logistics facilities typically located near delivery destinations. Microhubs can contribute to the use of eco-friendly vehicles for last-mile distribution. Furthermore, microhubs also have the potential to reduce motorised trips in dense areas, improve customer experience by reducing delivery time, and have the potential to reduce delivery costs. This solution is being implemented by the City of Hamburg to provide a flexible solution for the last mile (Hamburg Invest, 2022). Figure 1 illustrates the main types of urban logistics spaces.

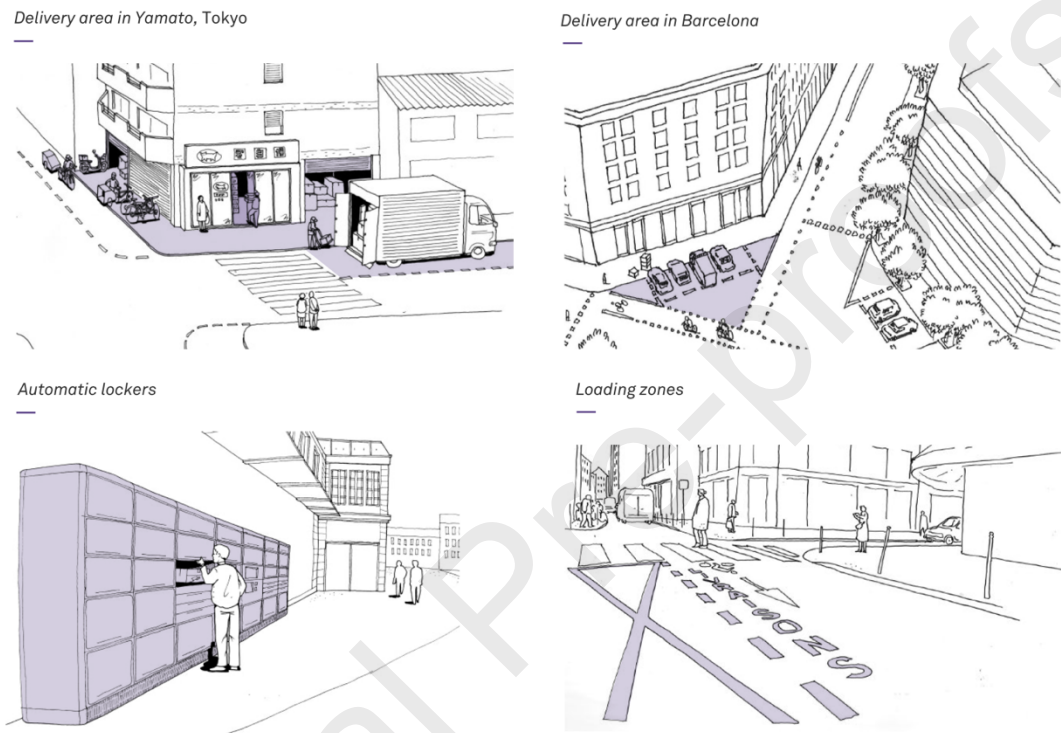


Figure 2 – Types of urban logistics spaces (Afilog, 2018).

With this delivery paradigm in mind, a company could use the microhubs network to deliver goods using crowdshipping. Since the system is integrated, crowdshippers can use micromobility vehicles to deliver packages, as Figure 2 illustrates. These facilities can play an important role, since they can offer a better level of service to the crowdshipper, increasing parcel accessibility and, consequently, boosting the probability of commuters acting as crowdshippers. This can also reduce total detour to pick up parcels, thus improving sustainability. This is even more important when the location of these facilities is closer to the main public transport terminals.

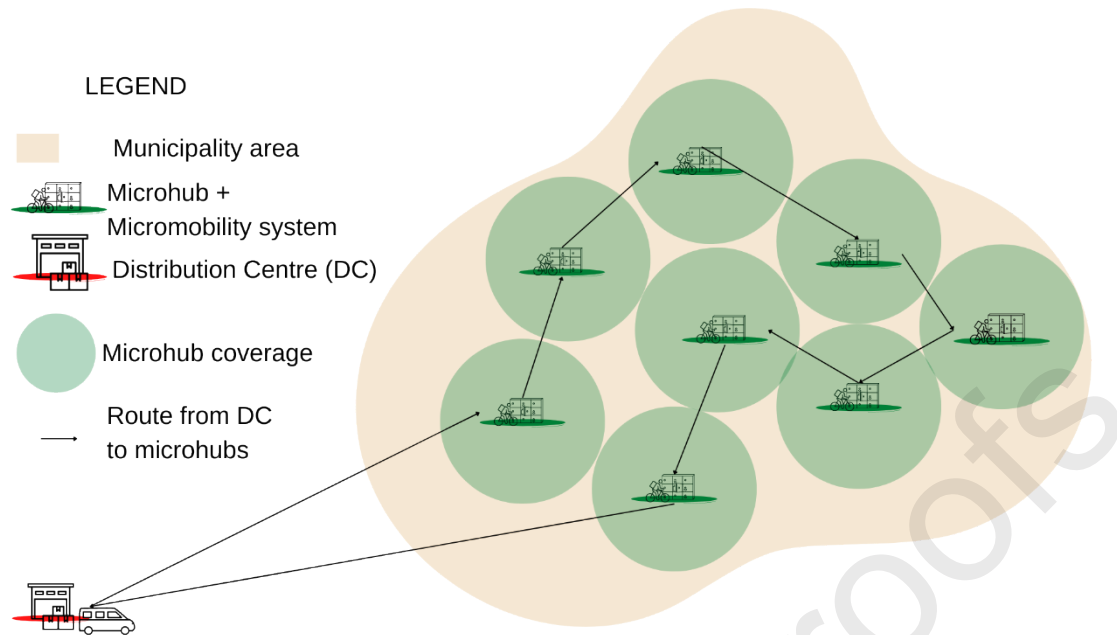


Figure 3 – Crowdshipping service using microhubs and micromobility vehicles

This paper explores the GoMoov<sup>1</sup> case, a company offering an e-shared mobility system integrated with a Maas4PaF platform that operates the deliver module based on crowdshipping principles (see Section 3.1 for operational details). It also proposes the creation of microhubs strategically located within the public transport network to expand the service area and enhance the level of delivery service based on GoMoov's operations data between May 2021 and February 2022. In addition, the paper discusses the importance of crowdshipping services for MaaS4PaF. In Brazil, it is uncommon to envisage a consumer to play an active role within the delivery process and lockers presence is limited to some province capitals. The click and collect model was still in its infancy when this pilot was deployed. That being said, the microhub proposal rests on the assumption that the cargo will be delivered to the final destination where the very-last leg of the delivery constitutes the GoMoov's target. The cargo would be collected by professional or occasional couriers at the microhubs and delivered to its final destination. The article does not consider an active consumer.

### 3 Description of the case study

GoMoov operates the e-mobility sharing system in the cities of Barra Velha, Penha, Balneário Piçarras, Jaraguá do Sul, and Joinville, all located in the province of Santa Catarina. Its headquarters are located in the Joinville Technology Park, which hosts several start-up companies. One of them being GoMoov, which launched a shared micromobility service in 2020 via a mobile application. GoMoov is a subsidiary startup of ALLmobility, a Brazilian start-up responsible for developing the: 1) GoMoov MaaS app, 2) e-micromobility vehicles with Brazilian technology, and 3) tracking system installed on these vehicles. GoMoov offers e-scooters and e-bike service-renting as options for micromobility displacements. Initially, the service was charged per minute (BRL 1.00 + BRL 0.50 per minute, 0.20€ + 0.10€/minute, on September 13, 2022). From August 2022,

<sup>1</sup> <https://play.google.com/store/apps/details?id=com.gomoov.customer&hl=en&gl=US>

customers can buy service packages: 60 minutes per day cost BRL 8.90 (1.74€) and 800 minutes per month cost BRL 29.90 (5.86€). The total fleet includes 300 e-bikes and 30 e-scooters.

The system adopts a free-flow strategy. However, to improve the management of public space, vehicles can be parked only in designated parking zones that are marked with a small totem or banner (Figure 5). GoMoov partnered with local businesses (Figure 5), located close to public transport stops, to use the space in front of the property to accommodate parking areas. The number of vehicles that can be parked in each parking zone depends on the availability of the negotiated space. The company allows in-app advertising in exchange for space. Figure 6 illustrates the location of 79 parking zones (PZ) in Joinville. The most concentrated area has a density of 10 PZ/km. Parking the vehicle outside the application's coverage area or parking zone results in a fine for the user. Most parking zones are located close to public transport stations or bus stops, to allow mode integration, although the system is not fully integrated since there is no partnership with the municipality or the public transport operator company. Among the travel options suggested to users, there is GoMoov e-micromobility integrated with public transport.



Figure 5 – Example of parking zone. Source: The authors.

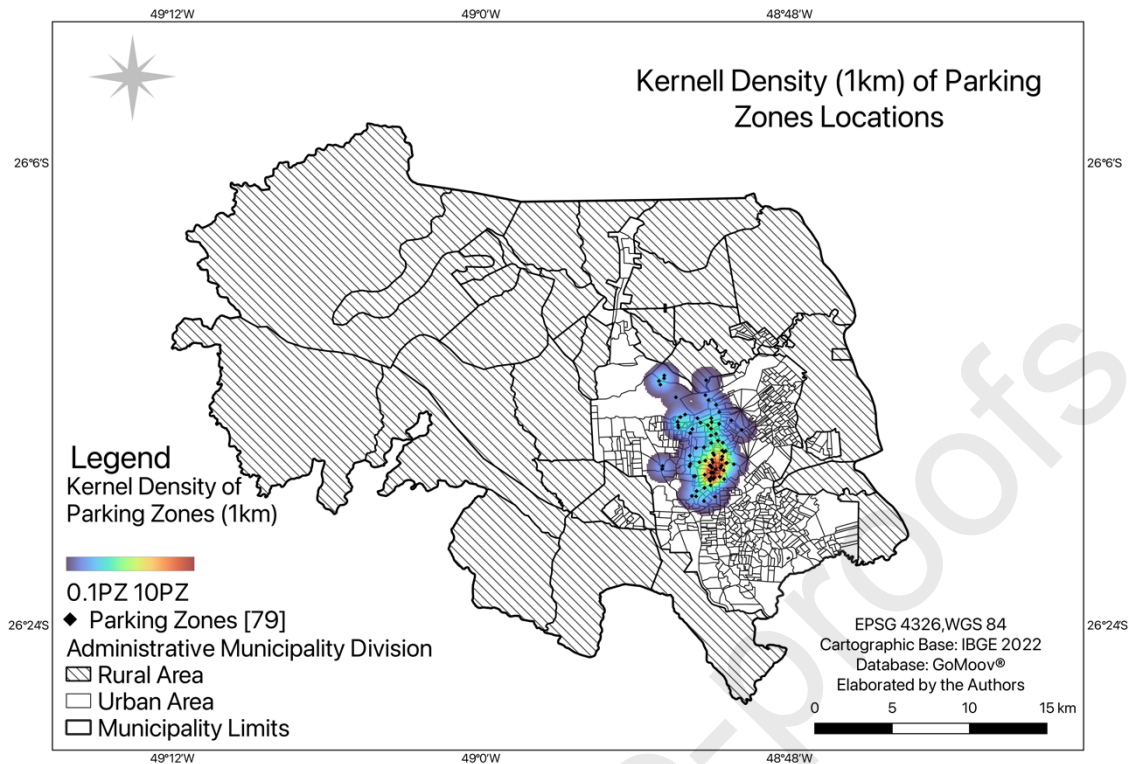


Figure 6 – Location of the parking zones in Joinville.

The company started its operation in December 2020 as an e-shared micromobility service, and in October 2021 started to expand its activities by offering e-commerce deliveries using its e-shared vehicle and a crowdshipping workforce. Last-mile deliveries were made by professional or occasional couriers that would go to the city distribution centre of the partner marketplace to retrieve the delivery cargo. GoMoov assigns the route to each courier according to the location of daily deliveries. The couriers would pick up an e-bike or e-scooter at the distribution centre to perform deliveries, and the marketplace would bear its cost. When a delivery fails, the couriers must return the cargo to the local distribution centre.

GoMoov can be considered a MaaS4PaF application for a series of reasons. The most important include (i) offering users a platform to pay for different transport services; (ii) offering both freight and passenger services; (iii) providing users with optimal displacement routes; and (iv) distributing the payment between transport operators and couriers.

The operational data from December 2020 to February 2022 indicate that 10,180 trips were made using the system. Most trips occur in the downtown of Joinville (Figure 7). Using a Kernell distribution function to obtain the density of the distribution of the origin and destination of the trips, one observes a similar distribution pattern. Figure 6 shows that the e-vehicle supplies, so there is still a part of the municipality that is not covered by the e-micromobility system, and this represents an issue when promoting the creation of an equitable micromobility and efficient distribution system.

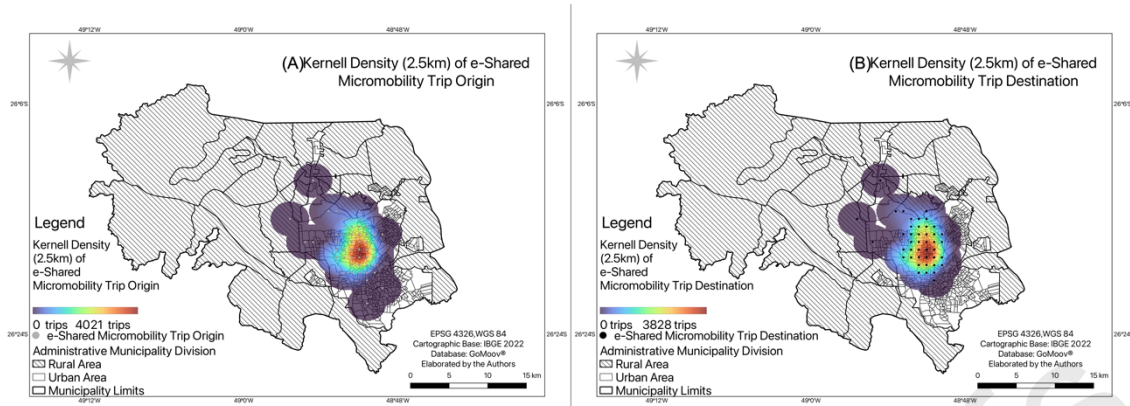


Figure 7 – Concentration of the origin and destination of trips.

The number of users is similar during the weekdays and increases on weekends (Figure 8). Most trips are made by e-bikes (67%) during the week. The use of e-scooters is more frequent on weekends (Figure 9).

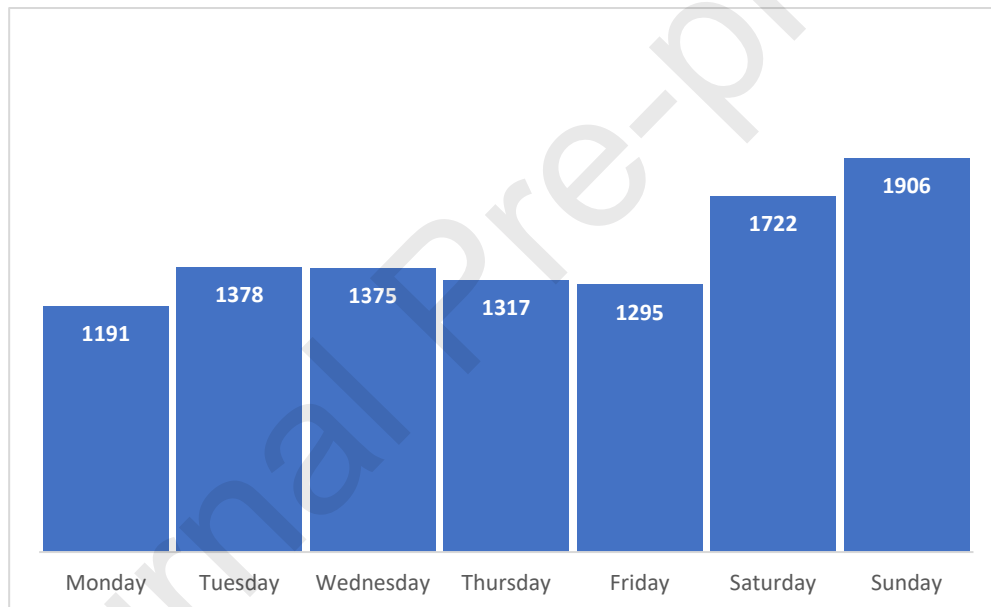


Figure 8 – Number of users per weekday

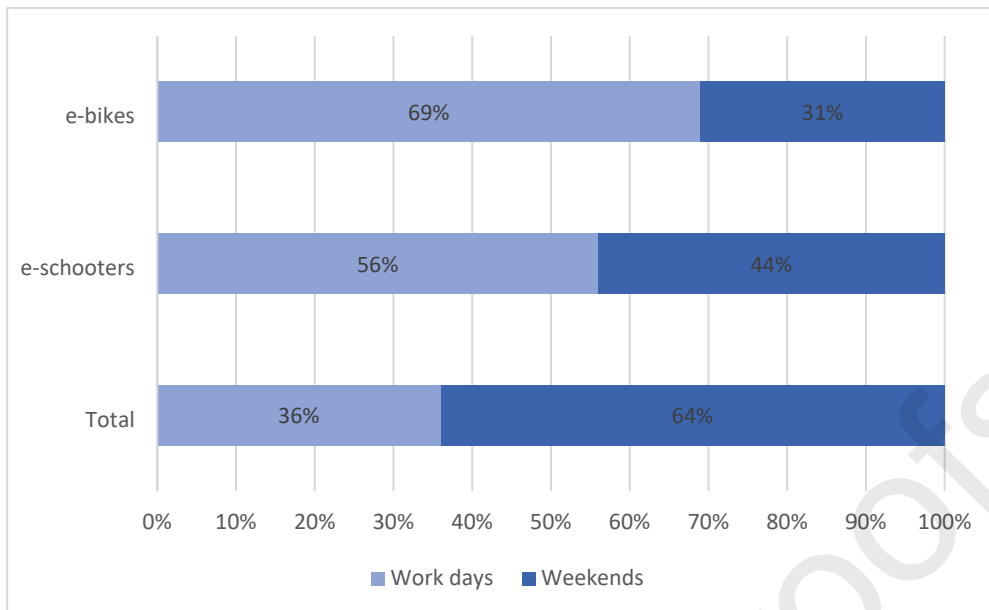


Figure 9 – Percentage usage of the micromobility system

To increase visibility and rentability, the business model included the delivery module in the application (Figure 10). Among the motivations for incorporating deliveries using e-bikes, one can include: a) increase in agility in deliveries, b) reduction of fuel value impact on product delivery, c) reduction of gas emissions pollutants and other environmental impacts, d) provision and improvement of customer experience, e) reduction of traffic accidents, f) overall traffic reduction in the city, and g) improvement of company's brand. Micromobility users can be transformed into crowdshippers. When a delivery must be performed with the serviced area, the system proposes the delivery to those who use for their personal displacement via the app and are available to perform the delivery. The nearest available person who accepts the delivery, picks up the order at the establishment, and delivers it using GoMoov that tracks the delivery.

The integrated service described in this section is possible thanks to the partnership between GoMoov and a big marketplace, which has been up-and-running since October 2021. They perform zero-emission last-mile deliveries, where the goods are transferred from the local distribution centre to the microhub, strategically positioned in the central area, using an electric vehicle. Crowdshippers can then collect their assigned packages and perform the deliveries, while getting paid for each task fulfilled. As reported by the company, deliveries that previously took more than 8 hours subsequently were performed in less than 4 via the crowdshipping service. The logistics microhub restocking is taken care of by a GoMoov courier company partner.

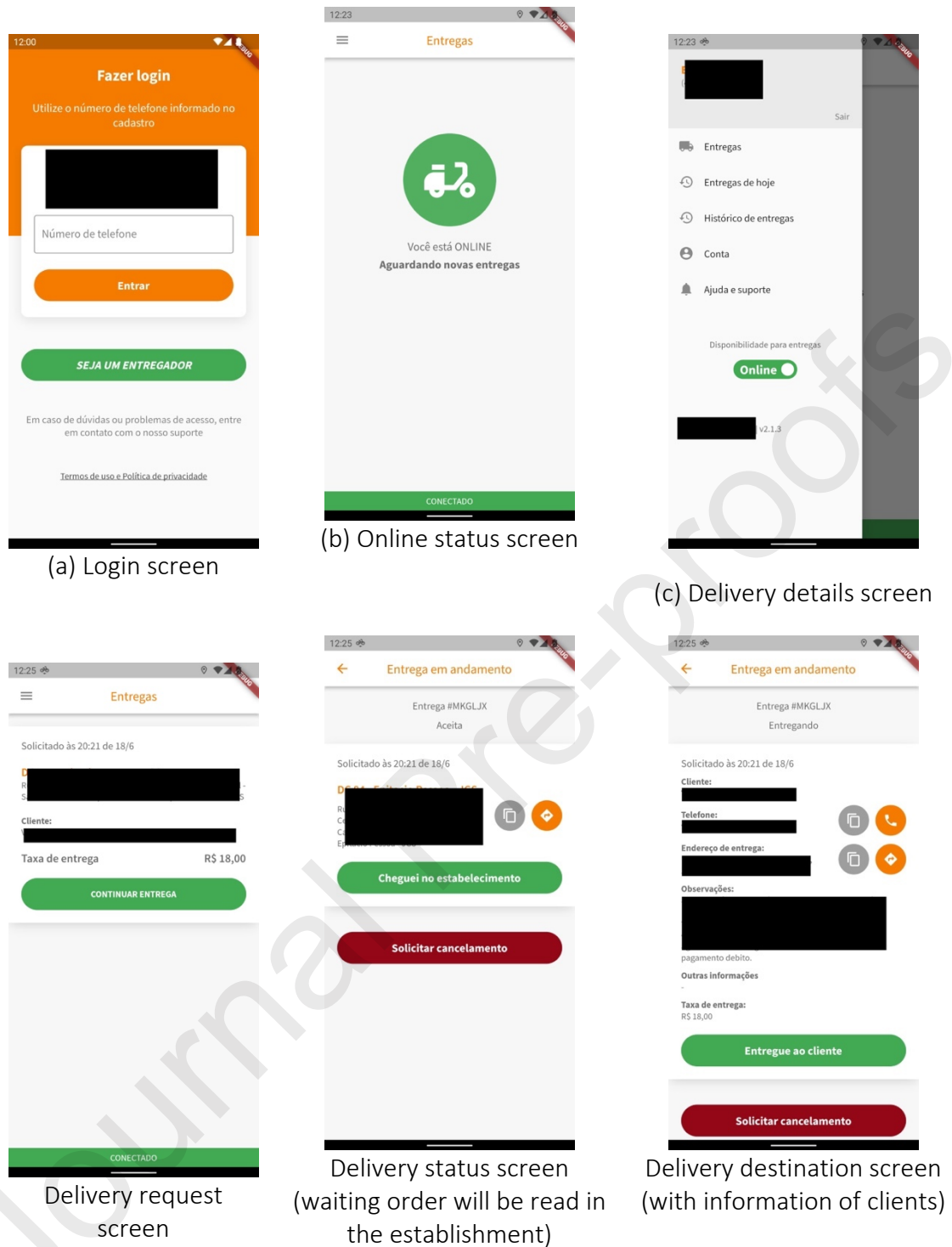
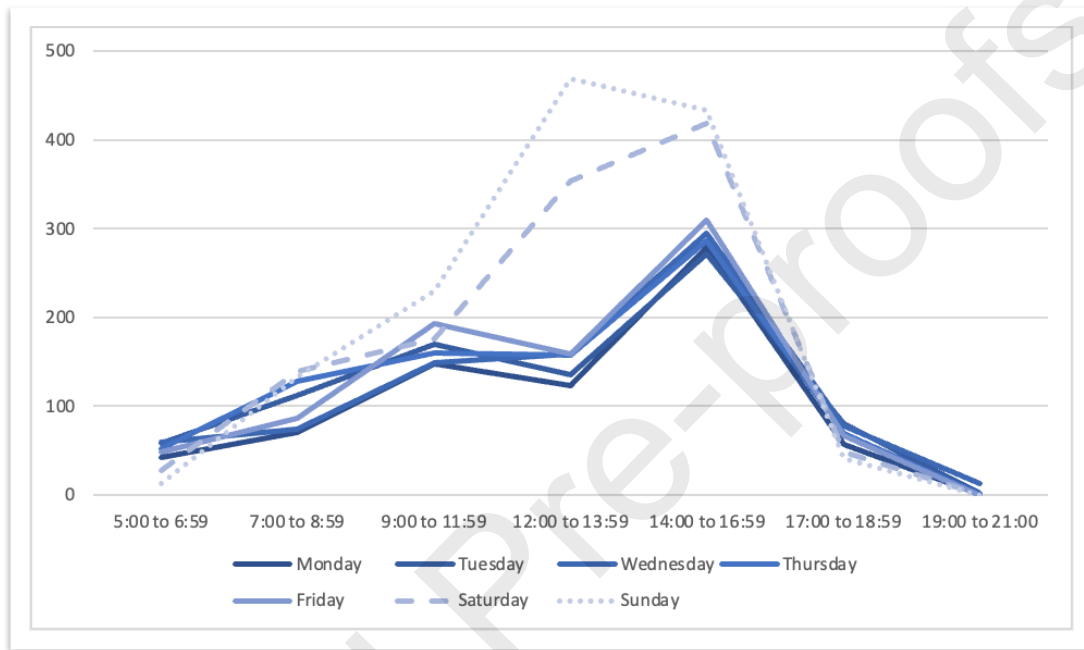


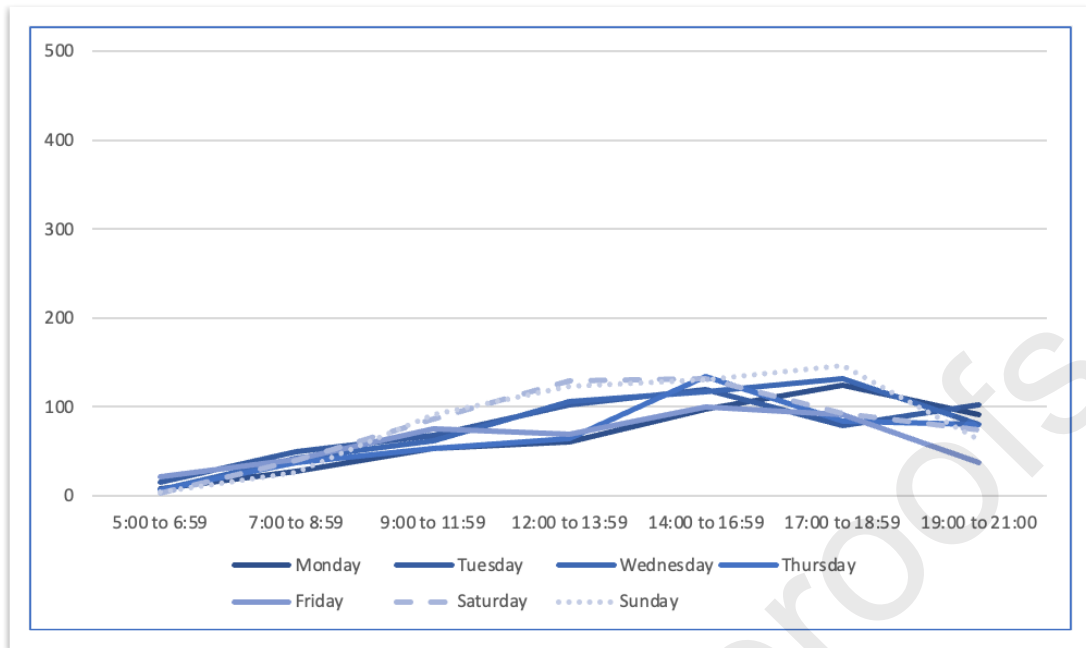
Figure 10 – Some screens of the delivery app. Note: Personal information was hidden. Source: GoMoov

The improvement in operations could also be seen from the perspective of the micromobility company. In an analysis of the operational activity of the micromobility system prior to the implementation of the delivery module, two different patterns can be observed (Figure 11A). On weekdays, the lower demand suggests a predominant leisure purpose use. The peak demand for its services did not correspond to the traditional commuting travel hours, but rather with the period when people make small

displacements to go shopping or do any other activity during the day. The company started its operation during COVID-19, which may have affected some of the commutes using the system and induced the integration of people and the freight module quickly, to maintain high vehicle productivity during the entire day. The change in the demand curve due to the start of operations can be observed in Figure 11B. On weekdays, the demand is similar to that on weekends, suggesting that there is a change in user behaviour compared to Figure 11A. In addition, one observes a similar pattern of trips throughout the days of the week.



(a) Demand between May 2021 and September 2021



(b) Demand between October 2021 and February 2022

Figure 11 – Demand

Furthermore, during five months of the company's operation (Figure 10A) and before the implementation of the delivery module, 6,571 trips were made. Five months after the implementation of the delivery module, only 3,610 trips were made mainly due to the December to February vacation period in Brazil. The company intends to implement the next module, integrating the app with public transport. When this module will be fully operational GoMoov, one could consider it a full MaaS4PaF in line with the definition Le Pira et al. (2021) propose.

The benefits this platform generates are many. First, the convenience for those who use micromobility, since they can rent and leave the e-vehicle anywhere. Furthermore, people have an option when choosing the best transport mode for them: (i) the micromobility network, (ii) public transport, or (iii) a combination of the two. Additionally, it also significantly reduces freight transport-related emissions, as the last mile delivery will be performed using e-vehicles (the marketplace courier partner already uses electric vehicles). On top of this, it reduces delivery time for marketplaces, improving their operational key performance indicators (KPI). Finally, the subsequent GoMoov app update also includes instant delivery options such that people can even purchase goods using the GoMoov platform. This update was successfully introduced, but does not represent the focus of this study.

The disadvantages of the platform are related to other stakeholders, like business, micromobility users, and public administration as well. To fulfil all the requirements of a complete MaaS4PaF the application should also include a public transport payment

feature, which is currently absent. Competition with other instant delivery platforms may lead people not to use the GoMoov app for cargo purposes.

## 4 Data Analysis

Based on the above reported service description, this paper identifies a last-mile hub network for parcel deliveries. The fundamental assumption is that microhubs are located in parking zones close to public transport stations or bus stops, since it is the only public transport service available in Joinville. Therefore, we set parking zones and bus stops as candidates. The population was set as the location of the demand, as people's houses represent the final destination of the delivery. The article assumes that any resident is equally likely to shop online.

To identify the location of microhubs, we solved a  $p$ -median problem. Set  $I = 1, 2, \dots, i$  of the potential location of microhubs, that is, parking zones and bus stations;  $J = 1, 2, \dots, j$  of the location of e-consumers, that is, residents;  $d_{ij}$  distance matrix between the potential location of microhubs and e-consumers. The e-consumers were concentrated in centroids of hexagonal grids proposed by Pereira et al. (2022). This geographical feature was chosen due to topological properties with advantages for spatial phenomena that include neighbourhood and connectivity (Pereira et al., 2022). The  $p$ -median problem identifies  $p$  facilities, where  $p \in I$ , minimising the distance to satisfy the demand of the customers (Beasley, 1985). In this paper, the distance matrix is given by the real distance, determined by the transport network from the potential location of the microhubs and centroids of the hexagonal grid. Based on the results, we discuss the operational, economic, and environmental implications of the MaaS4PaF platform. **Error! Not a valid bookmark self-reference.** details the data used.

Table 1 - Research Data and Usage

Data	Usage
Transport network	Distance matrix
Public transport stops	Potential candidates for locating microhubs
Residents	Potential e-consumers
Parcel deliveries destination	Weight to locate microhubs
Distance of displacement of 15 minutes by bicycle	Threshold to locate minihubs

To identify the potential delivery range for the established threshold buffers were created, using the Euclidean distance method. It should be noted that this simplification (that is, using the Euclidean distance) is only possible because the municipality has a relatively flat

topography and a good cycling network. If the municipality were characterised by a hilly topography, the buffer for network distance would have been more appropriate. Oliveira et al. (2022) provide additional details with respect to this method.

## 5 Results and Discussion

Figure 12 shows the location of the microhubs calculated by solving the p-median problem. Figure 13 shows the service area of the selected microhubs. The network is composed of 10 microhubs covering almost the whole Joinville (i.e., 98.96% of residents and 98.99% of dwellings). Four facilities are located at bus stops while the remaining six are located in pre-existing parking zones.

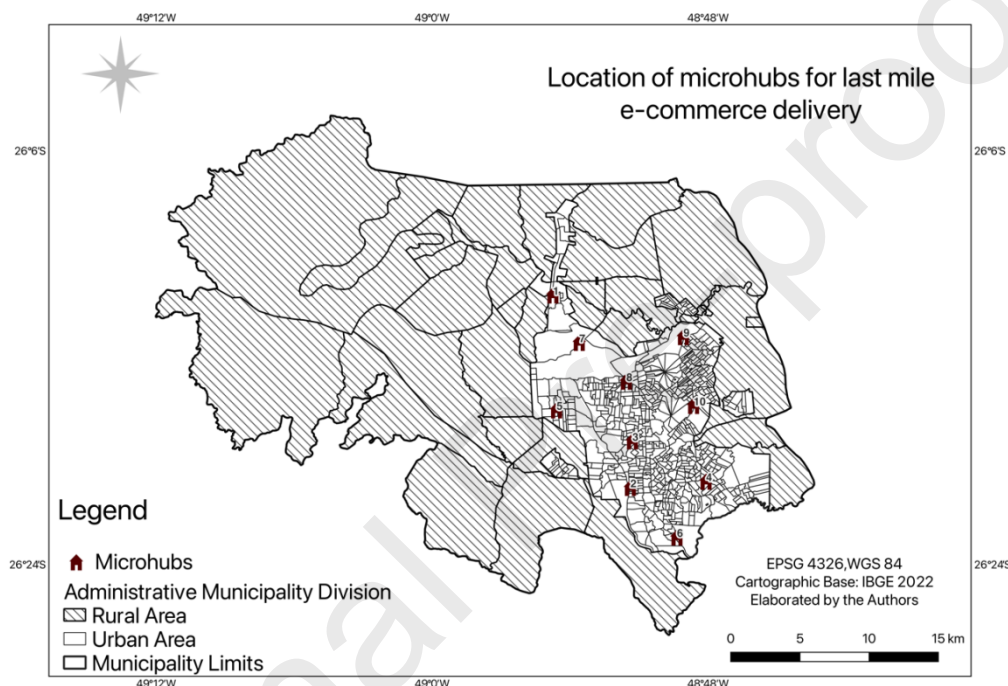


Figure 12 – Location of microhubs.

Pre-existing parking zones that have been turned into microhubs must allow a few meters for storage and the building must preserve delivery bays (Afilog, 2018). For Hamburg Invest (2022), an area of 15–20 m<sup>2</sup> serves a delivery area for approximately 120–150 items per day. Engaging partners determine the success or failure of the initiative. Business relationships must be fair and reflect the preferences of the various partners involved. Furthermore, considering the economic and environmental benefits of the solution for the city, as in Hamburg, the municipality could provide and/or facilitate the installation of microhubs in urban areas.

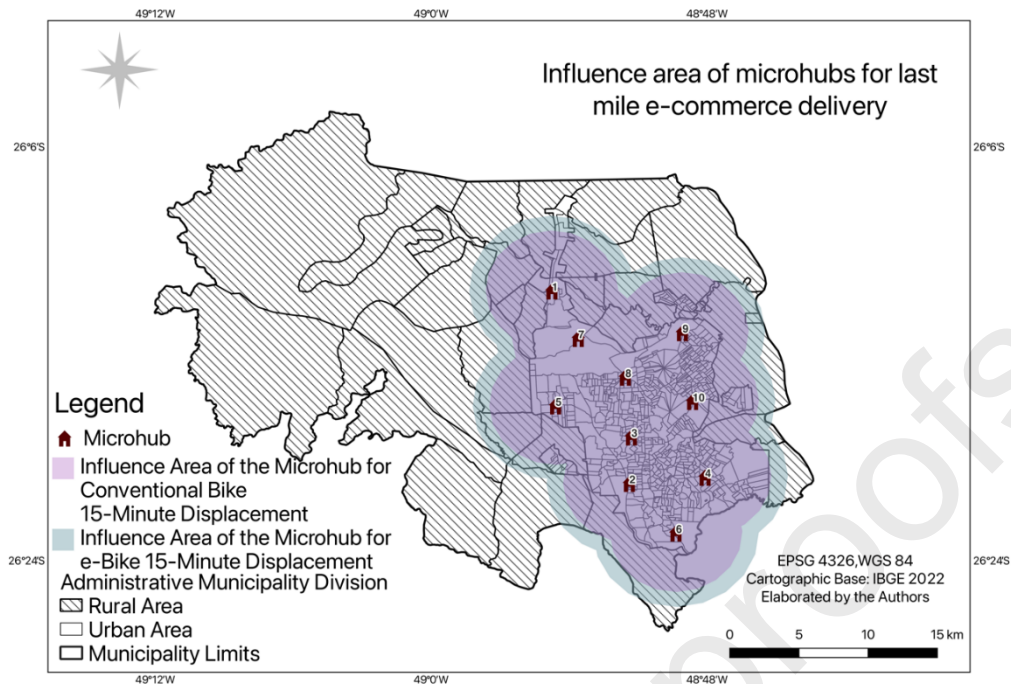


Figure 13 - Microhub service area.

The economic benefits might derive from the improvements impacting on the main stakeholders involved: GoMoov company (the MaaS4PaF provider), e-micromobility users, crowdshippers, and courier company. The introduction of the delivery module generated an increase in revenue for GoMoov due to the growth in trip demand. Furthermore, it increased the usage of vehicles, contributing to an improved distribution of e-vehicles in the city, reducing relocation costs to match demand. E-micromobility users benefit from innovation, since demand for deliveries can induce a price reduction, making e-shared micromobility more accessible. New parking areas equipped with lockers also support and expand the e-shared micromobility network, increasing accessibility and intermodality, thus improving overall public transport potential.

Lockers and microhubs can reduce crowdshippers', detour travel distance, promoting the system attractiveness and accessibility. Increasing the stops within Joinville from 1 to 10 generates benefits also for the marketplaces since the last-mile delivery is both faster and cheaper since crowdshippers are closer to their final destination.

Taking an environmental perspective, crowdshipping can promote the sustainability of deliveries when the trip is performed using cleaner vehicles and by a nondedicated nature of the trip (Aziz et al., 2022; Buldeo Rai et al., 2017; Lozzi et al., 2022; Nascimento et al., 2023). The solution presented here focusses on e-mobility and nondedicated trips, thus contributing to a more sustainable last-mile (Gatta et al., 2021, 2019b; Patella et al., 2021; Qi et al., 2017; Simoni et al., 2020). Furthermore, most of Brazil's electricity comes from renewable hydroelectric sources, making all this even greener. Additionally, the use of e-micromobility vehicles for parcel deliveries contributes to reduce the number of freight trucks circulating, which, in turn, also abates congestion related to e-commerce (Castiglione et al., 2022; Gatta et al., 2019a; Oliveira et al., 2022; Serafini et al., 2018).

## 6 Conclusions

The integration of cargo and passengers can be considered a promising solution for last-mile distribution and asset sharing (vehicles, network, and facilities). This is even more true for the last-mile distribution of parcels when combined with a crowdshipping service. Despite increasing works investigating crowdshipping (Pourrahmani and Jaller, 2021), to the best of our knowledge, no research discusses the potential benefits of using a MaaS platform for the freight service integrated with passenger transport. This article fills this research gap, first by describing the operation of a MaaS4PaF platform operated by GoMoov in Joinville, Brazil, and subsequently by analysing its parcel delivery operations. Using demand data, the article identifies the best microhub location considering a network of 10 facilities. It also shows that the system envisaged allows for increasing delivery efficiency and promoting crowdshipping service viability by solving a p-median problem. The network covers most of Joinville (that is, 98.96% residents and 98.99% dwellings). The company must expand the current network in 4 additional parking zones: since 4 facilities are located at bus stops, the other 6 microhubs are already in parking zones.

To achieve a successful integration between freight and people within a MaaS platform, the participation of stakeholders is crucial. Smooth system operation requires well-structured information sharing to ensure high system productivity. The authors are aware that further work is needed to develop a solid business model that should consider all the stakeholders involved to define deeply an adequate information, money, and value flow. Furthermore, it is necessary to identify key performance indicators to measure and monitor MaaS4FaP performance and equity.

This study presents some limitations that warrant careful consideration, particularly with respect to the timing and consistency of data comparisons. Although the choice of the study area is well justified and the rationale for the selected timeframe is clear, the inherent variations across pre and post-pandemic periods introduce some complexities that require further investigation in the future. Data collection was carried out during the COVID-19 pandemic when the crowdshipping pilot programme was still in its infancy, probably influencing consumer behaviour and logistics operations. With post-pandemic shifts in habits and the wider adoption of crowdshipping solutions in Joinville by 2024, the landscape may have evolved beyond the conditions this study has captured.

Furthermore, while the use of microhubs and instant delivery was proposed as a potential enhancement, these data were unavailable when the analysis was performed. Future research endeavours, ideally incorporating longitudinal datasets that span post-pandemic periods, could address these limitations. Access to such data would enable more precise classifications of typical versus atypical behaviour, facilitating standardised period comparisons, allowing the isolation of crowdshipping impact on last-mile deliveries KPIs. This study emphasises the need for future research in this area to provide a more comprehensive understanding of the role of crowdshipping in an evolving logistics landscape.

## 6.1 Future research

A marketing strategy could prove crucial in attracting crowdshippers and establishments to use the MaaS4PaF application and the e-shared micromobility network. From an economic perspective, MaaS4PaF stimulates the use of micromobility and public transportation system, thus promoting its overall financial viability. However, some business challenges must be addressed and overcome, as well as technological ones. The data-sharing versus data-confidentiality issue bears strong implications in the vertical and horizontal integration between stakeholders, making it a hard-to-fulfil task, especially when striving for a financially viable business model. The case study described and analysed in this paper can contribute to improving urban mobility and economic development.

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### Highlights

- Mobility as a service platform for freight and passenger transport (MaaS4PaF) can promote sustainable cities
- Few studies have analysed real data from real case studies or pilots for MaaS4PaF
- The GoMoov platform is innovative since the application jointly offers: micromobility renting service for people, micromobility renting for cargo delivery, bidding platform for crowdshipping service negotiations
- GoMoov can be considered a MaaS4PaF application.
- A network composed by 10 microhubs cover the urban area of Joinville to provide crowdshipping service using MaaS4PaF