

Specifics of material handling for last mile delivery

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The article analyses the limiting factors for material handling for last mile delivery based on the mode of transport. Material handling during last-mile deliveries has its own specifics, which can fundamentally influence the selection of suitable handling equipment, handling units, means of transport and technology. This is mainly manual handling, which often takes place in limited spatial conditions and with various traffic restrictions, such as entrance restrictions or pedestrian zones. These factors can be particularly limiting for vans, which are used most often for last-mile delivery. Cargo bikes are a suitable alternative, but they are not yet very widespread in the Czech Republic.

Using the example of the city of Pardubice, the critical places for this manipulation will be defined using the GIS system and the possibilities of using vans and cargo bikes will be compared.

KEY WORDS: *last mile delivery; cargo bikes, delivery vans*

1. Introduction

Last-mile delivery, the final leg of the supply chain where goods are transported from a distribution center to the end consumer, is a critical aspect of logistics operations [7]. In recent years, the focus on last-mile delivery has expanded beyond just speed and cost efficiency to include environmental and social sustainability factors, particularly in urban areas [2]. The environmental impact of last-mile delivery, especially in terms of greenhouse gas emissions, has become a significant concern [17]. With the rise of e-commerce and the increasing demand for quick deliveries, finding ways to optimize last-mile delivery has become a key area of research and innovation [9].

Efficiency in last-mile delivery is crucial for various sectors, including healthcare, where timely and efficient delivery of medical supplies can be a matter of life and death [11]. Factors such as achieving routing efficiency, meeting fulfillment timelines, and the types of goods being delivered have been identified as key influencers of last-mile delivery projects, particularly during challenging times like the Covid-19 pandemic [16]. Additionally, the adoption of new technologies like self-driving delivery robots and drones has been explored to overcome challenges such as traffic congestion and parking limitations in urban areas [5].

In the context of sustainability, the use of drones for last-mile delivery has been studied to reduce the negative impact of traditional delivery methods on urban development [12]. Innovations in last-mile logistics, such as smart scheduling and shared delivery services, have been proposed to optimize the design and control of first and last-mile delivery solutions [3]. Furthermore, the integration of predictive analytics, technology, and sustainable practices has been highlighted to enhance last-mile delivery operations [4]. The use of drones for parcel delivery encounters several legislative and technical obstacles. From this perspective, it is more advantageous to consider another method of delivery, for example, using cargo bicycles.

Customer preferences and behaviours also play a significant role in shaping last-mile delivery strategies. Studies have shown that providing information on the environmental and social sustainability impact of delivery options can influence e-commerce customers to choose more sustainable last-mile delivery services [8]. Moreover, offering a variety of delivery options that provide a consistent shopping experience across different channels and devices has been identified as a growth driver in the retail sector [9].

In the realm of urban logistics, addressing capacity constraints and optimizing delivery operations are essential for ensuring the smooth flow of goods in densely populated areas [13]. Leveraging new mobility-assist technologies and vehicle routing optimization can help maximize the efficiency of last-mile delivery networks [10]. Additionally, exploring crowd models and dynamic strategies can further enhance the efficiency of last-mile delivery services, especially in emerging economies [1,18].

The last-mile delivery is a complex and multifaceted aspect of logistics that requires a holistic approach to address various challenges and opportunities. By considering factors such as sustainability, efficiency, customer preferences, and technological innovations, stakeholders in the supply chain can work towards optimizing last-mile delivery operations and meeting the evolving demands of modern commerce.

Cargo bicycles have gained popularity as a sustainable and efficient mode of transportation for parcel delivery in urban areas. Cargo bicycles are environmentally friendly as they produce zero emissions during operation, unlike traditional delivery vehicles that run on fossil fuels. This can help reduce air pollution and combat climate change.

2. Definition of limiting factors for material handling for last mile delivery by cargo bicycles

The limiting factors for material handling for last mile delivery by cargo bicycles relate to various aspects including security, technical constraints, legislation, and others. These factors were identified according to practise and literature review. Here are some of them:

- Parcel characteristics (dimensions, weight, number of parcels for one delivery box)
- Elevation profile of city,
- Suitability of city infrastructure,
- Economic demandingness,
- Safety and security.

A significant limiting factor for parcel delivery is their size and weight. Compliance with this restriction is already checked when the shipment is accepted for transport. Therefore, there will be no situation where the shipment will not fit dimensionally into the means of transport by which it is to be delivered.

Manual handling is the most common method of handling for last mile delivery. The maximum weight of the parcel in this case may also be regulated by labour and legal regulations. Couriers delivering by vans have the option of using simple manual handling devices, such as hand trucks. Shipments for delivery by cargo bikes have more limitations than those for vans regarding cargo space size and manual handling. However, from this point of view, a cargo bike can be a suitable means of delivery for parcel boxes, which have a limited capacity and size of parcels. There are currently also cargo bikes available on the market with the possibility of dividing the cargo space, where the shipments can be effectively spread out to simplify handling during loading and unloading (Fig. 1).



Fig. 1 Cargo bikes with the possibility of dividing a cargo space: a – four-wheeler; b – two-wheeler.

The elevation profile of a city refers to the variation in altitude across different points in that city. This profile can significantly influence the use of cargo bicycles for last-mile delivery. Here are some ways how:

- **Physical Effort:** In cities with a lot of hills or steep terrain, it can be physically demanding to pedal a cargo bike, especially when it's loaded with goods or parcels. This can limit the use of cargo bikes in such areas.
- **Speed and Efficiency:** The speed at which deliveries can be made using cargo bikes can be affected by the city's elevation profile. In hilly areas, the speed of delivery might be slower due to the uphill climbs.
- **Range:** The range of a cargo bike, especially electric-assist ones, can be reduced in cities with a lot of uphill routes. This is because more energy is used to climb hills, which can drain the battery faster.
- **Infrastructure:** Cities with a flat elevation profile are more likely to have infrastructure that supports cycling, such as bike lanes and bike parking. In contrast, hilly cities may have less of this infrastructure, making it more challenging to use cargo bikes.

Despite these challenges, the use of cargo bikes for delivery processes has a positive environmental impact: it leads to the reduction of pollutants, noise, and vibrations caused by traditional vehicles; decreases traffic jams; causes more effective use of public space; and others. Therefore, it's important to consider these factors and find solutions that can make cargo bikes a viable option for last-mile delivery in cities with varying elevation profiles. For instance, using electric-assist cargo bikes can help overcome some of the challenges associated with hilly terrains.

The suitability of city infrastructure for cargo bike delivery is influenced by a combination of physical infrastructure, urban planning, and policy support. Each city will have its own unique challenges and opportunities in this regard, and a tailored approach is often needed to maximize the potential of cargo bikes for last-mile delivery. A well-maintained network of bike lanes and paths is crucial for the safe and efficient operation of cargo bikes. This includes regular maintenance to ensure the paths are clear of obstacles and hazards. Changes in traffic management, traffic calming, and other regulations can make a city more suitable for cargo bike delivery. For example, creating low-traffic neighbourhoods or implementing traffic calming measures can make streets safer for cargo bikes. The layout and design of the city can also influence the suitability of cargo bike delivery. Cities with compact, dense urban cores are

typically more suitable for cargo bike delivery as distances are shorter and cargo bikes can often navigate these areas more quickly and efficiently than motor vehicles. Government policies and initiatives that support the use of cargo bikes can also enhance their suitability for last-mile delivery. This can include subsidies for cargo bike purchases, the establishment of cargo bike rental systems, and the promotion of cargo bikes as a sustainable and efficient mode of transport.

When deciding which mode of transport is suitable for the delivery of last-mile parcels, it is necessary to consider the costs associated with it. Operating and maintaining cargo bicycles is generally more cost-effective than using motorized vehicles. They require minimal fuel and maintenance costs, leading to potential savings for delivery companies. Purchase price is also lower in comparison to truck.

Another cost in favor of cargo bikes can be entry fees to certain urban areas, typically historic city centers. These charges do not apply to cargo bikes, so delivery costs will be lower. In addition, not all delivery boxes can be legally reached by truck.

There are also some additional factors which can influence the use of cargo bicycles within cities for parcel delivery:

- **Limited Cargo Capacity:** Cargo bicycles have limited carrying capacity compared to traditional delivery trucks, which may be a challenge when transporting large or heavy parcels. This limitation can impact the efficiency of delivery operations.
- **Infrastructure Constraints:** Cities may lack adequate infrastructure to support the widespread use of cargo bicycles for parcel delivery. Issues such as limited bike lanes, lack of secure parking facilities, and restricted access to certain areas can hinder their deployment.
- **Weather Dependence:** Cargo bicycles are more susceptible to weather conditions, such as rain or snow, which can affect delivery schedules and the safety of delivery personnel. Adverse weather may also impact the condition of parcels being transported.
- **Perceptions and Regulations:** There may be perceptions among the public and regulatory barriers that limit the acceptance and integration of cargo bicycles into existing delivery systems. Concerns about safety, reliability, and compliance with traffic regulations need to be addressed.
- **Environmental Sustainability:** Cargo bicycles are environmentally friendly as they produce zero emissions during operation, unlike traditional delivery vehicles that run on fossil fuels. This can help reduce air pollution and combat climate change.

3. A model example for the city of Pardubice

In the model example, we focused on evaluating the availability of parcel boxes, which have become very popular in recent years and represent one of the typical delivery methods for last mile delivery. More than 10 delivery companies and e-shops currently operate parcel boxes in the Czech Republic. It is quite a large number considering the size of the market and it is possible to assume a larger scale of box sharing for more companies in the future. [14,15]

The city of Pardubice lies in a lowland. According to [6], the total area was 82.6 km² and the population was 92,362 in 2023. The current road system in Pardubice, which carries a large part of transit traffic through the city, causes problems in traffic. During peak times, congestion often occurs in the city center. A north-eastern bypass is currently under construction, which should partially ease the traffic load in the center.

The city is very suitable for the use of bicycle transport due to its flat terrain, a relatively extensive network of cycle paths and excellent time availability of the main destinations. However, not all cycle paths are suitable for the use of cargo bikes. In the case of parcel delivery by cargo bikes, it is therefore necessary to consider that the routes will be partly conducted on roads in normal traffic.

3.1. Definition of the problem and objectives

In the city of Pardubice, parcel boxes are operated by both large international courier companies and companies operating only on the Czech market. Currently, none of the parcel box operators in Pardubice use cargo bikes for delivery. Parcel boxes are in practically all parts of the city, including nearby municipalities. When placing the boxes, it is necessary to consider transport accessibility for both customers and service providers. For the customer, the box should be easily accessible on foot, preferably within walking distance from home, but also by other modes of transport (bicycle, car). So, there should be parking nearby. For the carrier, the box must be available according to the means of transport he uses. If the parcel box is not directly accessible by car, the delivery person must stop at a convenient location nearby and move the parcels manually. It therefore means longer time required for handling during loading/unloading. Other factors are also considered for parcel box location, such as suitable land and the rental price. The location is therefore always a compromise, and it is not always possible to drive directly to the parcel box.

Our goal was to analyse the transport accessibility of existing parcel boxes in the Pardubice area from the point of view of:

- Parking options nearby.
- Possibilities to stop and park the vehicle directly at the box - e.g., area size, entry restrictions.

Based on this analysis, it is then possible to select locations that would be suitable for service using cargo bikes.

3.2. Evaluation of the availability of boxes regarding the method of delivery and handling

We mapped the availability of 50 parcel boxes located in all urban districts of the city of Pardubice and three neighbouring municipalities. We used the GIS software on OpenStreetMaps for data processing. Of the total number of boxes, 41 are easily accessible by car, 9 are not directly accessible by car, but by cargo bike (see Fig. 2). Four off these nine boxes are right in the city center and the other 5 are within driving distance of about 10 minutes from the city center by bike. If a cargo bike were used for delivery, it would be possible to service other boxes located nearby with these boxes.

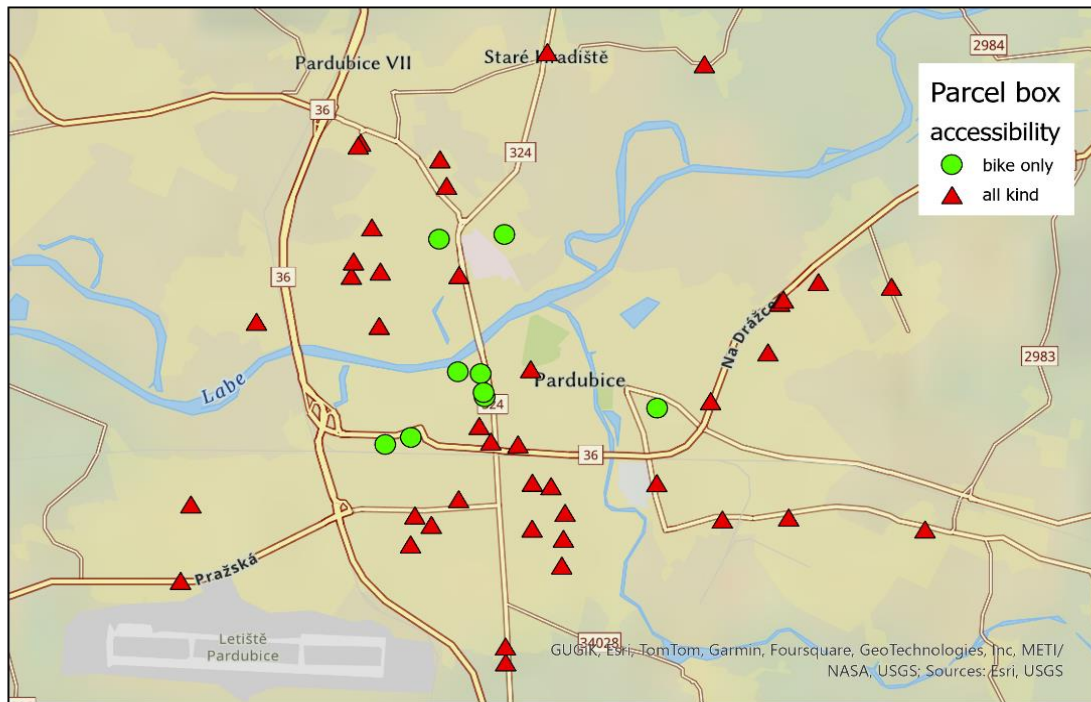


Fig. 2 Transport availability of parcel boxes in Pardubice

Replacing part of the deliveries with cargo bikes would be most easily feasible for large courier companies that already have experience in operating cargo bikes in other cities.

Here are the main aspects resulting from this solution.

Strengths and opportunities:

- existing cycling infrastructure in the city centre, largely usable for cargo bikes as well
- the location of the boxes in the center and within driving distance for a bicycle within approx. 10 minutes even during rush hour,
- reduction of the scope of handling operations during loading/unloading
- benefit to the environment,
- for companies, the possibility of positive promotion in relation to the environment.

Weaknesses and threats:

- the need to purchase cargo bikes and create facilities for their operation,
- the need to establish a micro-depot in the city center,
- risk of economic disadvantage of operation.

4. Conclusions

Cargo bicycles offer a sustainable and efficient solution for parcel delivery in urban areas, with numerous benefits including environmental sustainability, cost-effectiveness, and last-mile delivery efficiency. Delivering parcels to parcel boxes significantly reduces the length of delivery routes and can thus contribute to reducing transport emissions. If cargo bikes are used for delivery, this benefit can be even more significant.

While challenges such as limited cargo capacity, infrastructure constraints, and weather dependence exist, potential solutions like technology integration, stakeholder collaboration, pilot programs, and regulatory support can help overcome these barriers and promote the widespread adoption of cargo bicycles in the delivery industry. Further research and practical implementations are needed to fully realize the potential of cargo bicycles for parcel delivery.

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