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Sustainable Parcel Delivery in Urban Areas with Micro Depots

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Abstract:

Due to the growing trend in urbanization, city logistics becomes of paramount importance to provide the inhabitants of cities with vital goods. Targets of city logistics are the relief of the strain on the transport infrastructure and the reduction of mostly direct emissions such as nitric oxide. The German CEP industry (courier, express and parcel) plays a major role in supplying cities with necessary goods. However, it also has negative impacts on the quality of living in urban areas such as exhaust and greenhouse gas emissions and blocked roads. To dampen these negative effects, the CEP service provider UPS (United Parcel Service) uses micro depots as a more sustainable alternative for parcel delivery.

JEL Classification: O18, Q56, R41

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1 Introduction

Due to a growing trend in urbanization, more people live in cities today than ever before. According to the United Nations, the urban population amounted to 54 % in 2014 and is expected to grow to two thirds by 2050 (UN 2014). Furthermore, there is a trend towards mega-cities defined as cities with a large number of inhabitants, usually a population of more than 5, 8 or 10 million inhabitants (Gebhardt et al. 2014: p. 879–881).

For logistical companies, there are several challenges connected to the supply of densely populated urban areas. On the one hand, access to inner cities is constrained, as delivery vehicles compete with passenger cars for the same space leading to traffic jams, accidents and emissions. This is fueled by a growing delivery volume, smaller single deliveries, more just-in-time deliveries as well as inefficiencies along the delivery process. City officials often react by imposing stricter access regulations exacerbating the delivery situation. On the other hand, cities grow not only on population, but also in surface size leading to longer transportation times (BVL 2014: p. 36–29; Deutsche Post DHL 2010: p. 97). All this leads to lower service quality, lower delivery reliability and higher delivery cost, while simultaneously lowering the quality of living in the city (Deutsche Post DHL 2010: p. 97–98).

The CEP industry (courier, express and parcel) plays a major role in supplying cities with necessary goods. However, it also contributes to the negative impacts on the quality of living in urban areas. One way to counter these impacts is the use of micro depots for parcel delivery.

2 The German CEP Industry

CEP is an acronym for the three services the CEP industry usually provides: namely courier, express and parcel deliveries. Courier deliveries are usually same-day deliveries, express deliveries are usually shipped over-night, and parcel deliveries have no binding delivery date, but the arrival of parcels can be usually predicted to a day. Parcel shipments are also subject to weight and size restrictions (BIEK 2018: p. 9; Gleißner & Femerling 2012: p. 102).

The German CEP industry delivered 3.35 billion shipments in 2017 – an increase of 6.1 % in comparison to 2016. After the financial crisis of 2008/09, the industry has grown continuously, and since 2000 the volume of parcels has approximately doubled. One driver of this growth is the ongoing success of e-commerce companies relying on CEP service providers for the delivery of ordered goods. 83.7 % of the deliveries in 2017 were parcels, the rest were courier or express deliveries (BIEK 2018: p. 11–12).

Although the CEP industry also has a main leg of transport between hubs, the focus is often on the delivery of parcels from the local depot. This is a classical last-mile problem of logistics activities. The last-mile delivery to the final recipient is usually done by a small delivery truck. The daily route of a truck is called a loop. Within a loop, several smaller segments of the route – called units – can be distinguished. While roughly a loop determines the daily delivery area of a delivery vehicle, a unit determines the presorting of the parcels in the truck. Delivery trucks are still largely based on diesel technology. Electric vehicles can only be used sensibly, if the distance between local depot and the area of the loop is within a certain limited distance.

3 City Logistics

Although there is no uniform definition of the term "city logistics" in the scientific literature, a few areas of focus can be exposed. On the one hand, a wide definition of city logistics given by Taniguchi et al. (2001: p. 2–3) defines city logistics as "the process for totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, traffic congestion and energy savings within the framework of a market economy". This definition is not without problems due to the term "totally optimizing" and leaves us with no clear focus of activities. On the other hand, a narrow definition of city logistics only includes the use of urban consolidation centers (UCCs) at the edge of town to consolidate the flow of goods into the city (Jahns & Schüffler 2008: p. 222; Piontek 2009: p. 86–87; Schulte 2009: p. 205). To this narrow definition, the use of telematics and informatics (Zsifkovits 2013: p. 201) and the use of environment-friendly vehicles (Crainic et al. 2009: p. 2) can be added. From this definition, it becomes obvious that the focus of city logistics is on transport management in urban areas.

We define city logistics as the improvement of the supply of urban areas with goods (incl. return logistics), especially by using existing public infrastructure. The term "supply" limits the topic to delivery processes with transport management and the associated storage of goods. The use of existing public infrastructure separates the topic of city logistics from the topic of city planning. The measures of city logistics mainly make use of the following mechanisms (Deckert 2015: p. 34–35; Deckert 2017: p. 63–64; see fig. 1):

- **Consolidation of transports and matching of the flows of goods:** Typical measures are the freight consolidation in urban consolidation centers (UCCs) at the edge of town and the use of intelligent transport systems (ITS) to optimize transport routes, and to track and trace deliveries.
- **Separation in Space and Time:** Measures for separation in space include separate transport lanes as well as air or underground transport. Deliveries

outside of the rush hour (e.g. nighttime deliveries) and PUDO (pickup and drop-off) solutions are examples of measures for separation in time.

- **Use of Environment-friendly Means of Transport:** Typical measures include the application of environment-friendly delivery vehicles such as electric vehicles or the use of existing passenger infrastructure for freight transport, e.g. subway or tram.

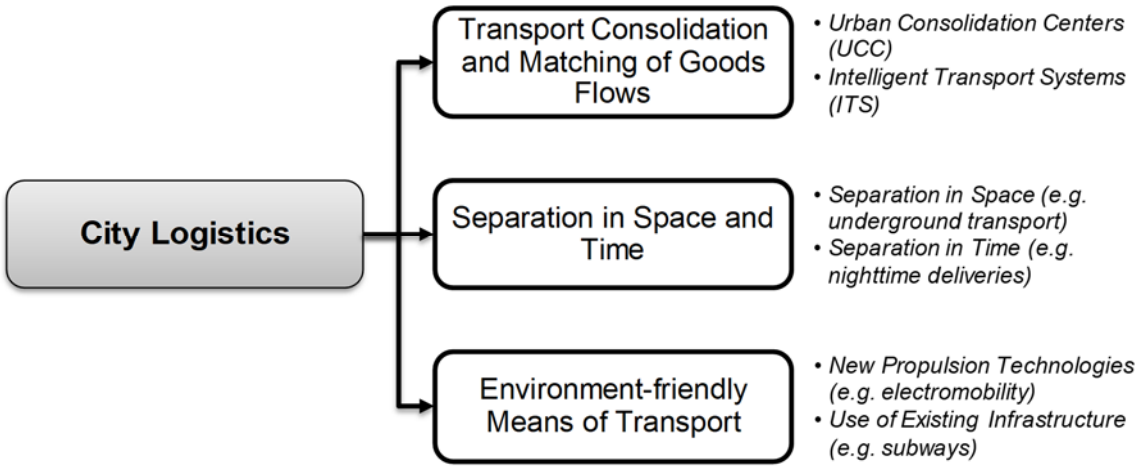

Figure 1: Mechanisms of city logistics (Deckert 2017: p. 64)

According to Crainic et al. (2009: p.1) the main target of city logistics is the reduction of the "nuisances associated to freight transportation in urban areas while supporting their economic and social development". In more detail, the targets of city logistics can be divided into the relief of the strain on the transport infrastructure to reduce traffic congestion and accidents and the reduction of noise and emissions such as greenhouse gases and exhaust fumes.

The measures of city logistics have different impacts on the targets (see fig. 2). The consolidation of freight leads to fewer transports and, thus, fewer delivery vehicles in the city. This reduces emissions and traffic congestion, but noise level per vehicle remains unchanged. By contrast, environment-friendly means of transport reduce the emissions per vehicle. Propulsion technologies such as electric engines also reduce the noise level. If smaller vehicles are used, e.g. cargo bikes, there is also a positive effect on traffic congestion. Separation in space and time mainly address traffic congestion and accidents, as transports do not compete with passenger traffic anymore. Since the separation in space often requires new means of transport such as drones or electric underground caps, it may also positively affect the other targets of city logistics.

Targets / Measures	Greenhouse Gas Emissions	Local Exhaust Emissions	Noise	Traffic Jams and Accidents
Consolidation	X	X		X
Separation (Space)	(X)	(X)	(X)	X
Separation (Time)				X
Means of Transport	X	X	X	(X)

Figure 2: Measures and targets of city logistics

4 The Concept of Micro Depots

A micro depot is an interim storage in the city, which can be either stationary or mobile. Usually it is realized as a container temporarily positioned near the center of gravity of the respective delivery area. Technically, the micro depot divides the last mile of transport into two steps: a second-last mile and a very last mile (see fig. 3). On the second-last mile, the container filled with parcels is transported by truck from the depot of the CEP service provider to the location of the micro depot and – in case of a stationary depot – parked there for the duration of the delivery process. On the very last mile, the individual parcels are taken from the micro depot and delivered to the final recipients e.g. by cargo bike. In case of a mobile micro depot, the container is moved after every loop to meet the cargo bike and refill it.

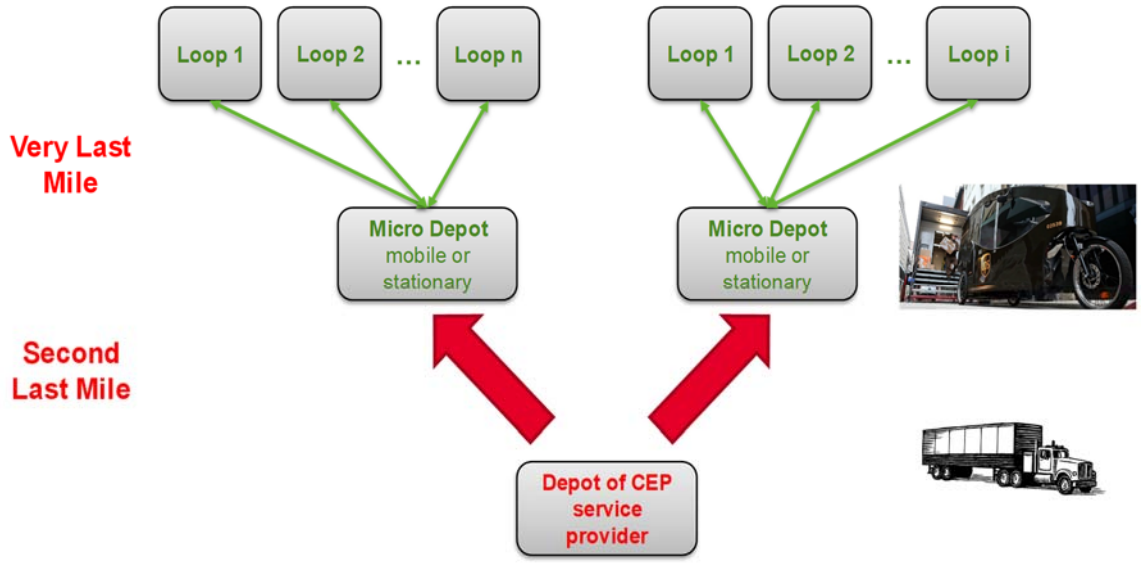

Figure 3: Concept of micro depots

From a logistical perspective, the micro depot is a combination of two mechanisms of city logistics: consolidation of transport volumes and use of environment-friendly means of transport. On the second-last mile, the volumes are bundled for a full truckload delivery to the micro depot. The delivery on the very last mile can then be performed with the use of environment-friendly means of transport (cargo bikes, electric cargo bikes or walkers).

The suitability of different propulsion technologies for transport depends on the length of the transport route and the transport volume. Currently electric vehicles are suitable only for local transport. For longer routes, other propulsion technologies are better suited, e.g. electric engine with range extender or classical combustion engine (Kampker et al. 2015: p. 298–299). E-cargo bikes have a lower range and a significantly lower transport volume than delivery trucks. For this reason, micro depots are particularly suited for the use of e-bikes, as a survey of the German association for CEP service providers has found out (BIEK 2017: p. 63–64).

By combining the two mechanisms of consolidation and means of transport the concept of micro depots is expected to simultaneously relieve urban infrastructure and reduce emission (see fig. 2). Electric bikes have no local emissions, neither greenhouse nor – more importantly for the air quality in cities – exhaust emissions such as nitric oxides or particulate matter. The only local emissions come from the truck to position the container. Furthermore, electric bikes generate less noise than trucks and do not block streets as much as delivery trucks do.

5 Micro Depots at UPS

The concept of micro depots in addition with bike deliveries has been practiced by UPS since 2012. At first, the concept was introduced in a project in Hamburg. As of now, it has become an elementary means of transport in several cities in Germany (see fig.4).

UPS, founded 1907 in Seattle, Washington as *The Messenger Company*, has more than 110 years of experience in logistics and transportation, and operates worldwide in more than 220 countries or territories today. Its history is one of embracing change. Especially whenever new technologies arose or external and internal challenges came up, the company adjusted so that today it is a technology-driven company. The use of technology is a core element to operate its global logistics network, to handle more than 20 million packages an average day, with a fleet of 119,000 UPS vehicles, including approximately 9,300 alternative fuel and advanced technology vehicles – the so-called rolling laboratory. UPS invests $1 billion annually in technology to enhance efficiency and improve customer service. One example is the proprietary UPS tool ORION (On-road Integrated Optimization and Navi-

gation). The advanced algorithms create optimal routes for delivery drivers from the data supplied by customers. Drivers and the vehicles can alter the routes immediately e.g. in case a road is blocked or a customer requires a different service. The Network Planning Tool (NPT) mentioned above, based on real-time data, optimizes the flow of packages in the UPS network from loading docks to sorting to the final destination.

City	Start	Micro depots	E-bike	Conventional bike	Walker	EV
Hamburg	2012 (Extension 2016)	5	●	●	●	●
Offenbach	2016	1	●			
Herne	2016	1		●		●
Oldenburg	2016			●		
Munich	2017	4	●	●	●	
Frankfurt	2017	1	●	●		●
Stuttgart	2017	1			●	●
Düsseldorf	Since 2012					●

Figure 4: Micro depots at UPS (excerpt)

The company started its deliveries with bikes a century ago and today in some cities this mode of transport is revived. Nowadays, the use of state-of-the-art technology combined with the concept of micro depots and bike deliveries leads to completely new opportunities for sustainable parcel delivery.

The concept of micro depots and the search for alternative means of transport in general has to be seen under the umbrella of Corporate Social Responsibility (CSR). In general, CSR is divided into three areas: economy, ecology, and social (Elkington 1999). CSR has been practiced by UPS at least since 1951 and had its strength in the social component, when James E. Casey founded the UPS Foundation. Meanwhile, the ecological component has become equally important within the sustainability strategy.

The ecological strategy of UPS is based on three pillars: avoid, reduce, and compensate (Stodick 2015). If possible, the company tries to avoid negative ecological impacts on the environment. The most ecological mile is the one which was not driven by a conventional UPS truck. Since this is not always feasible, the driven miles should be kept as low as possible. Therefore, the mentioned tools (ORION, NPT) to plan the most efficient routes come into action. Another way to reduce emissions is to use alternative means of transport such as electric or hybrid vehicles

or in certain areas conventional or e-supported bikes including micro depots. So far in many cases and because of a lack of availability of alternative means of transport, companies have to rely on conventional diesel trucks. One way to compensate CO_2 emissions is to take part in reforestation or other similar programs to compensate emissions (UPS 2017).

As a result, the concept of micro depots including bikes or walkers has a strong impact on the sustainability strategy (= avoidance). UPS operates this concept in several cities in Germany and has established a network of micro depots which vary in size and form (stationary/mobile). However, the largest bike operations with the most positive and measurable impact are based in Munich (20 bikes, four micro depots) and Hamburg (13 bikes, four walkers, five micro depots).

5.1 Micro Depots in Hamburg

Based on an initiative of the city of Hamburg, UPS started with a mobile micro depot pilot in 2012. This was after several discussions with the administration, and other stakeholders, especially the commercial initiative Hamburg Business Improvement District (BID), which represents the businesses in the inner city. The aim was to reduce traffic and emissions, respectively. UPS developed this micro depot solution with bikes, presented it to the city and was asked to implement it. It started with one depot, and four UPSers who used two e-bikes, a conventional bike and a handcart. With this, UPS was able to replace up to two conventional package cars of their class (7.49t trucks/28m³). Soon it became obvious, that the setting was scalable and the project became a concept. Already in 2015, the company extended the idea in agreement with the city and has now five micro depots in place replacing up to nine conventional package cars. Now 15 helpers using seven e-bikes, four conventional bikes and four handcarts deliver parcels in Hamburg. In addition to this, UPS operates an electric truck fleet (7.49t) – 21 trucks in total – and delivers to the rest of the inner city, which is not served by the micro depot system, with 13 converted e-trucks. The only diesel truck still in use is the one which brings the mobile depots into the city.

In terms of emission, UPS was able to reduce the driven kilometers and therefore the usage of diesel fuel. In 2016, the micro depot solution saved about 78,000 km over the year which means 14,000 l/diesel fuel and avoided 37t CO_2 emissions. The e-vehicles drove 111,192 km in the same period and saved 20,015 l/diesel fuel which reduced the emissions by another 52.84 t CO_2 (UPS calculations). The engagement of UPS was awarded in 2016 with the Hanse Globe for its concept and its scalability.

5.2 Micro Depots in Munich

UPS is partner of the City2Share project in Munich which is funded by the German ministry of environment. Based on the experience UPS gathered in Hamburg, the company was asked to take part in this project which started in 2016. After some calculations and finding appropriate spaces for mobile depots, UPS launched its part of the project with three e-bikes, three conventional bikes and two mobile depots. Within 14 months this kind of operation was extended to 20 bikes and four micro depots.

In comparison to Hamburg, the delivery structure in these areas varies a little bit. In Munich, we have a mixture of residential area and business area with small to medium sized enterprises. In Hamburg, the largest amount of deliveries is so called Business to Business (B2B) volume. The Munich approach of City2Share includes different stakeholders. The residential situation affects the policy-making structure, and the affected residents are involved in the processes. Another difference between these two city concepts is the use of e-vehicles (7.49t). Because of the narrow streets and due to the high contamination of the air, it makes much more sense to reduce car traffic and implement bikes instead of an exchange of diesel to e-vehicles. It is the goal to reduce traffic in general and micro-congestion situations specifically. Because of the fact that UPS in this case operates in a residential area, the company decided to design its containers together with a design school to adapt it better to the residential environment. Through the switch to micro depots and bikes, UPS saved approximately 30,000 l diesel fuel within 12 months and reduced emissions by approximately 120t CO_2. The approval rate for the UPS approach from this stakeholder group is close to 100 %.

6 Conclusion

Micro depots are a viable sustainable solution for the parcel delivery of urban areas leading to a reduction of local exhaust emissions and greenhouse gas emissions as well as a relief of the local traffic situation. The measured results show that a significant amount of greenhouse gas emissions can be saved in comparison to delivery trucks based on diesel engines. In a pilot project of micro depots in Nuremberg, Bogdanski and colleagues calculated a relative annual reduction of greenhouse gas emissions of 23 % and an annual reduction of particulate matter and nitric oxide by 25 % (Bogdanski, Bayer & Seidenkranz 2018: p. 101–123). Reductions, however, may vary due to the specific circumstances of the delivery situation (e.g. size of area, density of deliveries), the delivery vehicles used (e.g. e-bikes or conventional bikes) and the location of the micro depot (e.g. more or less close to the center of gravity of the area).

As the examples show, the concept is particularly suitable for densely populated areas. It is a concept for downtown rather than for suburbia. This finding is in line with the findings of the sustainability survey of BIEK, the German association of CEP service providers (BIEK 2017: p. 65–66). The insight leads to the conclusion that for some urban areas a combination of different solutions is required, e.g. micro depots and e-cargo bikes for the inner city and electric vehicles for the outer city, as shown in the example of Hamburg.

The main disadvantage of the concept is the temporary storage of containers in the city. Containers take up valuable space that could be used for other activities, e.g. parking of passenger cars. Furthermore, a container can disturb the visual appearance of the cityscape. This means that city officials and citizens of the city need to be involved in the decision process. It also means that the container needs to be either located at a spot where it is hidden from view or integrated into the cityscape to ensure the acceptance of the solution, as the example of Munich shows.

A challenge is the accurate measurement of achieved effects. The reduction of greenhouse gas emissions can be calculated by using the DIN EN 16258, and the reduction of exhaust emissions can be estimated by using default figures. It is harder, however, to determine the reduction of noise or strain on infrastructure. Furthermore, a better comparison of different delivery situations – e.g. in areas of high/low density of population – is needed to establish more accurately where micro depots are a viable solution and where other solutions might achieve better results.

Further optimization of the process can be achieved by switching from stationary to mobile micro depots. To establish the size of the effect, the use of mobile micro depots should be carefully analyzed and compared to the use of stationary micro depots. The interface between micro depot and delivery provides further opportunities for optimization. The presorting of parcels can reduce the time to refill the delivery vehicle at the micro depot. For this, it is necessary to develop suitable e-bikes, boxes for the presorting process and devices to load the boxes. With these further research and optimization activities, the concept of micro depots should find its way into the standard toolbox of the logistics expert.

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