Development and Test of a Low Emission Urban Delivery System

Stephan Seeck, professor,
HTW Berlin, Berlin

Robert Teschendorf, research associate,
HTW Berlin, Berlin

Eric Breitbarth, research associate,
4flow AG, Berlin

Maximilian Engelhardt, research associate,
HTW Berlin, Berlin

Birte Malzahn, professor,
HTW Berlin, Berlin

Markus Husemann, research associate,
BHT Berlin, Berlin

Wendelin Groß, research lead,
4flow AG, Berlin

Extended Abstract

Summary. This paper presents the results of a Berlin research project in which a low emission urban delivery system was designed and tested in collaboration with different urban logistics stakeholders. First, the paper shows the developed concept that includes a macro-hub and corresponding micro-hubs, while the vehicle fleet consists of electric cargo bikes as well as an electric van. Second, the key results of the corresponding 6-month field trial are discussed. Parcels have been delivered to B2B recipients. To investigate the feasibility, the ecological and the economic impact of the developed concept, transport data was constantly collected during the field trial. Based on the data, average costs and emissions per parcel were calculated and compared to a conventional delivery system. Furthermore, managerial implications were derived. Finally, the limitations of the study and further research are summarized.

Keywords. urban B2B deliveries, last mile, field trial

1. Motivation

Urban logistics can be described "as the means over which freight distribution can take place in urban areas as well as the strategies that can improve its overall efficiency while mitigating congestion and environmental externalities" (Rodrigue 2020). A functioning urban logistics is essential and indispensable for life in urban areas. Each and every good to be be consumed in urban areas has to be supplied by urban logistics systems. At the same time, traffic through urban logistics systems, i.e. urban freight traffic, is one of the biggest polluters in urban areas. Additionally, the war in Ukraine led to increasing costs and shortages for fossil fuels, in particular for diesel. In order to make supply chains, and thus also urban supply chains, more resilient to global risks and potential critical dependencies, companies are looking for alternative and ecologically sustainable ways to transform their urban supply chain fleets. As a basic prerequisite of alternative delivery systems, the reliable supply of urban areas has to be ensured. Electric vans and electric cargo bikes are two possibilities to become independent of fossil fuels. In times of shortages due to geopolitical insecurities and in the face of a global climate crisis, alternative and sustainable approaches of delivering urban areas have to be invented and implemented. Many past and ongoing projects consider the decarbonisation of the last mile, i.e. the delivery of consignments to end customers. The presented urban delivery system also includes the pre-last mile to unlock the full potential of decarbonisation of urban freight traffic.

The aim of the paper is to present the results of the Berlin-based research project WAS-PAST (Warenverkehr in Städten – Pakete und Stückgut), in which a low emission urban delivery system was designed and tested in collaboration with different urban logistics stakeholders. First, the developed low emission urban delivery system (Teschendorf et al. 2022) is outlined. Second, the key results of the 6-month field trial are presented and discussed.

2. Field study: Low Emission Urban Delivery System in Berlin

The presented concept and the corresponding field trial focused on the urban center of Berlin. Based on a comprehensive stakeholder requirements analysis, a 2-step distribution concept with one macro hub and two micro hubs (see figure 1) was devised for the field study. Only goods flows running from the outskirts of Berlin into the city center were considered, flows of goods beyond the outskirts were not within the project scope. Berlin-Westhafen was chosen as a macro hub due to its multimodal access (road, rail, river) as well as the availability of sufficient handling and storage facilities. The two other selected micro hubs were at Tempelhofer Damm and Alexanderplatz. The location of the three hubs and their coverage of the urban area is shown in figure 2. The isochrones show the accessibility of inhabitants within 5, 10 and 15 minutes by bike from the corresponding hub.

Due to contractual challenges, it was not possible to take the micro hub at Alexanderplatz into operations during the field trial. Deliveries from the macro hub Westhafen started July 18th, 2022. The micro hub at Berlin Tempelhofer Damm started operations on October 4th, 2022.

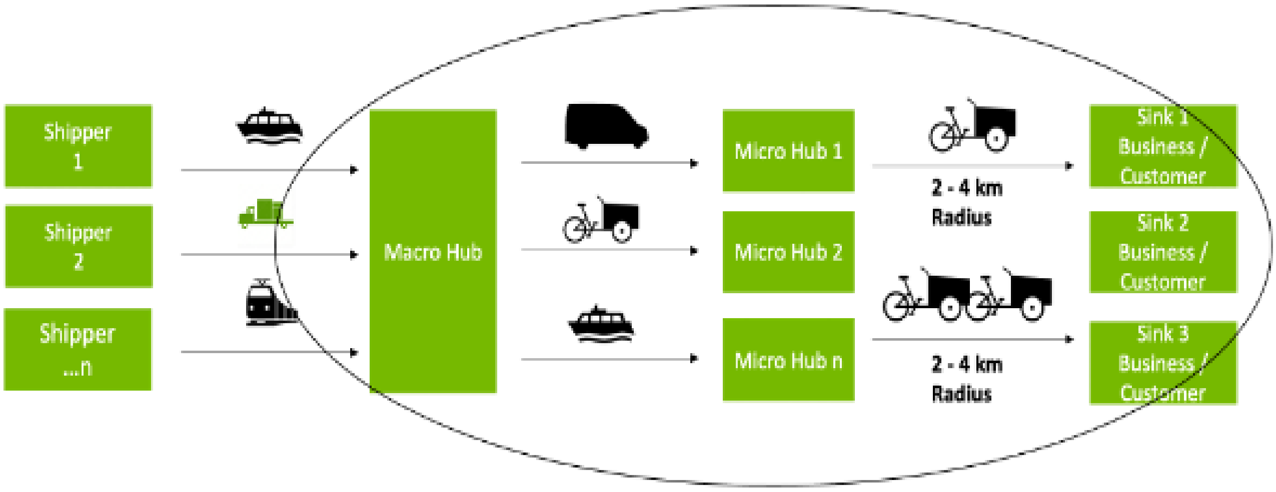

Figure 1. Structure of the multi-stage low emission urban delivery system

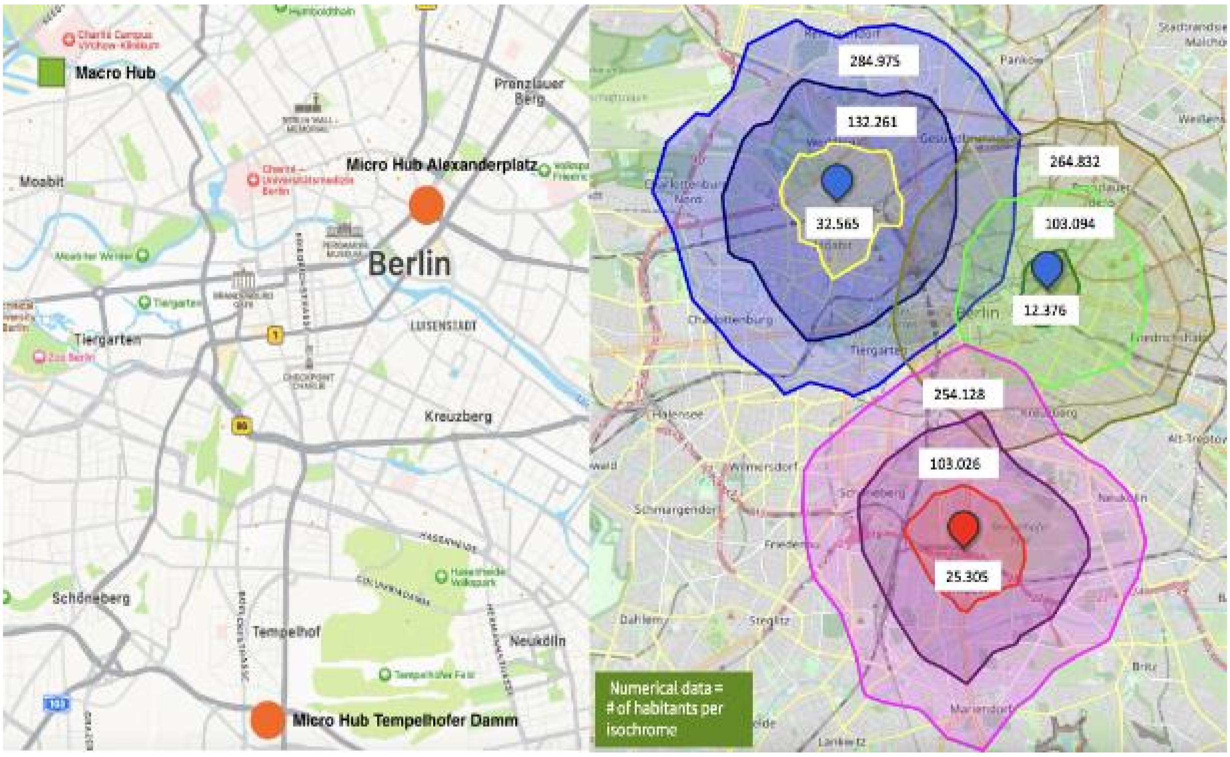

Figure 2. Location of micro hubs in Berlin and presentation of the isochrones of each hub

The field trial ended as planned on December 21st. The field trial had one special characteristic: The customers provided real shipment data. On this data basis the fleet and parcels were planned and operated. But instead of real goods, parcels with similar dimensions and weight containing stones and sand were transported. The reason for this procedure was that the customers could not change their complex operational logistics processes for the duration of the field trial. But they were eager to participate in the field trial due to their willingness to adjust their urban delivery systems towards sustainability. The solution allowed the customers to try out an alternative sustainable delivery structure without having to change their real world complex logistics processes, i.e. in a very low-risk way. The following conditions applied for the field:

Shipments were 100 percent B2B deliveries with primary destinations being shopping centers and retail outlets. Parcels were either very bulky, 60 × 40 × 40 cm and medium heavy, approx. 7 kg (had to be carried individually), or very small and light, approx. 1 kg. The delivery was always at ground level and all recipients could be accessed immediately. Delivery points repeated quickly.

3. Results and discussion

The key objectives of the field study were to examine if low emission urban delivery systems are able to prove economic advantages or at least economic equivalence and if they are able to reduce the environmental impact of urban deliveries.

3.1. Logistics performance indicators

A key performance indicator of a logistic system is its delivery reliability. In discussion with stakeholders it was stated that at least 95 percent delivery reliability must be reached in order to consider the system as reliable. During the field trial, 98.96 percent of all consignments were delivered in time.

Another important logistics indicator is the average time per stop. It includes the driving time as well as the pure stop time. The average time per stop is 15.38 min. This number indicates that the stop density was not quite high. On the one hand, it was easier to meet the timeframe to deliver consignments in time. On the other hand, a higher stop density could improve the productivity. Additionally, an analysis of the impact of driver skills on the average time per stop was conducted. Results show that time and cost savings of up to 30 percent are possible if every driver were to drive as quickly and reliably as the best driver in the field trial.

3.2. Economic performance indicators

Beside the logistical efficiency of the system, the economic performance is equally important. Therefore, the costs per parcel were calculated. The costs per parcel consists of two main elements, the pure delivery costs and the general expenses of the system. The direct delivery costs were calculated as follows:

$$direct\ delivery\ costs = time\ needed * minimum\ wage * additional\ cost\ factor \tag{1}$$

The time needed also includes the loading and unloading time at the beginning and end of each shift. 12 € per hour is the minimum wage in Germany. For a reasonable calculation the wage was multiplied by 1.25 to include the employers’ additional costs. The general expenses include the following costs: Energy costs, vehicle costs, software costs, equipment costs, rental costs (hubs), staff costs. The costs were modeled with an admin employee working 4 hours per day and receiving 20 € per hour. Employers’ costs were also considered.

The average direct delivery costs per parcel were 2,49 €, the general expenses 13,05 € per parcel. So the average costs per parcel were 15,54 €. The costs varied a lot over the 6 month period: The highest rate was 29,02 € in October 2022, whereas the minimum costs per parcel were 6,02 € in November 2022. The difference can be explained by the volume of parcels: In October the parcel volume was 124 parcels, whereas in November 611 parcels were delivered. An increasing package volume leads to a significant reduction in total cost share per parcel.

Analysis shows that in case 800 parcels were delivered by the system without any changes to the infrastructure, the total price per parcel could decrease to 4,90 € per parcel.

3.3. Environmental impact

To evaluate the environmental impact of the developed logistic system, a comparison with a traditional parcel delivery structure for last- and pre-last mile was conducted. Exemplary delivery days of a B2B CEP carrier were modeled, consisting of a parcel distribution center in the south of Berlin (trans-o-flex, Ludwigsfelde), delivery recipients from the field study and 50 random additional recipients in the modeled delivery area around the micro-hub locations. Using a 4flow vehicle routing algorithm, for all scenarios, optimal delivery routes were calculated in the traditional delivery concept (parcel DC to customers), a micro-hub delivery (parcel DC to micro-hubs to customers) and a macro-micro-hub delivery concept (parcel DC to macro-hub to micro-hubs to customers). The emission calculation was based on the advised "Method D: Equal allocation based on the number of stops" of DIN EN 17837. Typical emission factors for diesel vans, e-vans and e-bikes were used.

The results show a high dependence on the number of recipients consolidated in the micro-hubs and the locations of used hubs: E.g., a macro-hub at Tempelhofer Damm is environmentally more beneficial than a macro-hub at Westhafen due to shorter distance to the parcel distribution center. Figure 3 shows possible emission savings per day for the customers of the developed urban delivery concept resulting of the use of low-emission transport modes (e-van or e-bike). Minimum (2 parcels), average (x parcels) and maximum (y parcels) refer to the parcel quantity per day during the field trial.

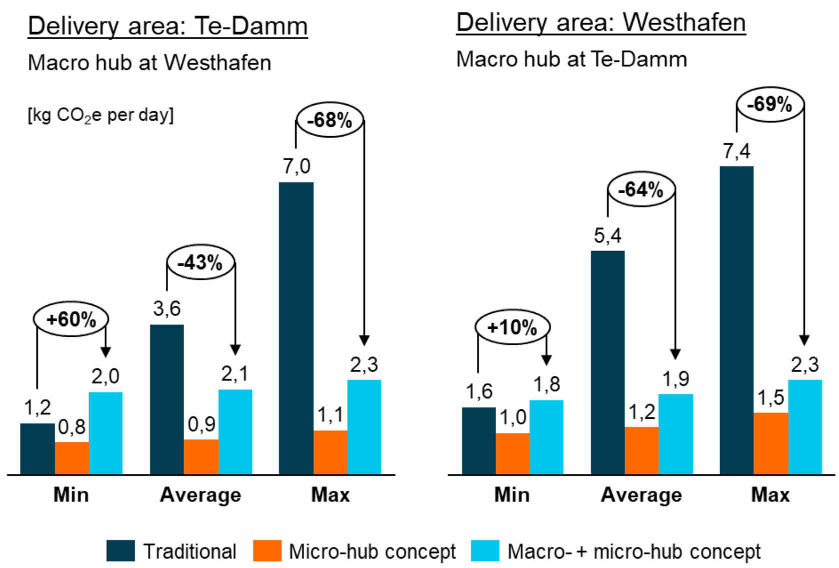

Figure 3. Emission impacts for two locations and different parcel quantities

Only with the minimum parcel quantity per day, a negative impact can be observed comparing the traditional delivery system to the macro-micro-hub concept. For average days, 43 to 64 percent of CO2e emissions of last- and pre-last mile can be saved. The more parcels are delivered, the higher the potential CO2e emissions savings compared to the traditional delivery system. The figure also shows an advantage of the micro-hub concept compared to the micro-macro hub concept regarding CO2e emission reductions. The reason of this effect is that the origin of the goods was located near to the second micro hub at Tempelhofer Damm. Due to this, a transport first to the farer located macro hub and then “back to” the micro hub increased the driven distance and the emissions. This effect would not be observed when operating more origins of the goods and/or more micro-hubs delivered consolidated from the macro-hub. To achieve even more environmental benefits, a higher quantity of parcels, e.g. consolidating full traditional delivery route(s), or more and optimized hub locations would be promising action fields.

4. Conclusion

The key objectives of this project were to ensure urban B2B deliveries while reducing the environmental impact and proving economic feasibility. It can be stated that the low emission delivery system worked reliably. The project goal of proving economic feasibility cannot be considered as fully reached. The average costs per parcel are relatively high in comparison to todays’ last mile costs. However, if the parcel quantity can be increased, the costs per parcel could be decreased below 5 € per parcel, which would make the low emission system competitive. The goal of proving a reduction of CO2e emissions of the alternative delivery concept has been achieved. The higher parcel volume, the higher the possible CO2e savings.

Overall, the project showed under real world conditions that low emission urban delivery systems could meet the requirements for sustainable, reliable and (partially) economic urban deliveries. In particular, by conducting a field study, the delivery system was tested to many practical challenges that cannot be uncovered by simulations and calculations. Examples for practical challenges are heavy weather conditions like snow and ice, damages, accidents, driver shortages, working schedule problems and so on. These practical experiences combined with collected data and scientific evaluated results are valuable for practitioners. Further research could investigate the use of innovative urban transport solutions like small autonomous boats or (semi-)automatic trailers of cargo bikes as alternatives to electric vehicles within the proposed system.

References

DIN EN 17837:2022. *Postal Services - Parcel Delivery Environmental Footprint - Methodology for calculation and declaration of GHG emissions and air pollutants of parcel logistics delivery services*.

Rodrigue, J.-P. 2020. *The Geography of Transport Systems*. 5th edition ed. [online] New York: Routledge. Available at: https://transportgeography.org/contents/applications/ch6a2en/, accessed on 23 April 2023.

Teschendorf, R., M. Engelhardt, B. Malzahn, M. Husemann, C. Butz, and S. Seeck. 2022. “Sustainable urban logistics concepts: a collaborative design approach considering stakeholder perspectives.” In *Hamburg International Conference of Logistics (HICL)* 33: 798-822. https://doi.org/10.15480/882.4698.

This paper could be cited as:

Seeck, Stephan, Robert Teschendorf, Eric Breitbarth, Maximilian Engelhardt, Birte Malzahn, Markus Husemann, and Wendelin Groß. 2023. “Development and Test of a Low Emission Urban Delivery System.” In *2023 International Scientific Symposium on Logistics: Conference Volume*, ed. by Thorsten Schmidt, Kai Furmans, Bernd Hellingrath, René de Koster, Anne Lange, and Hartmut Zadek, 139–145. Bremen: Bundesvereinigung Logistik. https://nbn-resolving.org/urn:nbn:de:bsz:14-qucosa2-855542 https://doi.org/10.25366/2023.133