Capacity Dynamics of Automated Parcel Lockers as a Last-Mile Delivery Scheme

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Abstract

More than half of the world's population live in urban areas, with the density increasing. Cities require goods and related logistics services, which fact has economic, environmental, and social implications. The usage of automated parcel locker (APL) systems is one of the most promising initiatives to improve urban logistics activities. Some studies confirm that online shoppers will use APLs more frequently in the future. We propose a novel model that considers the APL capacities combining the mobile APLs or increasing the capacity with different modular units to managing the demand dynamics to better use of resources. The aim is to determine the optimal APL configuration network with maximum e-customers demand covering without losing efficiency.

Keyworks: Last-Mile Logistics, Automated Parcel Lockers, Urban Logistics.

Last-mile logistics (LML) are often characterized as the most expensive and complicated part of the supply chain, featuring negative impacts on pollution and congestion in densely populated areas (Gonzalez-Feliu, 2017). The arrival of e-commerce has accentuated the number of individual home deliveries, increasing the LML flows. Investigating how to improve the efficiency of LML in urban areas is a significant driver for the success of e-commerce, and contributes to alleviating the negative externalities of urban logistics (UL) derived from it. The usage of automated parcel locker (APL) systems is one of the most promising initiatives to improve UL activities (Boudoin, Morel, & Gardat, 2013). The APL has electronic locks with variable opening codes and can be used by different consumers, whenever it is convenient for them. Some studies confirm that online shoppers will use APLs more frequently in the future (Moroz & Polkowski, 2016). APLs can be found around the world. Boudoin et al. (2013) and Zurel, et al. (2018) presented a general overview of different experiences.

Verlinde et al. (2018) remark that an APL has multiple benefits in comparison to home deliveries as less traffic in city centers, no double parking in front of customers' homes, and reduction of failed home deliveries, which gains time, fewer kilometers, stops, and off-hour deliveries, as well as a cost reduction for e-retailers and delivery operators. Environmental benefits are less pollutant emissions and less noise because of the possible reduction of delivery vehicles in the city. Social benefits are expected as an improved quality of life. The e-customers are free to choose the delivery time (24/7 availability) and select the most convenient APL location to pick up or send their parcels. Moreover, the APL could be a focal point for the local community. However, the APL has some disadvantages as low ease of use, depending on the company software interface and the payment flexibility possibilities. Also, storage feasibilities are limited and the APL is sensitive to crime or vandalism (Vakulenko, Hellström, & Hjort, 2018).

The APL locations are fundamental aspects for understanding the APL solution's potential impacts before the implementation. Moreover, the logistics organizations behind APL management, mainly in cases where parcel lockers are mobile or modular, can lead to a planning situation where the demand (and the following planning objectives and steps) need to take into account the cities and consumption dynamics. According to scientific literature, planning and optimization approaches are either purely static or consider traffic dynamics (mainly by discretizing them into a set of categories of traffic). However, managing the demand dynamics and the interactions between stakeholders in planning and optimization can lead to better use of resources and then to a more resilient and reactive configuration, without losing efficiency. To the best of our knowledge, no works deal with integrated dynamic planning methods. Thus, it can be interesting to show the advantages and interests of that dynamic planning. Guerrero and Díaz-Ramírez (2017) state that the APL strategy has not been discussed in the scientific literature, but observed in practice. These studies did not look at the APL installation costs, as well as the required capacity for seasonal e-commerce peaks. However, one of the most critical expectations of APL users is the close location from home or the way to work, and the availability of parking spaces (Iwan, Kijewska, & Lemke, 2016).

The aim of this research is threefold. First, we propose an organizational model that considers the APL capacities combining the mobile APLs or increasing the capacity with different modular units to managing the demand dynamics to better use of resources. This conceptual model is developed from the existing organizational schemes of current APL networks and the technological and organizational innovations being in progress. Second, we define the planning and optimization problem related to the tactical deployment of such networks. The aim of those plans is to determine the optimal APL configuration network with maximum e-customers demand covering without losing efficiency. The optimization problem is then completed by an operations management solving methods that can then be a decision-making tool for APL adoption as a last-mile delivery scheme, reducing the risk of failures in their implementations. Third, the research aims to assess both the organizational

model and the optimization framework on a realistic simulation. To do that, a data-driven scenario generation and assessment method is proposed, starting from a current situation (that of the biggest APL management company in Germany). The research has led to the deployment of a mixed simulation-optimization method that takes into account system dynamics and main planning and management objectives for last-mile distribution and is able to assess plans for a pluri-month period (i.e. of tactical nature). Results show however that the uncertainty of demand need further analysis, for example, and for further developments, the introduction of probabilistic/random demand generation. Furthermore, the organizational model could be applied in any city around the world, especially in cities in emerging markets, considering the APL schemes' few applications in these kinds of markets, and the numerical tools (optimization framework and scenario generator) are of standard nature and can be applied to any context if data standards are respected..

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