Computer Science Lab, of Systems Modeling and Optimization (LIMOS) – Axe Decision-support tools for Production and Services (ODPS)

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Title of PhD subject: Sustainable Last-Mile Delivery with Crowdshipping

Summary :

Last-Mile Delivery (LMD) is currently recognized as one of the most critical and expensive stages of the supply chain. According to the Statista Digital Market Outlook, e-commerce is expected to grow at an annual rate of 6.29% between 2025 and 2030. The rapid expansion of e-commerce contributes to substantial increases in traffic congestion and pollution in urban centers.

Crowdshipping has become a widely used solution for delivering packages purchased online. However, relying on Occasional Couriers (OCs) may generate negative environmental impacts when they enroll in a platform and make extra trips, in a business model similar to Uber. Crowdshipping can be modeled as a sustainable approach to address this issue, engaging OCs to deliver packages along their already planned trips. By reducing reliance on professional fleets, the LMD with Crowdshipping (LMDC) model can potentially lower operational costs and environmental impacts.

This research area is relatively recent. The problem was initially formulated by Archetti *et al.* (2016) as a Vehicle Routing Problem with OCs. In their formulation, several simplifying assumptions were adopted. The problem was treated deterministically, meaning that all OCs were assumed to accept any assigned delivery tasks, and a fixed compensation rate was applied. However, the stochastic nature of delivery acceptance significantly influences the solution.

Based on this, Gdowska *et al.* (2018) incorporated the probability that OCs would accept a delivery into the problem, given a predefined compensation. However, their study used a fixed compensation fee per OC. Barbosa *et al.* (2023) modeled the OC acceptance probability as a compensation function. The authors generated a dataset from interviews, recording whether deliveries were accepted or rejected and collecting associated data such as detour length, package weight, and compensation offered. Nevertheless, their proposed logistic regression model still defined the acceptance probability exclusively as a compensation function, thereby neglecting the influence of other important factors.

The LMDC variants studied in the literature generally adopt a one-day planning horizon and do not consider predefined delivery time windows. In real applications, however, time windows are a fundamental characteristic, significantly increasing the problem's complexity. Moreover, published works have mainly focused on minimizing total cost. For example, Cebeci *et al.* (2025) proposed a framework in which deliveries that incur a high additional cost on professional vehicle routes are matched with OC trips. In such models, a delivery is assigned to an OC if and only if it reduces the total cost. However, minimizing cost does not necessarily lead to maximizing OCs participation, which is often desirable for environmental reasons.

In this thesis, we propose modeling a new variant of the problem under realistic conditions, including delivery time windows and stochastic acceptance probabilities that depend on multiple factors, such as compensation level, package weight, and travel distance, among others. Furthermore, the problem will be addressed not only from an economic perspective but also from a sustainability perspective, leading to the definition of the Sustainable LMDC (S-LMDC). The aim is to minimize the total travel distance, ensuring that the total transportation and compensation costs for OCs remain below the upper bound set by a solution that relies exclusively on the professional fleet. The objective is to model a problem and propose resolution methods, as metaheuristics and matheuristics, that can be easily adapted to real cases, such as supermarket chains and takeaway restaurants.

References

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