

Parcel container capacity sizing optimisation for smaller-than-van logistics in last-mile delivery

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1 Introduction

Many companies employ containers to encapsulate parcels for last-mile delivery with smaller-than-van vehicles to reduce their physical heterogeneity, allowing containers to move through automated logistics infrastructures; see Figures 1a and 1b for an example of the parcel containers used at *La Poste*, the French postal service. The capacity of these parcel containers varies greatly from one company to another, thus raising the question about what the optimal parcel container capacity is.

In smaller-than-van logistics, parcels are first moved to *satellites* closer to end customers by trucks or vans, then assigned to smaller-than-van vehicles before being delivered. The cost of this modal shift is difficult to estimate, as a significant amount of labour and time is required to shift modes. Parcel containers represent a promising way to reduce the time required to perform the modal shift, and, although the benefits and drawbacks of containerisation have been extensively studied in maritime transport [4, 5], the use of parcel containers in urban smaller-than-van logistics remains underexplored.



(a) Parcel container.



(b) Parcel containers in a cargo bike.

FIG. 1: Parcel containers at *La Poste*, the French postal service.

For last-mile logistics, companies often employ *territory design approaches* to partition the served area into *districts* [2]. These approaches facilitate sorting parcels at the city distribution center, since not all parcels may be known when sorting begins. Under the territory design, knowing a parcel's destination suffices to determine the vehicle that will deliver it, since a vehicle delivers only the parcels of a single district. These approaches also foster familiarity between end customers and couriers, which is correlated with higher customer satisfaction [3].

We examine the use of parcel containers to improve smaller-than-van logistics efficiency in a territory design-based approach, focusing on determining container capacity and territory design for optimal operation. Using parcel containers in territory design-based approaches

implies certain operational constraints. For instance, logistics-service providers (LSPs) often desire that all parcels of a parcel container be delivered before considering parcels of another parcel container, and each parcel container carries only parcels of relatively close end customers. Because of these requirements, container capacity becomes a critical design decision: if capacity is too small, parcels of close end customers may be split across multiple containers, yielding suboptimal routing, whereas if capacity is too large, containers may carry substantial unused capacity.

Our study represents a first step towards a design of smaller-than-van logistics using parcel containers and the evaluation of its operational costs.

2 Our approach

We study the strategic problem of designing parcel containers for last-mile delivery using smaller-than-van vehicles. We are given as input a set of parcels, each associated with a destination and a delivery date, and a partition of the service area in geographical units named *basic units* from an LSP's historical data. This problem, which we refer to as the *Container Capacity Sizing* problem, involves determining an optimal capacity for the parcel containers and computing a territory design where districts are formed of basic units such that the long-run total distance travelled by the smaller-than-van vehicles is minimised.

Numerically, the territory design approach simplifies the computation of delivery routes: closed-form equations based on the shape of districts and parcel demand densities are used to approximate the total delivery distance required [1]. The actual delivery routes within each district are determined by the courier's local knowledge of the delivery area.

We extend the continuous approximation equations of [1] to estimate the length of a smaller-than-van vehicle tour when considering LSPs's operational constraints. Using these equations across a range of parcel container capacities, we compute the resulting operational costs and derive insights on the optimal parcel container capacity over a territory design provided by an LSP's historical data.

We also formulate the container capacity sizing problem as a integer linear program (ILP), and use an ILP solver to obtain solutions to the problem. From this, we derive further insights on the optimal parcel container capacity but also on the associated optimal territory design.

We evaluate our approach using instances derived from a French LSP's historical data for the cities of Paris, Bordeaux, and Toulouse.

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