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The City Logistics Facility Location Problem

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1 Introduction

City logistics has raised the interest of many researchers from different communities and countries in the last decade [1, 2]. The subject of this paper is the location of logistics platforms in the context of fast parcel delivery in urban areas.

A strong tendency that could be observed in most urban areas during last decades was to limit the presence of the logistics platforms within the city. Several simple reasons can explain this phenomenon. Inhabitants do not appreciate living around these platforms that might cause increases of traffic (and specially traffic of large vehicles), generate noise and pollution, or have some unpleasant visual impact. Also, available surfaces in cities are rare and expensive. From a pure economical point of view, carriers used to prefer less expensive locations, at some distance of the city, though the inconveniences of being distant from final customers. Also, local authorities gave priority to more noble activities for these available surfaces: commercial centers, apartments, public services as libraries or concert halls...

Due to many recent factors, the benefits of this policy, both for local authorities and carriers (and eventually inhabitants), can be questioned. Environmental issues become more and more important. New purchase channels as e-business modify profiles of carrier customers and imply different organizations and services. Disposing of urban platforms can then offer several possibilities as using electric vehicles (whose limited autonomy prevents from traveling long distances) or scheduling several successive deliveries or collection routes (which is not tractable with distant platforms).

Because of the special context of city logistics, usual location models cannot be used to determine optimal location of city distributon platforms. While some works started addressing the subject [3, 2, 4, 5], the literature still lacks from general models on this topic [6, 7].

The aim of this work is to propose a new model that we call the City Logistics Facility Location Problem (CLFLP). Our purpose when introducing the CLFLP, is to capture

essential aspects of distribution in cities, while maintaining a reasonable level of genericity and simplicity in the defintion of the problem. Practically, this model was adapted to the case of the city of Marseilles (France) and inserted into a Decision Support System. With a more academic point of view, the model could serve as a cornerstone for the development of new models and methods for strategic issues in city logistics.

2 The City Logistics Facility Location Problem

The City Logistics Facility Location Problem mainly addresses solutions for two stakeholders in city logistics: (i) carriers which want to optimize the location of their logistics platforms and the organization of their distribution scheme, (ii) local authorities which want to evaluate the relevance of available zones for the setting up of distribution platforms or compare different scenarios of distribution in the city.

The model involves a set D of spatially distributed delivery zones which represent the city, a set L of available surfaces for distribution platforms and a set V of existing vehicle types to transport goods: (i) from the logistics platforms to the delivery zones, (ii) within the delivery zones through routes.

Delivery zones represent districts in the city. The principle of aggregating the demand of final customers into districts replicates the actual organization of carriers. Indeed, as distribution in cities is a highly dynamic problem, considering desaggregate demand of customers at a strategic level is not possible. Also, the lack of automatic sorting systems in platforms generally imposes to define simple and permanent rules to gather customers together.

Each delivery zone $d \in D$ is characterized with a demand γ_d and a length δ_d which represents the length of the delivery route within d.

Two extreme possibilities exist in the literature to model transportation here. Either zones are simply assigned to platforms and transportation is simplified to back and forth travels between the platforms and the zones, or a location-routing modeling is involved so as to better evaluate impacts of transportation.

In our context, a location-routing approach is not satisfactory for at least two reasons. First, in practice, vehicle routes are limited to a very restricted number of zones (usually 1 or 2); secondly, the important part when evaluating the impacts of transportation concerns the initial and final portions between the platforms and the zones, and the distribution within the zones: travels between successive zones are generally very short and also very difficult to evaluate (remember that precise location of customers is not known).

We propose a compromise modeling by defining two types of zones: *single-vehicle* zones ($D_S \subseteq D$) and *multi-vehicle* zones ($D_M \subseteq D$).

For each *multi-vehicle* zone $d \in D_M$, parcels can be supplied by more than one vehicle

but cannot be consolidated with parcels of other zones. Each vehicle that delivers parcels in a *multi-vehicle* zone thus follows a simple route that goes from a platform, serves the zone and come back to the platform. It corresponds to the simplified modeling evoked above. However, as vehicles are explicitly considered in the model, amount of delivery are limited by vehicle capacity constraints, thus potentially implying the use of several vehicles.

For each *single-vehicle* zone $d \in D_S$, parcels have to be delivered by a single vehicle. Such *single-vehicle* zones are typically zones with a limited demand. In a same delivery route, a vehicle can deliver parcels in several *single-vehicle* zones. Travel distances between zones are not considered. In order to avoid including distant zones in a route, a set $\Delta_d \subseteq D_S$ of *compatible* zones is assigned to each *single-vehicle* zone $d \in D_S$. Each route has then to be composed exclusively of zones compatible one to another. We then evaluate transportation costs as follows: the transportation cost of a route depends on the nearest zone served (indicating the cost of entering and leaving the city from a distant platform) and the set of delivery zones (indicating the distances traveled during the deliveries). Constraints are introduced, through the use of the compatibility between zones, to avoid including distant zones in a same delivery route.

Each available surface $l \in L$ for logistics platforms has a capacity q_l (measured in number of doors which can be built). Each door of l can ensure the distribution of given amount of parcels per day. The total cost of selecting l is composed of a fixed cost plus a variable cost proportional to the number of doors opened.

Vehicles of type v have a capacity β_v and a distance-autonomy α_v^{dist}. Their driving time per day is limited to α_v^{time} (specific technical characteristics, workload limit...). They are furthermore limited to travel on a subset $J_v \subseteq D$ of delivery zones (because of the legislation, the width of the streets...). The travel times involved in our model depend on the vehicle types. The total cost of using a vehicle of type v is composed of a fixed cost plus a variable cost proportional to traveled distance.

3 Mathematical modeling and experiments

We proposed two different integer programming formulations for the CLFLP. Roughly speaking, the difference between these two formulations is that the first formulation explicetly introduces flow variables for each vehicle and considers the assignment of zones to vehicles independantly. In the second formulation, the set of all feasible combinations of compatible zones is introduced and items from this set are selected and assigned to vehicle types (vehicles are not explicitely considered).

In order to evaluate these models, a set of instances was introduced, based on realistic data from the city of Marseilles. Results demonstrate the superiority of the second model

unless compability between zones is very high (which is not relevant in practice). Real-size instances for a city of the size of Marseilles can be solved in a few seconds. Optimal solutions cannot always be obtained in a reasonable time for larger instances. Perspectives are the development of ad hoc heuristic methods or more efficient mathematical programming models. Practically, several contacts have been esatablished with carriers and cities to implement the model.

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