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Simulation of Mutualized Urban Logistics Systems with Real-Time Management

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Abstract

This work aims at proposing a new organization of urban merchandize distribution based on mutualized and optimized resources. In this context, our contribution is twofold. On one hand, we develop a set of models to manage merchandize distribution. We develop a new reservation system that enables customers to request a merchandize transportation service (delivery and collect) or to book a vehicle for self-service purposes. Requests are processed by two main decision modules (1) an online module that immediately searches for a feasible solution for a request, and decides to accept or reject it, and (2) an offline module that looks for optimized solutions starting from the feasible schedule defined by the online module. On the other hand, we develop a new discrete event simulator, called MODUMS which integrates the proposed models, implements such a logistic system and evaluates its economic and environmental impact. MODUMS takes as inputs realistic information about the transportation means, geographic data and demand information requests that are generated according to some probability distributions. It gives as outputs indicators on the impact of mutualization on the quality of urban logistics in terms of, for example, number of delayed or rejected requests, filling rate of vehicles, total distance and quantity of CO2.

Keywords: Urban Logistics; Real-Time Management; Freight Distribution; Simulation; Optimization

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1. Introduction

This work is done in the context of MODUM (Mutualization and Optimization of Urban Freights Distribution) project, supported by the French National Research Agency (ANR). This project aims at proposing a new organization of urban merchandize distribution based on mutualized and optimized resources. The major challenges of MODUM consist in pooling resources (e.g. deposits and vehicles), avoiding empty return vehicles and prohibiting large tonnage entering downtown.

Firms in direct competition built their supply chains in an independent, redundant and compartmentalized way (Chanut and Paché, 2011). This non-optimal use of resources at collective level and the multiplication of waste due a redundancy of physical means are the main motivations behind the establishment of new solutions for urban logistics. According to Gonzalez-Feliu et al. (2014) which shares the vision of Ambrosini and Routhier (2004) and Anderson et al. (2005), urban logistics can be seen as the pluridisciplinary field that aims to understand, study and analyze the different organizations, logistics schemes, stakeholders and planning actions related to the improvement of the different goods transport systems in an urban zone and link them in a synergic way to decrease the main nuisances related to it. Resource pooling appears as a good alternative for the mastering of logistics that become a source of competitive advantage (Christopher, 2011; Chanut and Paché, 2011).

In this context, we propose a mutualized logistic architecture composed of a set of urban distribution centers (UDCs) connected by a ring around a city, and a set of parkings and customers inside the city. In order to ensure rapid and optimized displacement of massive flows in the ring, we propose to use a dedicated fleet for shuttles (trains, large trucks...) in order to carry goods between UDCs. With a view to sustainable development, we use clean (i.e. ecological) vehicles of limited size and tonnage to ensure intra-urban deliveries (i.e. within the city).

It is common opinion that a system based on UDC can be the right solution for pollution and congestion problems related to urban good distribution. Implemented system has given contrasting results. In the last years, researchers studied such a delivery system to better understand the causes of failure and the reasons of success (Crainic et al., 2004; Quak and de Koster, 2009; van Roijen and Quak, 2010).

In this context, our contribution is twofold. On one hand, we develop a set of models and mechanisms to manage merchandize distribution. We develop a new reservation system that enables customers to request a merchandize transportation service. Two types of requests are considered: delivery and collection requests. The former requires transporting goods from a UDC to a customer, the latter from a customer to a UDC. Delivery requests are defined by the quantity to deliver, its availability date at a specified UDC, the customer to which the merchandize is directed and a time windows during which service needs to take place. Analogous definition characterizes collection requests, where the availability date is replaced by a limit date to depose merchandize at the UDC. A third class of requests allows sharing empty clean vehicles with users who can book them for self-service purposes. Request addressed to the reservation system do not necessarily ask for service during the current day. Requests are processed by two main decision modules (1) an online module that immediately processes arriving requests by searching for a feasible insertion in the current planning, and decides to accept or reject them, and (2) an offline module that operates when the reservation system is closed. It looks for optimized solutions starting from the feasible schedule defined by the online module. A self-service request is directly either accepted or rejected by the system. Differently, if a delivery/collect request is rejected for the given associated (availability or limit) date, it is reinserted in the online module for its posteriori processing with new associated dates. The online process is executed all the day as long as the reservation system is open. When a request is accepted, it is inserted in the feasible schedule and the planning of the allocated vehicle is updated. Based on the feasible schedule defined for the next days, the offline module computes the operational planning in an offline manner by proposing optimized feasible solutions.

On the other hand, we propose and develop a new discrete event simulator, called MODUMS (MODUM Simulator) which integrates the proposed models, implements such a logistic system and evaluates its economic and environmental impact. MODUMS takes as inputs realistic information about the transportation means, geographic data and demand information with the tuned probability distributions of requests. Transportation means data concerns clean and shuttle vehicles and gives information on their: number, capacity, initial positions, frequency of shuttles, capacity of shuttle vehicles and their speed. Geographic information represents the elements that compose the logistic network including their positions, distances and capacities (for example, positions of the UDCs, ring, customers and parkings). Demand information defines requests that are generated according to some probability