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## Enabling Carrier Collaboration via Order Sharing Double Auction: A Singapore Urban Logistics Perspective

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### Abstract

A recent exploratory study on the collaborative urban logistics in Singapore suggests that cost reduction and privacy preservation are two main drivers that would motivate the participation of carriers in consolidating their last mile deliveries. With Singapore's mild restrictions on the vehicle types or the time windows for the last-mile delivery, we believe that with proper technology in place, an Urban Consolidation Center like the Tenjin Joint Distribution System in Fukuoka Japan may be implemented to achieve cost reduction with some degree of privacy preservation. Participating carriers keep their respective private orders and have the option to get their remaining shareable orders consolidated with those from the other carriers' fleet. To this end, we propose in this paper a double auction mechanism that enables such consolidation with an objective to maximize the total cost savings attained by all participating carriers. Our experimental results on 5 zones of delivery in Singapore CBD demonstrate that the proposed double auction is able to bring about reductions in the number of inter-zone travels, thereby producing cost savings to the participating carriers.

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### 1. Introduction

Last-mile deliveries in urban areas exert serious pressures on the environmental, social, and economic well-being of many major cities around the world. These three aspects are usually referred to as *planet*, *people*, and *profit* (Quak

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and Tavasszy, 2011). On the planet, the impacts are contributed by the use of unsustainable natural resources like the fossil fuel. On the people, the impacts are primarily due to air pollution and noise. On the profit, the impacts encompass economic losses because of traffic congestion and low utilization of transport vehicles. In addressing these issues, many local authorities have imposed time windows and vehicle restrictions on last-mile deliveries, which complicate the operations of the deliveries from the perspective of the carriers. Consequently, receivers experience longer wait times and service performance is affected. One solution is for carriers to operate small electric vehicles for deliveries into the city center; however, these are not efficient for long-distance inter-city transport.

An urban consolidation center (UCC) provides a plausible solution to this phenomenon. La Petite Reine and Binnenstadservice represent two contemporary examples of UCCs implemented in Paris and the city of Nijmegen in the Netherlands, respectively. These UCCs operate their own eco-friendly last-mile delivery trucks. To enhance the financial sustainability of this type of UCCs, Handoko et al. (2014) recently proposed an auction mechanism which seeks to maximize the profit of the UCCs. By completely passing their last-mile delivery responsibilities to these UCCs at some costs, participating carriers can retain the use of their large trucks for the economies of scale outside the city center, while overcoming the vehicle-type restriction and simultaneously addressing the complicated scheduling caused by the time-window restriction in last-mile deliveries. However, these carriers will no longer be able to retain and choose to deliver their private orders themselves to the respective receivers.

A recent exploratory study on the collaborative urban logistics in Singapore (Lindawati et al., 2014) suggests that *cost reduction* and *privacy preservation* are two main drivers that would motivate the participation of carriers in the UCC. In Singapore, the government authority imposes mild restrictions on the vehicle types or the time windows for last-mile delivery. Rather, electronic road pricing (ERP) that depends on the vehicle type has become the means to discourage urban traffic during peak hours. This suggests that a UCC like the Tenjin Joint Distribution System in Fukuoka, Japan (Panero et al., 2011) may be implemented to achieve cost reduction with some degree of privacy preservation. Participating carriers keep their respective private orders and have the option to get their remaining shareable orders consolidated with other carriers' fleet. This enables carriers to reduce the amount of fragmented deliveries (i.e. small deliveries to diverse locations).

For this to work, the underlying technology that performs multi-party consolidation of freight for last-mile delivery must take into consideration cost efficiency and privacy preservation. In this paper, we propose a double auction mechanism that enables such consolidation. For simplicity, our objective is to maximize the total cost savings attained by all participating carriers. Note that the model presented in this paper is aimed at solving the basic problem to perform order sharing with privacy preservation. Practical considerations such as admin and warehousing costs, shipment requirement and compatibility can be easily incorporated as objective and constraints of the model. We also assume for simplicity that the UCC serves as the auctioneer and provides facilities to perform physical transfers (cross-docking) of the shareable orders from one truck to another.

## 2. Literature review

Urban logistics involves multiple stakeholders (Ambrosini and Routhier, 2004) which include the receivers, the carriers, the shippers, as well as the public authorities. To reduce congestion and environmental impacts related to urban freight deliveries, several schemes have been proposed in the literature (Muuzuri et al., 2005; Benjelloun et al., 2010; Russo and Comi, 2010). Mancini et al. (2014) groups these actions into three main categories: (1) policy actions, (2) organizational actions, and (3) technological actions. Effective combination of all three categories of actions would enable efficient reduction of the travelled distances, thereby reducing congestion and minimizing environmental nuisances (Gonzalez-Feliu, 2012). For this reason, it is attractive to focus on the schemes where different actors bring their freight to the consolidation platform, which mainly is located in the surroundings of a city, from where commodity needs to be transported to the customers within the city (Crainic et al., 2012).

Allen et al. (2007) defines an Urban Consolidation Center (UCC) as “a logistics facility situated in relatively close proximity to the geographic area that it serves (a city centre, an entire town, or a specific site such as a shopping centre), to which many logistics companies deliver goods destined for the area, from which consolidated deliveries are carried out within that area, in which a range of other value-added logistics and retail services can be provided.” Urban consolidation has thus become one of the pillars of city logistics, which can take place at different stages of the

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