Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 12 (2016) 26 – 39

Transportation Research Procedia

www.elsevier.com/locate/procedia

The 9th International Conference on City Logistics, Tenerife, Canary Islands (Spain), 17-19 June 2015

Synchronized multi-trip multi-traffic pickup & delivery in city logistics

Teodor Gabriel Crainic [a,b]*, Phuong Khanh Nguyen [b], Michel Toulouse [b,c]

[a] *School of Management, Université du Québec à Montréal, PO Box 8888, Station Centre-ville, Montreal QC, Canada H3C 3P8*
[b] *CIRRELT - Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation, U. de Montreal, PO Box 6128, Station Centre-ville, Montreal QC, Canada H3C 3J7*
[c] *Vietnamese-German University, Hoa Phu Ward, Binh Duong New City, Binh Duong Province, Vietnam*

Abstract

The paper introduces the first methodology addressing with a single fleet of vehicles the routing of the three different types of transportation demands encountered in City Logistics, inbound, outbound and intra-city traffic. We propose a tabu search meta-heuristic calling on various neighbourhoods, dynamically selected, to provide an efficient search combining exploration and exploitation capabilities. The result analysis of extensive computational experiments qualify the impact of a number of major problem characteristics and search strategies on the quality of the meta-heuristic, the behaviour of the solutions, and the management of the City Logistics system.

Peer-review under responsibility of the organising committee of the 9th International Conference on City Logistics

*Keywords:*Vehicle routing, pickup and delivery, synchronization, inbound, outbound and intra-city City Logistics transport, tabu search

1. Introduction

Most City Logistics (CL) literature and projects address inbound movements only, reflecting the dominant position the traffic proceeding from the exterior of the city towards its centre occupies within the travel patterns observed in most cities. Yet, the volumes of freight produced within the city and shipped to locations within or

---

* Corresponding author. Tel.: +1-514-343-7143; fax: +1-514-343-7121.
E-mail address: TeodorGabriel.Crainic@cirrelt.net

Peer-review under responsibility of the organising committee of the 9th International Conference on City Logistics
doi:10.1016/j.trpro.2016.02.023

outside it may be significant. Moreover, addressing the needs of these different types of transportation demands in a comprehensive manner and with a unique fleet of vehicles, may greatly contribute to achieve the CL mobility, environmental, and quality-of-life objectives. It is therefore relevant to investigate the possible integration of these traffic types into "normal" CL operations. The goal of this paper is to contribute to this investigation.

To our best knowledge, Crainic *et al.* (2012) were the first to investigate this issue within the context of two-tiered City Logistics systems (Crainic *et al.*, 2009). They examined, at a conceptual level, several integration strategies of three types of traffic, the *customer-to-customer* (*c2c* for traffic with origin and destination at customers located within the CL-controlled part of the city, i.e., the city centre), the *customer-to-external zone* (*c2e* from the city centre to destinations outside the city limits), and the "classical" *external zone-to-customer* (*e2c*). They discussed methodological and managerial challenges associated to the integration, but no problem definition was provided, nor any modelling or algorithmic contribution. We formally introduce and define the *Multi-trip Multi-traffic Pickup and Delivery Problem with Time Windows and Synchronization* (*MTT-PDTWS*) addressing the three traffic types.

The first algorithm for the MTT-PDTWS is our second contribution. We extend the work of Nguyen *et al.* (2013, 2015a) to address the challenges of integrating c2c operations into route planning. Computational results are discussed to qualify the impact of a number of major problem characteristics, parameters and search strategies on the quality of the meta-heuristic, the behaviour of the solutions, and the management of the City Logistics system.

The paper is structured as follows. We define the problem and set it within the literature in next section. The tabu search meta-heuristic and its components are presented next, followed by the section dedicated to the experimental results, and the conclusion.

2. Problem Description

In the MTT-PDTWS, a homogeneous fleet of vehicles of capacity Q operates out of a single garage g to perform multiple-tour delivery and pickup routes servicing three types of customer requests: e2c, c2e and c2c. The MTT-PDTWS is a new variant in the vehicle routing problem class, the original characteristics setting it apart from and generalizing most *Vehicle Routing Problems with Backhauls* (e.g., Cherkesly *et al.*, 2014; Vidal *et al.*, 2014) being 1) multicommodity demand defined as time-dependent origin-to-destination customer requests; 2) synchronization of activities at facilities; and 3) multi-tour routes.

We model the time-dependency characterizing demand and operations in the MTT-PDTWS through time windows. We first model facilities, which become available to receive vehicles for loading and unloading operations at particular time periods only. Such facilities correspond to the main City Distribution Centre/Platform for single-tier City Logistics and to satellites for two-tier ones. A particular set of loads destined to specific customers may be available at each such time period to be taken away and distributed. Then, as a given facility may be open at several moments during the schedule length considered, with a different set of loads at each occurrence, we define supply points as particular combinations of facilities and availability time periods. Each supply point $s \in S$ has a no-wait, hard opening time window $[t(s) - \eta, t(s)]$ specifying the earliest and latest times a vehicle may arrive at s, respectively. The vehicle may stop at a waiting station (e.g., a parking lot) $w \in W$ before moving to s.

The second time-dependency phenomenon concerns customers requesting different services: 1) receive e2c loads from different supply points, possibly within different time windows; 2) ask for c2e loads to be picked up and transported to one of a given subset of supply points; 3) specific pairs of customers may ship c2c loads between them. Each customer may require more than one of these three service types. We model this time dependency by identifying each particular load as a customer demand and defining 1) The set of *delivery-customer demands*, $d \in C^D$, each being characterized by the supply point where it is available, the customer it must be delivered to, and the time window when the delivery must be performed; 2) The set of *pickup-customer demands*, $p \in C^P$, each characterized by the customer shipping it and the time window within which the pickup must be performed, as well as by the set of admissible supply points $S_p \in S$ to which the load may be delivered, the choice of a particular one being part of the decisions characterizing the MTT-PDTWS; and 3) The set $(\overline{p}, \overline{d}) \in \mathcal{R}$ of *c2c-customer demands*, each request requiring a load to be transported from a *c2c-pickup-customer* demand $\bar{p} \in C^P_{c2c}$ to a *c2c-delivery-customer* demand $\bar{d} \in C^D_{c2c}$. Let $(i, q_i, \delta(i), [e_i, l_i])$ stand for the quantity $q_i > 0$ ($q_{\overline{p}} = -q_{\overline{d}}$ for $(\overline{p}, \overline{d}) \in \mathcal{R}$) to be