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Interval travel times for more reliable routing in city logistics

Patrick-Oliver Groß [a]*, Michael Geisinger [a], Jan Fabian Ehmke [b], Dirk Christian Mattfeld [a].

[a] *Technische Universit¨at Braunschweig, Decision Support Group, M¨uhlenpfordtstraße 23, 38106 Braunschweig*
[b] *Freie Universit¨at Berlin, Advanced Business Analytics Group, Garystraße 21, 14195 Berlin*

Abstract

Due to varying traffic volumes and limited traffic infrastructure in urban areas, travel times generally are uncertain and differ during the day. In this environment, city logistics service providers (CLSP) have to fulfill deliveries cost-efficiently and reliably. To ensure cost-efficient routing while satisfying promised delivery dates, information on expected travel times between customers needs to be exploited. If a sufficient amount of data is not available or expensive to acquire, deriving this information presents a major challenge for CLSP. Therefore, we propose the usage of interval travel times (ITT) to enable cost-efficient and reliable routing in urban areas. ITT define an expected range of travel times, which can be derived with relatively low effort by CLSP. We modify an existing approach from the domain of robust planning to the requirements of routing in urban areas. Further, we present and discuss the process of deriving ITT. An exemplary city logistics setting is developed and different routing solutions are examined. Computational experiments show that, in contrast to well-known deterministic approaches, routing considering ITT allows both cost-efficient and reliable routing.

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* Corresponding author. Tel.: +49 531-391-3216 ; fax: +49 531-391-8144.
E-mail address: p.gross@tu-braunschweig.de

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1. Introduction

Urban transportation mainly deals with last-mile deliveries. Last-mile deliveries are one of the most important parts of the supply chain, but also represent a very expensive and inefficient part of the entire supply chain (Gevaers, Van de Voorde and Vanelslander, 2011). The need for making last-mile delivery operations more efficient and environmentally acceptable has led to the concept of city logistics (Crainic, 2008; Taniguchi et al., 2001). City logistics concepts focus on integrated solutions that allow for efficient and reliable urban transportation while reducing negative impacts. In this course, city logistics service providers (CLSP) face two major challenges.

On the one hand, e-commerce and online retailing has been growing continuously (ATKearny, 2013). Today's e-commerce business models require cost-efficient as well as customer-oriented last-mile deliveries in order to stay competitive (Agatz et al., 2011). This becomes especially challenging when customers are promised on-time delivery, e.g., in attended home delivery applications (Ehmke and Campbell, 2014). On the other hand, advancing urbanization causes increased traffic demand along the limited infrastructure of urban traffic systems. As a result, travel times vary heavily throughout the day, which counteracts the efficient and reliable planning of delivery tours.

City logistics concepts can correspond to these challenges by applying different optimization approaches and by integrating different levels of travel time information. Optimization approaches require information on the expected travel times of the urban traffic network to provide delivery tours with reasonable quality (Ehmke, Steinert and Mattfeld, 2012). The estimation of realistic travel times for the considered traffic network has a major impact on the quality of routing. Therefore, travel time models representing single travel time values per link, e.g., road distance and their corresponding speed limit, are not a sufficient input for reliable routing in urban areas (Eglese, Maden and Slater, 2006). To ensure cost-efficient routing while satisfying promised delivery dates, information on the expected range of travel times between customers needs to be exploited.

In this paper, the usage of interval travel times (ITT) is proposed to enable cost-efficient and reliable routing in urban areas. ITT define a best-case and a worst-case travel time. They can be derived with relatively low efforts by CLSP. The use of ITT allows for applying methods from the area of robust planning. To the best of our knowledge, ITT have not been studied within the scope of routing in city logistics. Thus, in this paper, we present and discuss the process of deriving ITT. Further, we extend an approach from the domain of robust planning and modify it to the requirements of routing in urban areas. In particular, we modify the approach of Montemanni et al. (2007) for city logistics and additionally consider customer time windows. We present a mathematical model and compare the results of routing with ITT to deterministic routing, especially with regard to efficiency and reliability of delivery tours.

The remainder of the paper is organized as follows: (1) A literature review on city logistics routing models, the role of travel time information and technology to determine travel times is given. (2) The concept of robust optimization is introduced by means of the Robust Traveling Salesman Problem and additionally extended by time windows. (3) A case study for robust routing in city logistics is presented. This includes the derivation of ITT and the evaluation of the robust routing approaches in the context of city logistics. (4) A conclusion is given and future work steps are illustrated.

2. Related Literature

In our literature review, we discuss related approaches to routing in city logistics. In particular, models and methods that incorporate different types of travel time information are considered. How travel times are modeled has a significant impact on the efficiency and reliability of routing. Thus, we finally discuss different approaches to model and consider travel times.

2.1. Routing in City Logistics

When dealing with optimization models to compute cost-efficient delivery tours, two basic modeling approaches are well known. Focusing on the order of customers within a delivery tour, the basic modeling approach is represented by the Traveling Salesman Problem (TSP). Lawler et al. (1985) and Laporte (1992) give an overview of the TSP. When additionally considering the assignment of customers to several vehicles, the basic modeling approach is the Vehicle Routing Problem (VRP). For a recent overview of the VRP see Laporte (2009). Both problems belong to the