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Exploiting travel time information for reliable routing in city logistics

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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-efficient and reliable. To ensure cost-efficient routing while satisfying promised delivery dates, information on expected travel times between customers needs to be exploited.

If 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 present and discuss the process of deriving ITT. Further, we investigate an existing approach from the domain of robust planning within the scope of routing in urban areas. 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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Keywords: reliability, interval travel times, robust, routing, city logistics

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 et al., 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).

In city logistics, four major stakeholders can be identified according to their influences and interests: shippers, carriers, residents and administrators (Taniguchi et al., 2001), each differing in tasks and goals. We limit our scope

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to the carriers operations, considering the shippers influences. Shippers, e.g., online retailers, send and sell goods to companies or private individuals. Their main objective is to maximize the service level for their customers, in terms of fast and on-time delivery. The transportation of these goods is brought out by carriers, e.g., city logistics service providers (CLSP), on behalf of the shippers.

Their main objective is to minimize the transportation cost. In this course, carriers have to conduct cost-efficient as well as reliable delivery tours while facing two major challenges: an increasing demand and rising customer expectations for city logistics services as well as the uncertainty of travel times within the urban traffic system, especially with regard to arterial connections.

City logistics concepts respond to these challenges by integrating different levels of travel time information into suitable optimization approaches. Optimization approaches require information on the expected travel times of the urban traffic network to provide delivery tours with reasonable quality (Ehmke et al., 2012b). The estimation of realistic travel times and the consideration of uncertainty within the 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 et al., 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 can be interpreted as 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 investigate an approach from the domain of robust planning in the scope of routing in urban areas. In particular, we build on the work of Montemanni et al. (2007) and investigate the robust traveling salesman problem with ITT in the context of city logistics routing. We present the corresponding algorithm and compare the results of routing with ITT to deterministic routing, especially with regard to efficiency and reliability of delivery tours in a city logistics context. The main contribution of this paper is to investigate the suitability of the approach for city logistics routing applications and propose further research opportunities.

The remainder of the paper is organized as follows: First, a literature review on city logistics routing models, the role of travel time information and technology to determine travel times is given. Second, the scope of reliable routing in city logistics is captured by a problem description and then exemplified within a case study. This includes exemplary instances of the described problem, the derivation of ITT and a routing with an algorithm that utilizes ITT. Third, the case study is evaluated by simulation. Routes are examined with regard to structure, efficiency and reliability. Finally, a conclusion is given and future work steps are illustrated.

2. Related Literature

In our literature review, we discuss related routing approaches 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

CLSP have to carry out cost-efficient delivery tours. The basic modeling approach refers to the well-known Vehicle Routing Problem (VRP) introduced by Dantzig and Ramser (1959). Many variants of the VRP have been investigated and adapted to model different real world scenarios. An overview on the development of the VRP is given by Laporte (2009). For city logistics applications, specific properties and effects have to be considered, e.g., restricted access zones or time dependent travel times (Taniguchi et al., 2001; Crainic et al., 2009; Cattaruzza et al., 2015). Kim et al. (2015) summarize this under the term "City VRP" and give a comprehensive overview on different approaches. In the following, we focus on routing approaches that allow considering influences within the urban traffic system, in particular the uncertainty of travel times.