European Journal of Operational Research 233 (2014) 193–207

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Innovative Applications of O.R.

Customer acceptance mechanisms for home deliveries in metropolitan areas

Jan Fabian Ehmke *, Ann Melissa Campbell

Department of Management Sciences, Tippie College of Business, University of Iowa, Iowa City, IA 52242-1000, United States

A R T I C L E I N F O

Article history:
Received 6 February 2013
Accepted 19 August 2013
Available online 30 August 2013

Keywords:
Routing
Home delivery
Feasibility check
Congestion
City logistics

A B S T R A C T

Efficient and reliable home delivery is crucial for the economic success of online retailers. This is especially challenging for attended home deliveries in metropolitan areas where logistics service providers face congested traffic networks and customers expect deliveries in tight delivery time windows. Our goal is to develop and compare strategies that maximize the profits of a logistics service provider by accepting as many delivery requests as possible, while assessing the potential impact of a request on the service quality of a delivery tour. Several acceptance mechanisms are introduced, differing in the amount of travel time information that is considered in the decision of whether a delivery request can be accommodated or not. A real-world inspired simulation framework is used for comparison of acceptance mechanisms with regard to profits and service quality. Computational experiments utilizing this simulation framework investigate the effectiveness of acceptance mechanisms and help identify when more advanced travel time information may be worth the additional data collection and computational efforts.

1. Introduction

Online retailing is the fastest growing retail sector in the US, with an overall growth of about 15% in the past year (US Census Bureau, 2012). Sales from online retailers are expected to increase from $155 billion in 2009 to $250 billion in 2014. In Western Europe, an even higher yearly compound growth rate of 11% from €68 billion to €114.5 billion over the same years has been predicted (Schonfeld, 2010). Efficient and reliable delivery of orders is crucial for the lasting economic success of online retailers. The particular challenge of planning and executing attended home deliveries, where customers must be home to receive the delivery, has been demonstrated by the failures of Webvan (bankruptcy in 2001) and Publix Direct (shut down in 2003).

Attended home deliveries require customers and logistics service providers to agree on a service time window in order to avoid failure of delivery. For logistics service providers, accepting more deliveries can yield more revenues, but it can make it harder to reliably make deliveries within the service time windows. The same challenge also holds for service technicians, such as plumbers and appliance repairmen, where the attendance of the customer is required in order to conduct a service. We will focus our discussion in this paper on deliveries, but all of the ideas presented here can be translated to the service technician context, where even more complex constraints such as varying service times and the skill level of technicians must be considered.

Satisfying the tight service time windows for attended home deliveries in metropolitan areas can be especially difficult due to congested traffic networks. Logistics service providers need to consider expected traffic conditions in deciding which deliveries they can reliably complete on time. Many currently use fairly simple ways to account for congestion. They may assign fewer customers per vehicle in high traffic areas, or they may incorporate a standard amount of buffer time before arrivals in order to increase the likelihood of on-time delivery. However, unnecessary buffer times may lead to increased driver and equipment idle time, increased costs, as well as a decreased number of kilometers traveled per hour (Kim, Lewis, & White, 2005). At the same time, too many delivery commitments may be accepted during rush hours, leading to lateness and violation of service time windows. An approach to time window management that incorporates both detailed information on expected congestion and time-dependent vehicle routing has the potential to create better solutions. To the best of our knowledge, this idea has not been explored in the literature and is thus the motivation for our paper.

In this paper, we investigate the interaction of commitment to a service time window and the reliability of actual deliveries. We develop and compare strategies for deciding which requests to accept, building on ideas introduced in Campbell and Savelsbergh (2005). To this end, we introduce several acceptance mechanisms that differ in the amount of travel time information that is incorpo-

* Corresponding author. Present address: Advanced Business Analytics Group, Department of Business Information Systems, Freie Universität Berlin, 14195 Berlin, Germany. Tel.: +49 30 83858731.

E-mail addresses: jan.ehmke@fu-berlin.de (J.F. Ehmke), ann-campbell@uiowa.edu (A.M. Campbell).

0377-2217/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.ejor.2013.08.028

rated. We consider both time-dependent and stochastic travel time information in the decision of whether to accept a delivery request. A time-dependent, real-world inspired simulation framework allows for evaluation of the resulting tour plans. The simulation framework enables the comparison of the acceptance mechanisms with regard to maximization of profits and service quality. This enables us to evaluate the extent that time-dependent and stochastic travel time information may be worth the additional data collection and computational efforts. In Section 2, we sketch recent work on the management of service time windows as well as on time-dependent vehicle routing. The Home Delivery Problem in Metropolitan Areas (HDPMA) is presented in Section 3. Acceptance mechanisms for the solution of the HDPMA are introduced in Section 4. Experimental design and computational experiments are discussed in Sections 5 and 6. We present managerial insights and conclude the paper in Section 7.

2. Literature

The fulfillment process for online retailers as described by Campbell and Savelsbergh (2005) is initiated by a customer who places an order and selects a time window for delivery. When the service provider accepts the request, the order is assembled. After a certain "cut-off date", delivery tours are scheduled. The following overview summarizes literature on the management of service time windows for order placement (Section 2.1) as well as literature on the routing and scheduling of delivery tours (Section 2.2). Order assembly is beyond the scope of this paper and therefore not discussed.

2.1. Management of service time windows

Literature on the management of service time windows is either on a tactical or an operational level. The tactical level is about the design of service time windows, including decisions on the overall number, length and possible overlap as well as the general concept of delivery fees. The design of service time windows aims at the maximization of the captured demand while limiting expected operational costs. Punakivi and Saranen (2001) report that completely flexible, unattended delivery services reduce costs by up to a third relative to attended deliveries with two-hour service time windows. Campbell and Savelsbergh (2005) found that the expansion of 1-hour service time windows to two hours may increase profits by more than 6%. Agatz, Campbell, Fleischmann, and Savelsbergh (2011) introduce an approach that anticipates routing costs in time window design. Given service requirements and average weekly demands for each zip code area of a delivery region, time windows for each zip code area are determined which minimize the expected costs of delivery.

The operational level refers to the actual selection of a service time window by a customer and the commitment of the service provider. Service providers need to decide when to open and when to close service time windows for selection. Campbell and Savelsbergh (2005) introduce several acceptance mechanisms for determining whether a request can be feasibly accommodated in any of the predefined service time windows. Service providers may offer incentives for the selection of certain service time windows that limit expected costs of delivery based on the profitability of a new request with respect to already accepted and still expected requests. Campbell and Savelsbergh (2006) show that incentive schemes can substantially reduce delivery costs, since customers may accept wider service time windows supporting a more efficient combination of requests in vehicle routing and scheduling operations. Azi, Gendreau, and Potvin (2012) examine a sample of future demand scenarios in order to assess the profitability of dynamically arising requests. The aforementioned papers do not consider time-dependent and stochastic travel time information in the assessment of routing costs and feasibility.

2.2. Routing and scheduling of delivery tours

Once orders have been placed and have a service time window, delivery tours are planned by vehicle routing and scheduling procedures. The corresponding Vehicle Routing Problem with Time Windows (VRPTW) aims at the determination of the optimal tour plan, where (1) every tour departs and terminates at the depot, (2) every customer is visited exactly once by one vehicle, (3) the number of tours is minimal, and (4) every customer is served within its service time window. A secondary objective is to either minimize the total distance traveled or the total travel times of the particular tours. Service time windows can be soft or hard. Soft service time windows may be violated, but violation induces penalty costs in the objective function. Hard service time windows are strictly enforced in order to keep a solution feasible. For the latter, even just finding a feasible schedule with a given number of vehicles is known to be a complex problem (Hashimoto, Yagiura, & Ibaraki, 2008).

The VRPTW has been extensively studied in the last 25 years. Exact algorithms and model formulations are reviewed by Baldacci, Mingozzi, and Roberti (2012). Metaheuristics provide high-quality solutions with reduced run time; see Bräysy and Gendreau (2005b) for a review paper. Lau, Sim, and Teo (2003) discuss heuristic solution approaches for the VRPTW with a limited number of vehicles. Pisinger and Ropke (2007) elaborate on a general heuristic for vehicle routing problems including the VRPTW. Pillac, Gendreau, Guéret, and Medaglia (2013) provide a review on dynamic variants of the vehicle routing problem, distinguishing formulations and solution approaches based on the degree of dynamism of considered information.

For vehicle routing and scheduling in metropolitan areas, literature on the time-dependent extension of the VRPTW is relevant. The TDVRPTW captures costs and travel times between depot and customer locations based on the time of the day. Thanks to the availability of more accurate travel time information, there has been an increasing number of papers in the last 10 years that consider information on congestion, e.g., Ando and Taniguchi (2006), Donati, Montemanni, Casagrande, Rizzoli, and Gambardella (2008), Fleischmann, Gietz, and Gnutzmann (2004), Haghani and Jung (2005), Hashimoto et al. (2008), and Ichoua, Gendreau, and Potvin (2003). Maden, Eglese, and Black (2010) present a metaheuristic solution approach ("LANTIME"). Ehmke, Steinert, and Mattfeld (2012a) adapt the LANTIME heuristic for usage with taxi speed data for time-dependent routing in metropolitan areas. Kok, Hans, and Schutten (2012) investigate the impact of time-dependent travel times on the reliability of tour plans. Their experiments underline the necessity of time-dependent vehicle routing in metropolitan areas in order to provide efficient and reliable delivery tours.

3. Home delivery problem in metropolitan areas

In this section, we define the integrated routing and scheduling problem that is studied in this paper. The idea is to maximize the number of requests accepted for delivery by enhanced feasibility checks that provide immediate feedback to a customer during the order process. In particular, we investigate how different levels of travel time information may improve the evaluation of whether a new delivery request is feasible in a potential tour plan. From a fulfillment process perspective, this corresponds to the operational management of service time windows.