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A decision support system for optimizing dynamic courier routing operations

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ABSTRACT

In this paper, we propose a prototype of a decision support system (DSS) that integrates a hybrid neighborhood search algorithm to solve the offline and online routing problems arising in courier service. In the dynamic operational environment of courier service, new customer orders and order cancellations continually arrive over time and thus disrupt the optimal routing schedule that was originally designed. This calls for the real-time re-optimization of routes. As service level is sensitive to whether allowable service time intervals are wide or narrow, it is valuable to study how adjustable and flexible time windows influence the courier service efficiency in a dynamic environment. To capture these dynamic features, a dynamic vehicle routing problem (DVRP) that simultaneously considers new customer orders and order cancellations is investigated in this study. Meanwhile, fuzzy time windows are formulated in the DVRP model to quantify the service level and explore the service efficiency. To tackle the new problem, we propose a competitive hybrid neighborhood search heuristic for (re)optimizing the offline and online routes. Numerical computational experiments and the comparison with results from Lingo show that our algorithm is capable of re-optimizing dynamic problems effectively and accurately in a very short time. The proposed model and algorithms are able to enhance courier service level without further expense of a longer traveling distance or a larger number of couriers.

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1. Introduction

The rapid development of information technology has facilitated communication in business as well as in personal affairs and consequently leads to the striking growth of goods being shipped across areas or countries. With more demanding requirements for fast shipment delivery, courier services are provided by express companies (e.g. DHL, Federal Express) to fulfill such requirements, to gain competence in the industry, to get more customers and sustain a high level of service. Courier service is the first part of a domestic or international parcel shipping service, in which the couriers react to the real-time customer requests by collecting the parcels at all customer locations. The parcels are consolidated into a vehicle and delivered back to the mailing center for further processing and shipping (Gendreau & Potvin, 1998).

The demand-responsive transportation in courier service reflects its time-sensitive character, posing a great challenge to provide on-time and quick-response customer service. The dynamically changing customer requests, such as new customer orders and customer order cancellations, frequently occur after the couriers have been dispatched. They might consequently interrupt the execution of the pre-determined courier routing schedule, which is very likely to result in increased transportation cost and delayed customer service. In this context, the decision making problem concerns how to dynamically adjust the pre-determined routing schedule to cope with the real-time customer requests. The complexity of this problem is due to the following main concerns and difficulties:

(a) Under the condition that all real-time customer requests (including new customer orders and order cancellations) must be processed, the question arises of how to re-schedule the pre-determined courier routing plan. Is it necessary (1) to employ more couriers to complete the service; and/or (2) to preserve the same service level as before or even enhance the service level?

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(b) The new plan should be re-scheduled quickly because the call center has to reply to the customers about whether/how/when the courier will service them.
(c) Traditional Transportation Management Systems (TMS) are not flexible enough to help the fleet manager continually to re-route the couriers in real-time to adapt to the dynamic environment.

Obviously, even an experienced fleet manager might fail to tackle the above challenging problems. It is necessary to formulate a dynamic courier routing model and a computer-based system with a robust algorithm to cope with the dynamism of customer requests. This problem of courier service can be approached as a dynamic routing and scheduling problem. However, very few studies (Benyahia & Potvin, 1998; Gendreau, Guertin, Potvin, & Taillard, 1999; Mitrović-Minić, Krishnamurti, & Laporte, 2004) that investigate courier routing problems have been published.

The contribution of this paper is to propose a prototype decision support system embedded with a hybrid neighborhood search algorithm, with emphasis on solving a comprehensive dynamic courier routing problem (DCRP) that captures many features of operational problems arising in real-world fleet management. This problem is distinct from the dynamic vehicle routing problems (DVRP) that are typically addressed in the literature, as it is characterized by: (1) employing fuzzy time windows to depict the service level; and (2) jointly considering two types of online customer requests: new customer orders and order cancellation.

The rest of the paper is organized as follows. Section 2 reviews the literature on DVRP, discusses the integration of fuzzy time windows and DVRP, and presents studies on decision support systems (DSS) concerning routing problems. A description of the dynamic courier routing problem with order cancellation and fuzzy time windows (DCR-OCFTW) and mathematical models are provided in Section 3. Section 4 follows to introduce the architecture and core modules of the proposed DSS. The hybrid neighborhood search (HNS) algorithm designed for tackling the DCR-OCFTW is described in Section 5. The extensive computational experiment results are reported and discussed in Section 6. Finally, Section 7 concludes this research work and suggests the direction for future study.

2. Literature review

2.1. Dynamic vehicle routing problem

The Vehicle routing problem (VRP) concerns physical distribution that involves the transport of goods from production sites to warehouses and from warehouses to customers (Tsai, Tsai, & Tseng, 2003). VRP is a classical NP-hard problem (Monekosso & Remagnino, 2004) that has been received extensive research attention since it was first introduced by Dantzig and Ramser (1959). The traditional VRP deals with a deterministic operational environment where all information is known (offline) before routes are constructed and remains static during the execution of the routing plan. However, the circumstances in the real world are not always deterministic and static because uncertainties, such as breakdown of vehicles, traffic control, and continually arriving customer requests, frequently occur. Reflecting such uncertainty in a dynamic operational environment, DVRP has recently engaged researchers' interest. As opposed to traditional VRP, DVRP is featured by the on-going fashion in which the vehicle locations, traveling times and customers are revealed over time. The typically studied DVRP concerns a dynamic operation in which the customer requests are released during the planning period (online requests) and should be assigned in real-time to appropriate vehicles. It is motivated by a variety of real-life applications such as dynamic fleet management, vendor-managed distribution systems, courier service, repair or rescue service, dial-a-ride service, emergency service, as well as taxi cab service (Ghiani, Guerriero, Laporte, & Musmanno, 2003).

Pillac, Gendreau, Guéret, and Medaglia (2013) gave a clear taxonomy of VRP from the perspective of how the information evolves and presents itself. Basically, VRP can be categorized as Static and Deterministic Problems, Static and Stochastic Problems, Dynamic and Deterministic Problems and Dynamic and Stochastic Problems, as shown in Table 1.

Most existing models, in terms of DVRP, fall into the category of Dynamic and Deterministic Problem, that is, the input of the model that is realized over time is still deterministic. So far, various classes of DVRP with different aspects of operational constraints and a number of exact and approximate algorithms are proposed in the literature. A large fraction of studies incorporate a time window constraint in the dynamic problem. Gendreau et al. (1999) took soft time windows into account in the real-time routing problem with a bi-objective function of minimizing the traveling distance and the total time span between the arrival time and the latest service time at each customer location. A tabu search incorporated with an adaptive memory that serves as a repository of the routes of the best solutions visited during the search, is proposed and implemented on a multi-processor platform with a parallelization scheme to solve a classical pickup and delivery problem with time windows. The parallel tabu search was designed to increase the computational effort and thus accelerate the search process, which is very important for making a prompt routing decision in response to new occurring events. Gendreau, Guertin, Potvin, and Séguin (2006) used a very similar approach to solve an extended problem in which pickups and deliveries were considered. The problem is motivated by the same-day local courier service. Cheung, Choy, Li, Shi, and Tang (2008) proposed a two-phase heuristic, which is composed by an initial feasible solution construction heuristic and a genetic algorithm based searching method, for solving both static and dynamic versions of a classical pickup and delivery problem with time windows. The dynamic information contains the real-time vehicle position, load level of each vehicle, online arrival of new customer orders, and the traveling time of each arc at a certain time instant, which is coped with to modify the existing routes by a re-optimization approach. Hong (2012) employed the philosophy of Large Neighborhood Search (Shaw, 1997) with a route improvement approach to solve the DVRP with time windows. Madsen, Tosti, and Vælds (1995) investigated a repairmen dispatching problem, an interesting scenario where the time windows are not specified by the customers. Instead, a time window of a fixed interval for repair service will be given to a customer when

Table 1
Taxonomy of VRP. Source: Pillac et al. (2013).

		Information quality	
		Deterministic input	Stochastic input
Information evolution	Input known beforehand	Static and Deterministic Problems	Static and Stochastic Problems
	Input changes over time	Dynamic and Deterministic Problems	Dynamic and Stochastic Problems

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