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A recovery model for combinational disruptions in logistics delivery: Considering the real-world participators

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ABSTRACT

The existence of uncertainties may result in various unexpected disruption events in logistics delivery, which often makes actual delivery operations deviate from intended plans. The purpose of the paper is to develop a combinational disruption recovery model for vehicle routing problem with time windows (VRPTW), trying to handle a variety and a combination of delivery disruption events. Firstly, a novel approach to measure new-adding customer disruption, which considers the real-world participators (mainly including customers, drivers and logistics providers) in VRPTW, is developed. Then the paper proposes methods of transforming various delivery disruptions into the new-adding customer disruption, and determines the optimal starting times of delivery vehicles from the depot to provide a new rescue strategy (called starting later policy) for disrupted VRPTW. Based on the above, a combinational disruption recovery model for VRPTW is constructed and nested partition method (NPM) is designed to solve the proposed model. Finally, computational results are reported and compared with those of previous works, which verifies the effectiveness of the proposed solution and draws some interesting conclusions.

1. Introduction

With the rapid development of e-commerce and mobile commerce, logistics delivery activities have become increasingly important in economic development and daily life. The general process of once delivery activity is: (i) customers' requests are asked; (ii) logistics providers schedule delivery plans; (iii) drivers (delivery staff) travel according to the planed routing and serve customers as they expect. It seems easy to complete the process, especially with the help of advanced technologies nowadays! However, in the real world there are various unexpected disruption events encountered in the delivery process such as vehicles breakdown, cargos damage, changes of customers' requests including service time windows, delivery addresses and demand amount, and so on (Bertsimas and van Ryzin, 1991; Wang et al., 2009a; Li et al., 2009b; Berbeglia et al., 2010; Yeo and Yuan, 2012; Uskonen and Tenhiälä, 2012). These disruption events often make actual delivery operations deviate from intended plans, which may bring different disturbances on the participators (such as customers, drivers and providers) in logistics delivery.

Existing literatures, which we will review later in the following, have put forward effective solutions for the disrupted vehicle routing problem (VRP) with a certain disruption event, but most of the proposed models and algorithms can deal with only a certain type of uncertainty. It is not easy or impossible for each proposed solution to solve actual disrupted VRP with the reality that various disruption events (vehicles breakdown, cargos damage, and changes of customers' service time, delivery addresses, demand amount and so on) often occur successively or even simultaneously. An example is used to illustrate the combinational disruption of vehicle routing problem in Fig. 1. Fig. 1(a) shows the original routing where three vehicles serve seven customers: vehicle 1 serving customers 1 and 2, vehicle 2 serving customers 3 and 4, vehicle 3 serving customers 5, 6 and 7. Fig.1(b) shows several possible disruption events: (i) vehicle 1 breaks down when traveling to customer 2 after serving customer 1; (ii) the delivery address of customer 4 changes when vehicle 2 is serving customer 3; (iii) customer 7 decreases the demand when vehicle 3 is in the way; and (iv) there are three new-adding customers 8, 9 and 10. These disruption events may occur successively or even simultaneously, especially when the number of customers is large. One purpose of this study is to develop a common disruption recovery model for vehicle routing problem with time windows (VRPTW) which may handle a variety and a combination of disruption events.

Moreover, most existing researches for disrupted VRP focus on producing new routings with the minimum costs, ignoring the real-world participators in logistics delivery (mainly involving

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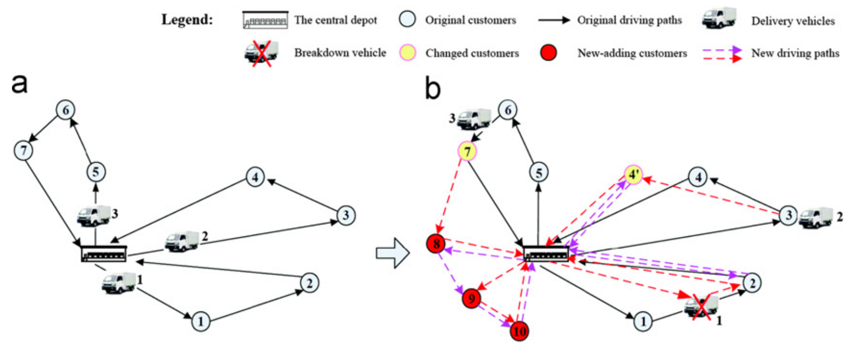

Fig. 1. Combinational disruptions in logistics delivery and some recovery alternatives. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

customers, drivers and logistics providers). For some disruption event, there may be several recovery alternatives, but different participators may prefer different alternatives. In Fig. 1(b), the pink and red dotted routings represent some recovery alternatives: (i) for customer 2 who cannot be served on time because of the breakdown of vehicle 1, the pink routing which takes less waiting time is better than the red routing, but the logistics provider may prefer the red routing which can pick up the cargos in vehicle 1 to serve customer 2; (ii) customer 4 who changed the delivery address may like the pink routing better, but the provider would like to send vehicle 2 to the new address of customer 4 after serving customer 3, which need not dispatch more vehicles; (iii) for the new-adding customers 8, 9 and 10, the provider may want to dispatch vehicle 3 to serve them if there are enough cargos in the vehicle, but the driver of vehicle 3 may complain about this because he or she is too tired now; and so on. It is important to consider the satisfaction of customers and drivers (staff) which has important effects on the long-term development of delivery firms, as well as delivery costs (Sessomboon et al., 1998; Jozefowiez et al., 2008; Wang et al., 2009b; Ding et al., 2010; de Haan et al., 2012). We try applying the thought of Disruption Management to produce solutions which are satisfactory to the above three participators, which is the second purpose of the study.

To sum up, the major contributions of this paper include: (i) proposing a novel approach to measure new-adding customer disruption quantificationally, considering the real-world participators in logistics delivery; (ii) designing methods of transforming different disruption events into the new-adding customer disruption; (iii) developing a combinational disruption recovery model for VRPTW and its nested partitions method. The paper is organized as follows. Section 2 reviews some related literatures. A new approach to measure the new-adding customer disruption, which considers the real-world participators in VRPTW, is developed in Section 3. Section 4 transforms different disruption events into the new-adding customer disruption, determines vehicles' optimal starting times from the depot, and constructs a combinational disruption recovery model for disrupted VRP. Section 5 designs the nested partitions method for the proposed recovery model. In Section 6, computational experiments are demonstrated to verify the effectiveness of the model and the algorithm. Lastly, conclusions are drawn, with recommendations in future works.

2. Literature review

Vehicle routing problem with time windows (VRPTW), which was proved as a NP-Hard problem, is an abstraction of vehicle scheduling problems in real-world delivery systems. Since being proposed by Dantzig and Ramser (1959), VRP has been one of research focuses in fields of operations research and combinatorial optimization. A variety of models and algorithms for VRP have been proposed (Burak et al., 2009), and more and more researchers are taking delivery disruption events into account.

Most of them have studied the dynamic vehicle routing problem (DVRP) which focuses on two kinds of uncertainties (i.e., dynamic/stochastic service requests and dynamic travel times). Bertsimas and van Ryzin (1991) developed a model for stochastic and dynamic vehicle routing in which service demands were stochastic and Bertsimas and van Ryzin (1993) extended their study to DVRP with multiple capacitated vehicles. Swihart and Papastavrou (1999) established a stochastic and dynamic model for the pick-up and delivery problem where service requests occurred according to a Poisson process and the pick-up locations of the requests were independent. Secomandi (2000) applied neuro-dynamic programming (NDP) in finding approximate solutions for the vehicle routing problem with uncertain customers' demands, compared the performance of two NDP algorithms and generated higher quality solutions. Bent and Hentenryck (2004) considered a dynamic VRPTW with stochastic customers to present a multiple scenario approach (MSA) that continuously generated routing plans for scenarios including known and future requests. Branke et al. (2005), Hvattum et al. (2006), Cheung et al. (2008), Cortes et al. (2009), Berbeglia et al. (2010), Lorini et al. (2011) and so on, have also produced various effective solutions for DVRP.

Meanwhile, some scholars have studied the VRP with vehicle disruption events. Mechanical failures, accidents, and traffic jam may hinder or disrupt planned schedules (Fleischmann et al., 2004; Li et al., 2007; Lorini et al., 2011). When a vehicle on a scheduled trip breaks down, one or more vehicles need to be rescheduled to serve the customers on that trip. Fleischmann et al. (2004) described the derivation of travel time data from modern traffic information systems and presented a general framework for the implementation of time-varying travel times in various vehicle-routing algorithms. Li et al. (2007) proposed a vehicle rescheduling problem (VRSP) with vehicle breakdown disruption, and developed a prototype decision support system (DSS) to minimize operation and delay costs while serving the customers on the disrupted trip.

The thought of Disruption Management, which aims at minimizing the deviation of actual operations from intended plans with minimum costs, provides an effective idea to deal with real-time and unpredictable events (Jens et al., 2001). At present, Disruption Management has been widely applied in flight scheduling, machine scheduling, supply chain coordination, and so on (Yu and Qi, 2004). Some researchers have introduced the thought into logistics delivery. Wang et al. (2007) developed a disruption recovery model for the vehicle breakdown problem of VRPTW and proposed two rescue strategies: adding vehicles policy and neighboring rescue policy. Zhang and Tang (2007) considered the vehicle