Disruption Management for the Vehicle Routing Problem with Time Windows

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Abstract. This paper presents a rescheduling model of a vehicle routing problem when a disruption occurs at a particular time and lasts for a period of time after a subset of the customers has been visited. In such cases, continuing with the original schedule is likely to be infeasible. The rescheduling model taken here is significantly different from the original one due to the fact that the objective is to find a new schedule that minimizes total distance and deviations from the original plan, and that the different neighborhood size and several new constraints must be considered during the recovery procedure. A hybrid algorithm, which is to hybridize ant colony optimization (ACO) with scatter search, is adopted to determine good approximate solutions. Computational experiments were also tested to determine the effects of factors affect the recovery procedure, and our studies will be helpful to disruption management for the vehicle routing problem.

Keywords: Disruption management; ant colony optimization; hybrid algorithm; scatter search.

1 Introduction

The vehicle routing problem with time windows (VRPTW) has many real-world applications in the field of transportation and logistics. Typical applications of the VRPTW include bank deliveries, postal deliveries, delivery and distribution companies and express delivery companies. The VRPTW has attracted considerable research interest, and it has been addressed in deterministic frameworks. However, these models do not depict accurately the actual problems encountered. In practice, most companies spend an enormous amount of resources and efforts in generating plans so as to maximize their profits. Nevertheless, these plans are often interrupted by disruptions caused by various uncertainty disruptions associated with vehicle breakdown and other unforeseen events. These disruptions make deviations from the original plan inevitable. For small deviations, the original plan may still be executed with little or no need for adjustment. In more serious cases, the original plan may be infeasible. If not dealt with properly in a timely manner, such deviations will directly affect the companies' performance.

Disruption management is an emerging field in which operations research techniques are applied to deal with delays in a number of different environments. The literature on rescheduling is extensive. Yu and Yang [1] were the first to explore

D.-S. Huang, L. Heutte, and M. Loog (Eds.): ICIC 2007, CCIS 2, pp. 225–234, 2007.

issues related to real-time control of airline operations, and the successful application of their ideas has led to a growing interest in disruption managements. Disruption management techniques have been applied to many areas, such as production planning [2], project management [3], single machine scheduling [4], and parallel-machine scheduling [5]. Disruption management literatures related to the VRPTW is still rather scare. There only exist several literatures about the stochastic vehicle routing problems [6,7]. The main difference is that in our paper disruptions will happen at a particular time. The disruptions are associated with rare events of perhaps large consequence, and these occurrences are difficult to predict and extremely hard to deal with. The work presented here is the attempt to model and analytically solve disruption management problems that arise in the VRPTW.

The distinctive features of this paper can be summarized as following points: First, this paper describes the recovery problem, which is different from the classical VRPTW. This paper describes the introduction of the formulation for disruption management in the vehicle routing planning. We not only take into account the original objective function in the changed environment, but also consider deviations from the original schedule. Second, the rescheduling model is significantly different from the classical one due to the fact that the different neighborhood size and several new constraints must be considered. In the rescheduling model, we shouldn't need to search the entire customers, and only searching a unvisited subset, which is the set of customers that includes the interrupted customer as well as all the customers for which vehicles have not served at the disruption time. Moreover, in the recovery procedure, we present the hybrid algorithm, which is to hybridize the solution construction mechanism of the ACO with scatter search. Finally, within the scatter search framework, in addition to the local updating and global updating, we also use a temporary rule to update common arc pheromone values in the solution construction process of the ACO. The remainder of the paper is organized as follows. In Section 2, we describe disruption management. In Section 3, a hybrid algorithm is proposed to tackle the disruption management. Finally, the computational results are reported in Section 4, and the conclusion is given in Section 5.

2 Disruption Management for the Vehicle Routing Problem

Disruption management describes the efforts involved in the recovery procedure after a disruption occurs. It arises when unforeseen events have disrupted an existing schedule, and it is becoming more severe. Schedule recovery procedure is to modify the original plan and produce quick responses to accommodate sudden uncertainty disruptions in the VRPTW. In the most general cases, all parameters that define VRPTW may be disrupted and will trigger a rescheduling process. In this paper, we consider mainly a vehicle disruption. A vehicle disruption is said to occur when a vehicle becomes unavailable for some period of time. Possible reasons include vehicle failure, or the traffic conditions. Due to these disruptions, it takes more travel time or service time to complete than initially planned. An example of the original schedule with two vehicles is depicted in Fig. 1 (a). Fig. 1 (b) depicts the original schedule of the example problem, in which a disruption occurs at a particular