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Routing Problems with Time Dependencies or how Different are Trash Collection or Newspaper Delivery from Street Sweeping or Winter Gritting?

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Abstract

The focus of this paper is on the windy rural postman problem with the additional option to zigzag street segments during certain times of the day. If a street is narrow or traffic is light, it is possible (and often desirable) to service both sides of the street in a single pass by zigzagging. However, if a street is wide or traffic is heavy, we must service the street by two single traversals. For some streets, we further assume that they may only be zigzagged early in the morning when the traffic is low. Real-life applications arise, among others, in trash collection and newspaper delivery. This problem is solved by transforming it into a node routing problem and present a mathematical formulation.

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Keywords: windy rural postman problem; arc routing with time dependent zigzag options; time windows; city logistics; mathematical model; real-life applications

1. Introduction

This paper addresses an important class of arc routing problems, called the windy rural postman problem (WRPP), with several practical extensions that commonly arise in trash collection and newspaper delivery. In the WRPP, some (not necessarily all) of the streets in a network must be serviced and the street distances are asymmetric. We consider

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a variant of the WRPP by adding the additional option to zigzag street segments during certain times of the day. In more detail, if a street is narrow or traffic is light, it is possible to service both sides of the street in a single pass by zigzagging. However, if a street is wide or traffic is heavy, we must service the street by two single traversals. For some streets, we further impose the restriction that they may only be zigzagged at specific times of the day, e.g. in the early morning when there is virtually no traffic. This variation is denoted as the windy rural postman problem with zigzags and time windows (WRPPZTW) and was first suggested by [1]. We present a transformation of this arc routing problem into a node routing problem and give a mathematical formulation that can be solved by standard solvers (e.g. CPLEX, Gurobi). For a full version of our paper with a detailed discussion of related work, solution approaches, and computational study see [2].

Fig. 1 presents an example of WRPPZTW to introduce the problem in more detail and to motivate the use of zigzags with and without time windows. In Fig.1(a), there is an arc routing problem instance. There are five nodes. Node 0 is the depot. Solid lines represent arcs which require service. For simplicity, in this instance, all solid lines have travel time $D = 10$, normal service time $S = 5$, and service time in zigzag (zigzag time) $Z = 12$. Dashed lines are arcs over which one can travel. The number besides a dashed line is its travel time. For instance, for arc $(0,4)$, the travel time is 10. If we solve this instance as a traditional arc routing problem, the optimal route is shown in Fig.1(b) and its objective value is 110. Notice that arcs $(0,4)$, $(4,0)$, $(4,1)$ are not used in this solution although they can be shortcuts to access node 0. Now, if zigzagging is required on segment $\{2,3\}$ (one segment $\{i,j\}$ consists of two arcs (i,j) and (j,i)) and allow segment $\{3,4\}$to be zigzagged, the route in Fig.1(c) is now optimal and the objective value is 97. Here, the double-line arc and the triple-line arc represent zigzagging an edge which is zigzag possible and zigzag required, respectively. Furthermore, if segment $\{0,1\}$ can be zigzagged before time 25, we can obtain an even better route (see Fig. 1(d)). The objective value is reduced to 93. Lastly, these zigzags with time windows can change a route dramatically. If we allow the same three segments to be zigzagged, but a time window is imposed on segment $\{3,4\}$, instead of segment $\{0,1\}$, then a very different result is obtained. For example, if we can zigzag on segment $\{3,4\}$ before time 35, then the optimal route is changed to be the one in Fig. 1 (e) with objective value 101.

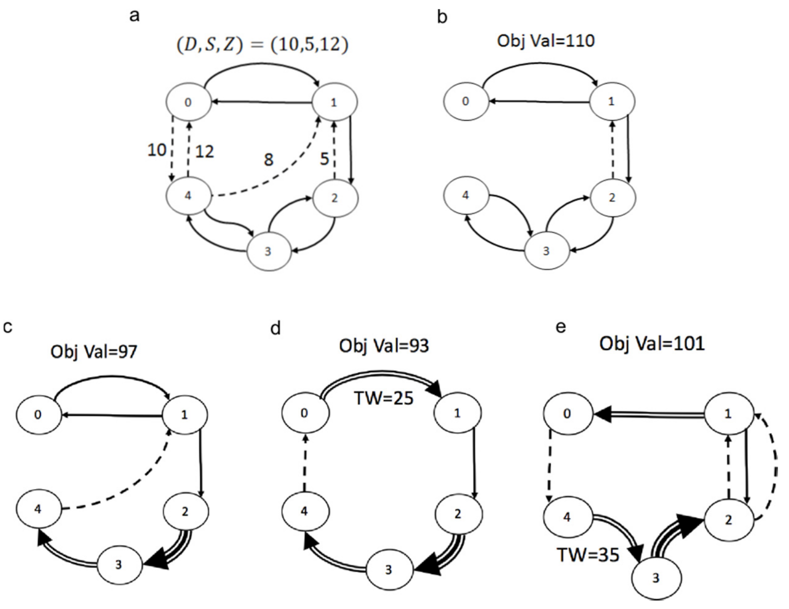

Fig. 1. (a) example; (b) solution in traditional setting; (c) zigzags allowed; (d) zigzags with time windows; (e) time windows change routes.

The WRPPZTW combines two variants of arc routing problems, arc routing problems with zigzag options and arc routing problems with time dependencies. A limited amount of literature has been published on arc routing problems with time dependencies. These dependencies relate, e.g., to service and travel times or costs that change over time or