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The Multi-Path Traveling Salesman Problem with Stochastic Travel Costs: Building Realistic Instances for City Logistics Applications

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Abstract

One of the main issues related to routing problems applied in an urban context with uncertainty related to the transportation costs is how to define realistic instances. In this paper, we overcome this issue, providing a standard methodology to extend routing instances from the literature incorporating real data provided by sensors networks. In order to test the methodology, we consider a routing problem specifically designed for City Logistics and Smart City applications, the multi-path Traveling Salesman Problem with stochastic travel costs, where several paths connect each pair of nodes and each path shows a stochastic travel cost with unknown distribution.

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1. Introduction

In the past decade, City Logistics pushed researchers towards the definition of a new paradigm of transportation and supply chain integration in urban areas. In recent years, this paradigm has been extended with the introduction of

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the concept of Smart City (Chourabi et al., 2012), where "smart" implies to incorporate a plethora of methods and disciplines in a holistic vision in order to mitigate problems generated by the population growth and its rapid urbanization. In this context, new transportation issues emerge, bringing researchers to define new transportation problems and, in particular, to incorporate information about uncertainty due to the transportation costs and multiple attributes (Perboli et al., 2012; 2011; Tadei et al., 2012). One of the main issues related to routing problems applied in an urban context with uncertainty related to the transportation costs is how to define realistic instances (Tadei et al., 2014). In fact, the instances present in the literature are often too much artificial to really reflect the peculiarities of urban transportation, and the freight transportation in particular. In this paper, we overcome this issue, providing a standard methodology to extend routing instances from the literature in order to incorporate real data provided by sensors networks. This type of data start to be freely available thanks to several European and National grants (see, for example, the data provided by the AperTO project of the municipality of Turin and the Open Data Services of the Piedmont Regional Council).

In more detail, the introduction of this problem is also motivated by a real-life Smart City application, the PIE_VERDE project, a project funded by the ERDF - European Regional Development Fund for the development of new planning tools for freight delivery in urban areas by means of electrical vehicles. In this project, one of the goals is to plan and manage a two-echelon delivery service, where trucks are not allowed to enter into the city. Freight is then consolidated in small peripheral depots and from them brought to customers by means of environmental-friendly vehicles (Crainic et al., 2012; Perboli et al., 2011). In this application context, a crucial part is played by the planning of periodic tours between recurrent nodes and the usage of environmental friendly vehicles as hybrid and electric LDV. In this case, the aim is to plan a tour for each vehicle valid for a given time horizon. Unfortunately, at the time of planning, the decision maker has only a partial idea of the different paths interconnecting any pair of nodes of the transportation network. Moreover, due to congestion the travel time profile of these paths rapidly changes during the day. Similar problems can be found also in other applications, like garbage collection or periodic replenishment of medium-sized grocery stores, where the truck tours are designed in advance and cannot be changed for a fixed number of weeks. Recently, the European project CITYLOG, a joint project between IVECO and TNT, presented the BentoBox, a modular system of containers for envelopes delivery. The containers are usually placed in malls and shopping centres and the company needs to design fixed tours in order to store the envelopes into them.

As test routing problem, we consider the multi-path Traveling Salesman Problem with stochastic travel costs (mpTSPs), a recently introduced stochastic variant of the Traveling Salesman Problem (Tadei et al., 2014). Given a set of nodes, where each pair of nodes is connected by several paths and each path shows a stochastic travel cost with unknown distribution, the mpTSPs aims at finding an expected minimum Hamiltonian tour connecting all nodes. Despite the PIE_VERDE project, the mpTSPs arises in City Logistics when one has to design tours to provide services such as garbage collection, periodic delivery of goods in urban grocery distribution, and periodic checks of shared resources as in bike sharing services. In these situations, the decision maker must provide tours that will be used for a time horizon, which spans from one to several weeks. In such a case, the different paths connecting pairs of nodes in the city are affected by uncertainty due to different time-dependent travel time distributions of the different paths. Moreover, in many cases even an approximated knowledge of the travel time distribution is made difficult by the large size of the data involved and the high variability of the travel times.

This paper contributes to extend the Transportation literature along different directions. First, we introduce a standard methodology to build realistic instances with time-dependent travel times starting from a network of speed sensors (Deflorio et al, 2012). The methodology we propose is easy to replicate, not requiring a deep statistical analysis on the historical data, and can be adapted to other cases where only a partial information about the road network is available. Second, we deeply analyse the results obtained by combining the academic instances with real data on the traffic flows taken from the city of Turin in Italy, showing the benefits and the limits of the methods presently available in the literature to solve the mpTSP.

The paper is organized as follows. In Section 2 the mpTSPs is introduced and the relevant literature is presented. Section 3 is devoted to sketch the experimentation plan, with a special focus on the design of the instances and the traffic scenario generation. The computational results of the newly defined instance sets are discussed in Section 4. Finally, Section 5 summarizes the lessons learned by this computation study and gives some highlights on future works.