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Time dependent travel speed vehicle routing and scheduling on a real road network: the case of Torino

Simona Mancini[a]

[a]*Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy*

Abstract

Vehicle routing and scheduling play a crucial role in the distribution chain. Although this research area has been broadly studied in the literature, there is still a lack of models closely representing real life problems. Most of the models proposed address constant travel times between nodes, without taking into account rush hours traffic congestion. In real applications in urban contexts the increasing of travel times due to congestion effects cannot be neglected. Models dealing with time dependent travel times work with simplified step functions, discretizing the time horizon in small time intervals. Even if this approach is broadly used, assuming travel times varying with discrete jumps is a strong approximation of real world conditions which evolve continuously. Another strong approximation adopted in the literature is that travel time (or speed) is computed on direct links, while in the real world vehicles travels on a road network, in which Euclidean distances do not hold anymore. In this paper, a vehicle routing problem (VRP) on a real road network with time dependent travel speed expressed by a polynomial function is addressed. Despite the difficulty to work with these kind of function, in this way congestion evolution behavior may be more precisely represented. In real situations, it is common to face different congestion peaks during the day, each one of which generally has different characteristics. Morning peaks are very sharp, i.e. congestion level rapidly increase reaching its maximum value which last for a short time after what congestion rapidly decrease, while evening peaks are generally much more spread across a longer time period and congestion variations are much more smoothed. Step functions, commonly used in practice, cannot represent at all realistic situations and peaks; linear functions may acceptable represents sharp peaks but not wider once. Polynomials, indeed, are able to better describe each type of peak. An application on Torino road network is presented. Speed evolution laws on main arcs are computed basing on real data obtained from an analysis carried out on averaged travel speed measured by an electronic system with 5 minutes intervals over two weeks. Small streets for which this data are not available are supposed to have a constant travel speed. Computational results show that taking advantage on the available information on different rush hour peaks intensity and spread on different arcs, it is possible to obtain better vehicle routing and scheduling plan.

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1. Introduction

The frenzy increase of life rhythm, within large urban centers, in the modern society yield to the necessity of reaching an high level of efficiency in freight distribution, in order to provide better services and to be more competitive. City logistics service providers are nowadays are expected to offer more reliable and reasonably priced delivery services. The complexity of underlying supply chains and increasing customer requirements demand for advanced planning systems producing cost-efficient and customer-friendly delivery tours. In fact, in the modern society, customers have become more exigent, and their requirements in terms of delivery conditions have strongly increased. They require goods to be delivered as soon as possible or within specific time windows during the day, therefore time has assumed a crucial role in logistics operation decision making. Due to a growing amount of traffic in the last decades and a limited capacity of the road network, traffic congestion has become a daily phenomenon (Kok et al. 2012). Traffic congestion may have several causes. Some are predictable, such as the large amount of commuter traffic during daily peak hours, while others are less predictable, such road accidents or vehicle breakdown. While the second ones cannot be foreseen, the first ones systematically occur, and it has been proved that the greatest part of observed delays depends on them (Skabardonis et al. 2003); therefore, they should be taken into account during the freight distribution planning stage. This is not a trivial issue because congestion level does not evolves according to the same law on all the arcs belonging to the same urban area, and traffic peaks may be reached in different moments of the day for different arcs, and they may last for few minutes, as for longer periods. Today's planning systems do not consider such time-dependent information; instead, they refer to rough travel time estimates in order to determine delivery tours while ignoring time-dependent variation of travel times. Thus, resulting delivery tours may be far from optimality, reliability and sometimes even far from feasibility. Inaccurate estimation of travel times may lead to higher routing costs, dissatisfaction of customers, driver overtimes, and penalties due to failing to meet customer time windows, with negative consequences on the quality of the service provided.

Another crucial issue concerns the network representation. Models presented in the literature generally work on networks composed by nodes and direct arcs connecting each couple of nodes. This representation does not hold for realistic problems, in which nodes are connected by path composed by part of different arcs, each one of which characterized by its own average speed and a variable congestion level during the day. Time-dependent travel time (or travel speed) models generally consider direct arcs and group them into few classes having the same congestion evolution function, (Ichoua et al. 2003). This is a strong simplification which does not allow to correctly represent real urban networks.

This paper deals with vehicle routing and scheduling on a real network with time dependent travel speed. The network is assumed to be composed by two kind of arcs. The first one represents main roads, which are affected by traffic congestion and characterized by a variable travel speed during the day. Each one of these arcs has its own travel speed variation law. The second kind of arcs represent small street not affected by congestion, for which we may assume constant travel speed. The network is connected, i.e. it is possible to reach each point of the network starting from every other point. The arcs are considered always one-way. For two-ways road two different arcs are generated, each one with its own characteristics. In fact, traffic congestion level can be sensibly different depending on the direction along which we travel it. For instance, during early morning hours, arcs entering the city centers are generally strongly congested, while traffic is fluid on the opposite direction, while the opposite behavior can be observed in late afternoon.

The goal of the paper is to show that taking into account time-dependent travel speed during the vehicle routing and scheduling phase, may yield to obtain better tours configurations with a consequent reduction of global travel times, and therefore, to be able to provide a better and cheaper service for the customers.

The paper is organized as follows. In Section 2, a deep and critical analysis of literature review on time-dependent vehicle routing is provided. In Section 3 a description of the problem analyzed is given, while the heuristic method, used to optimize the routing and scheduling of vehicles, is described in Section 4. An application on the real road network of Torino, in Italy, is showed in Section 5, where vehicle tours configuration provided considering time-dependent travel speed arcs are compared with the solution obtained considering static travel speed on arcs. Finally, Section 6 is devoted to conclusions and future developments.