Integrated optimization and decision support systems for attended home delivery and service problems

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This a summary of the author's Ph.D. thesis, supervised by Manuel Iori and Carlo Alberto Magni and defended on February 10, 2023 at the University of Modena and Reggio Emilia. The thesis is written in English and is available from the author upon request at dario.vezzali@unimore.it and from https://hdl.handle.net/11380/1298349.

The thesis deals with the wide class of *Attended Home Delivery* (AHD) and *Attended Home Service* (AHS) problems, which have experienced a fast growing rise in the last two decades. The purpose is twofold: (i) to provide a state-of-the-art overview of AHD and AHS problems and (ii) to solve specific real-world applications in service industries, like gas and water distribution, and maintenance services through integrated Decision Support Systems (DSS), based on mathematical formulations and additional modules.

In the first part of the thesis, we provide an extensive survey on AHD and AHS problems. Given the multi-stage nature of these problems, the most relevant articles on demand management and routing in AHD and AHS are reviewed. In line with the rest of the work, a focus on practical applications is maintained.

In the second part of the thesis, we present real-world applications of AHD and AHS problems for which a formal problem definition is given, an exact or heuristic solution method is developed, and an integrated DSS is implemented. First, we present a DSS for solving a specific three-stage AHS problem that arises in the context of public tenders for gas distribution in given territorial areas. In this real-world AHS problem, some machine learning models are invoked before optimization and simulation methods to recreate unknown information, based on a mix of available historical data and additional open data. The DSS, implemented as a modular system, is currently used by *IRETI SpA*, an Italian multi-utility company, to design and fine-tune the organizational models proposed in the public tenders. The results of this work have been published in B.P. Bruck, F. Castegini, J.-F. Cordeau, M. Iori, T. Poncemi, D. Vezzali, "A Decision Support System for Attended Home Services", *INFORMS Journal on Applied Analytics*, 50(2), 137–152, 2020.

AHD and AHS problems also occur in a *business-to-business* environment, where companies provide services to other companies. In particular, one may find service providers that subcontract the execution of maintenance services to external qualified suppliers, as in the case of those general players competing in the facility management industry, named Global Service Providers (GSP). Starting from a real-world supplier selection problem arising in the facility management industry, we present a DSS in which multi-criteria decision analysis is applied to group and weigh the multiple criteria that occur in the problem of selecting the best supplier for a given contract. The DSS has been implemented and tested with *H2H Facility Solutions SpA*, an Italian GSP company. Preliminary results of this work have been published in B.P. Bruck, D. Vezzali, M. Iori, C.A. Magni, D. Pretolani, "A Decision Support System to Evaluate Suppliers in the Context of Global Service Providers", In *Proceedings of the 23rd International Conference on Enterprise Information Systems - Volume 1: ICEIS*, 420–430, 2021.

In the last part of the thesis, we address two other applications of AHD and AHS problems. In particular, we present a real-world case encountered in the city of Mashhad (Iran), where a complex water distribution network must be inspected daily by a group of technicians. This problem, called the Vehicle Routing Problem for Water Distribution Networks (VRPWDN), is characterized by the presence of precedence constraints and multiple visits. To solve the VRPWDN efficiently, we propose a Mixed Integer Linear Programming (MILP) formulation and an iterated local search algorithm, and test them on randomly created and realistic instances. Finding an effective and efficient solution for real-world AHD and AHS problems in a more automated and sustainable way is not limited to the operational side, but can be translated into a suitable accounting and financial model to provide a reliable valuation of the technical project. Starting from a real-world problem arising in the context of water distribution, a net present value is set as the objective function of a MILP formulation describing the specific smart-meter installation scheduling project faced by *IRETI SpA* in the province of Reggio Emilia. Computational experiments on realistic instances are performed using alternative approaches and different time horizons.