



## Review

## Home health care routing and scheduling: A review



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## ABSTRACT

In home health care (HHC) operations, nurses are scheduled and routed to perform various services at clients' homes. As this often requires a combination of vehicle routing and scheduling approaches, resulting optimization problems are complex and, hence, of high interest to stakeholders such as researchers, practitioners and policy-makers. With demand for HHC expected to increase substantially, future work is essential to decrease costs and to guarantee service quality. In this review, we provide a comprehensive overview of current work in the field of HHC routing and scheduling with a focus on considered problem settings. Recent advances in HHC optimization are highlighted and future research directions discussed.

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## 1. Introduction

Population aging and a decrease in informal care are likely to lead to a substantial increase in demand for home health care (HHC) services [51]. In 2011, more than 4.7 million patients received HHC services in the U.S. and of the 12,200 HHC service providers registered, which employed 143,600 full-time equivalents in 2012, around 78.7% were classified for profit [34]. In Europe, between 1% and 5% of the total public health budget is spent

on HHC services [31]. An overview of the settings in various European countries is given in Genet et al. [32]. Current risks and trends in HHC are further discussed in Rest et al. [56].

To compete in the market and to lower public expenditures, increasing service quality and decreasing costs are major focus points. Out of this important topic of high public interest originates various challenging optimization problems. Among these, HHC routing and scheduling problems have gained considerable interest over the past years. Considering a wide range of regulative and operational constraints, HHC planners assign nurses to clients and schedule working times. Additionally, travel routes and arrival times of nurses to each client have to be planned. Nevertheless, although these tasks are highly complex, routing and scheduling of

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HHC services are often done manually [26,61,65], resulting in high organizational efforts and potentially sub-optimal solutions. For instance, in a survey on the working time of HHC nurses in two municipalities in Norway, Holm and Angelsen [39] show that driving time accounts for between 18% and 26% of working time, of which 22% of the driving routes were underestimated. This indicates the high potential of optimization in routing and scheduling to improve operations and lower expenses.

Various topics in HHC routing and scheduling are closely related to other research fields. An overview of operations research (OR) methods in health care is given in Brailsford and Vissers [16] as well as in Rais and Viana [52]. Cheang et al. [24] and Burke et al. [19] review nurse rostering. Workforce routing and scheduling problems are investigated by Castillo-Salazar et al. [23] and a computational study is provided. The authors list HHC as one real-world application. A high-level overview on logistical management problems in the field of HHC is given in Gutiérrez and [33] and OR applications in HHC in Vidal [11].

HHC routing and scheduling solution procedures differ substantially as problems considered often originate from different national and regulatory settings. To close this gap, this review provides an overview of work in HHC routing and scheduling. Therefore, an extended definition of HHC is used, which includes various health related services performed at clients' homes such as home care, mobile care and extramural health care, terms which are often used interchangeably in the literature. The focus of this review is set on the routing and scheduling of nurses to clients, whereas the terms 'nurse' and 'client' are used for the remainder of the paper to describe any staff member performing a task or customer receiving a health care related service respectively.

The objective of this review is to compare different objectives and constraints and to further highlight future research directions. To focus on the most relevant work, only published journal articles available online by October 2015 were included. As a consequence, conference publications, book chapters as well as technical reports and working papers are not considered. To derive the list of articles in this review, work containing the terms 'home care' or 'home health care' as well as 'routing' or 'scheduling' in the

keywords or abstract was collected. Each shortlisted article was studied in detail and excluded if not within the scope of this review. Hereby, in particular HHC papers which deal with the delivery of medicine or equipment were excluded as the focus of this review is set on the routing and scheduling of nurses. In a final step, the reference sections of the remaining articles were scanned as well as any other articles citing these articles. Additional works of interest were added to the shortlist and again checked for relevant references or citations. Fig. 1 gives a network representation, created with the software Gephi [8], of main topics in the field of HHC routing and scheduling based on selected authors' keywords of the papers reviewed in this work. These include time windows, continuity of care and synchronization issues as well as various solution methods.

Short classifications of selected HHC routing and scheduling papers are found as part of the literature review in Bachouch et al. [4], Gayraud et al. [30], Mankowska et al. [46], Maya Duque et al. [47] and Braekers et al. [15]. These classifications acted as a basis for this work and were verified, merged and extended. The resulting review is structured as follows: Section 2 gives a brief general problem description of HHC routing and scheduling. Section 3 analyzes single-period planning problems, while work on multi-period problems is investigated in Section 4. The review concludes by highlighting promising future research directions in Section 5 and concluding remarks in Section 6.

## 2. Routing and scheduling of home health care services

HHC planners face complex and challenging optimization problems on different decision-levels, such as shift scheduling, staff assignment and staff routing decisions [33]. In most cases, a set of heterogeneous nurses has to be assigned to heterogeneous clients, who are spread over the operational area. Therefore, various requirements potentially have to be considered, such as matching nurses' skill and clients' requirements, respecting preferences, various regulations as well as additional real-world complications of HHC services such as continuity of care or workload balance

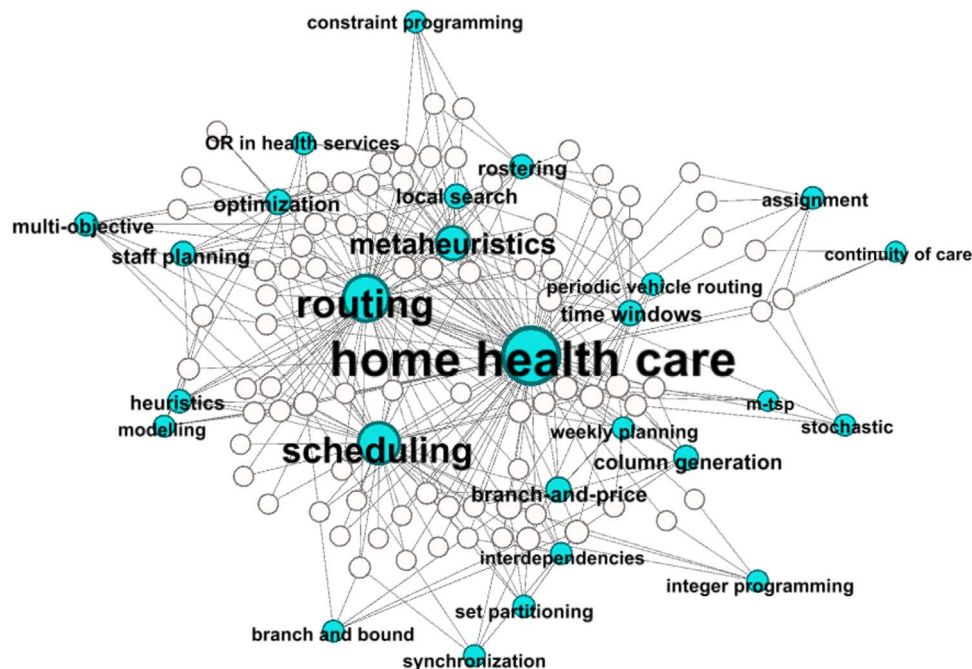


Fig. 1. Visualization of selected author's keywords of the reviewed papers (white circles represent authors; filled circles keywords with the size of the circle representing how often a keyword was included in the sample).

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