Operations Research for Health Care 13-14 (2017) 1–22

Contents lists available at ScienceDirect

Operations Research for Health Care

journal homepage: www.elsevier.com/locate/orhc

OR problems related to Home Health Care: A review of relevant routing and scheduling problems

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ARTICLE INFO

Article history:
Received 26 February 2016
Accepted 11 June 2017
Available online 29 June 2017

Keywords:
Home health care
Vehicle routing problem
Literature review

ABSTRACT

The home health care routing and scheduling problem (HHCRSP) consists of designing a set of routes used by care workers to provide care to patients who live in the same geographic area and who must be treated at home. Hence, care activities, i.e., patient visits, must be planned to minimize measures, such as travel costs or to maximize the quality of service delivered to patients while respecting several constraints.

The HHCRSP is an extension of the vehicle routing problem (VRP) with unusual side-constraints that make the issues difficult to solve. This paper details a comprehensive overview of recent OR models developed for the HHCRSP, a field that has received a great amount of attention in recent years. To summarize the existing research contributions, we initially identify the most relevant features considered in the HHCRSP models, and then analyze the existing literature according to the way the different studies formulate the constraints and objective functions. We then provide an overview of methods developed to solve the HHCRSP and discuss future research directions.

Contents

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http://dx.doi.org/10.1016/j.orhc.2017.06.001
2211-6923/

1. Introduction

Home health care (HHC) consists of a wide range of health care services that are provided in patients' homes in cases of illness or injury. As reported in recent demographic studies, health care services in many countries are shifting from hospitals to home health care providers. According to Genet et al. [1], in Europe 1%–5% of the total public health budget is spent on HHC, which is expected to generate three main advantages: a decrease in hospital admissions, a decrease in hospitalization duration, and ability for to remain in their homes. Recent literature reviews regarding operations research (OR) models applied to HHC can be found in [2–5]. Additionally, a hierarchy of operations management decisions in HHC organizations has been recently proposed in [6,7].

These studies reveal a great number of decisions related to the human resource planning issue that lead to OR problems (see Fig. 1). Among these issues, the districting problem is a subject of interest at a strategic level. This problem consists of partitioning the HHC service territory into clusters of patients and aggregately assigning each cluster to a set of resources, e.g., care worker [8,9]. Districts are designed according to various criteria. For example, a first criterion can be the respect of the maximum distance between two patients assigned to the same district, which would be closer than the current acceptable value. Another possible criterion is the balancing of workloads among the designed districts. Resource dimensioning, another OR problem in HHC, addresses the problem of identifying the level of resources required in HHC and assigning these resources to the districts. Resources can be people or materials, e.g., the number of care workers to deliver care services or the number of technical devices required [10]. Resource dimensioning is generally done at a tactical level. At an operational level, two main problems appear: the operator assignment problem and the home health care routing and scheduling problem (HHCRSP). The first consists of deciding which care workers deliver care services to which patients [11], whereas the HHCRSP aims at scheduling patient visits assigned to each care worker. These two problems can be considered simultaneously or independently [12,13].

Fig. 1 summarizes the human resource planning process described above, by referring to the outputs associated with each decision level and the related OR problems.

The goal of this paper is to analyze the existing literature pertaining to OR models applied to the HHCRSP that are found in relevant journal papers, conference proceedings, Ph.D. theses, and books that represent 17 years of work in this field. HHC routing and scheduling solutions differ from existing models since problems considered often originate from different national and regulatory settings. Existing publications were initially selected by browsing the bibliographic databases Web of Science, Science Direct, Jstor, semanticscholar, CiteSeerX and using Google Scholar. Keywords used in the search were: "home health care", "home care", "resource scheduling", "routing", and "vehicle routing problem". Additional publications were identified based on the reference lists of the selected works.

The present literature review differs from earlier studies because it focuses primarily on the HHCRSP on which an increasing number of academic studies have been conducted in the last two decades (Fig. 2). This trend is due first to the fact that HHC is a promising and growing sector [5] and, second, most home care providers do not use OR tools to design care worker routes which can result in sub-optimal solutions. Furthermore, in most settings, the personnel dedicated to this task have limited skills because typically they come from a medical, rather than an OR background. Rintala et al. [14] studied the potential role of operations management research in organizing and improving home care for the elderly. They presented a review of existing service operations management literature in order to present typical managerial implications. Next, they described a case study in a home care context, and conducted interviews. Working groups collected suggestions on the types of operational level problems the management research could solve and HHCRSP was identified among these problems.

A recent literature review related to HHC routing and scheduling problem was published [15]. However, we propose a complementary and extended literature review with some important differences. First, Fikar and Hirsch [15] included mainly published journal articles available online before October 2015. We extended the review to other relevant sources of information, such as conference proceedings, book chapters and technical reports. We also extended the review to works dealing with the more general issue of routing and scheduling problems, which may concern both human resources as well as material resources, e.g., delivery of medicine or equipment. Moreover, features related to HHC operations are discussed in more detail and the studies are positioned in a larger framework that deals with OR problems in HHC. For example, the continuity of care that is a main feature in home care context, is integrated in different ways in existing models (e.g. as a constraint that states all visits of a patient is assigned to the same care worker or to a limited group, or as an objective function to minimize the number of different care workers per patient). In this case, we discuss how this feature and its different levels (full or partial continuity of care) is taken into account as assignment constraint or objective function in the literature. Thus, we propose a finer classification of the available literature, which is based on constraints in existing models and objective functions. Finally, we propose a deeper analysis of methods developed thus far to solve HHC routing and scheduling problems and a benchmark for instances and data sets used in the available literature. Two other literature reviews related to HHC routing and scheduling problem are available: a technical report [16], which deals with human resource scheduling and routing problems in a home health care context, and a conference paper [17], which focuses on HHC staff scheduling. Papers included in the present paper are partially found in [15]. Hence, our paper verifies some of the existing classifications in the literature and extends the topic by developing a more comprehensive and up-to-date review on the HHCRSP.

To classify existing research contributions, we propose a review that highlights the most relevant features, constraints and objectives considered in the existing studies. We also present available methods to solve the HHCRSP and provide directions for future research.

This paper is organized as follows: In Section 2, the HHCRSP is briefly described by highlighting relationships with some well-known combinatorial optimization problems. Section 3 describes features that we consider the most relevant for the HHCRSP models and details how they are modeled as constraints in the literature. In Section 4, existing papers are classified according to how they formulate the objective functions. Then, Section 5 addresses methods that enable obtaining exact and approximate solutions for the HHCRSP. Section 6 provides a discussion on results obtained and concludes with suggesting for promising future research directions.