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Home Health Care Problem Related to Routing and Scheduling

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Abstract: Home Health Care (HHC) is a form of nursing that provides medical and non-medical health services to patients in their places of residence. It aims to help individuals who require treatment, monitoring, or recovery to receive professional medical services in the comfort of their homes. The purpose of this paper is to propose a literature survey on HHC dealing with routing and scheduling and some discussions on current trends with a focus on the medical resource aspects.

Keywords: Home Health Care, Vehicle Routing, Routing and scheduling.

1. Introduction

Home Health Care (HHC) is a human-centered service that takes hospitals, communities or companies as the mainstay, and designates care workers to bring necessary medical equipment and medicines to patients' homes to provide medical checkups, rehabilitation care and life care services according to their service needs, which is very different from the traditional medical service model. In the process of home services, a series of problems such as scheduling of home services, allocation of caregivers and planning of home routes arise, which can be referred to as the Home Health Care Routing and Scheduling Problem (HHCRSP). The purpose of HHCRSP is to minimize the cost of services and optimize the allocation of resources while meeting the needs of patients.

With the expansion of home bed care services, the content of HHC is also gradually expanding and enriching. The transportation and scheduling of medical equipment and materials have become an important sub-problem in HHCRSP. Unlike traditional material distribution problems, medical material distribution in the field of HHC has more complex constraints. When carrying out the distribution of medical materials, not only the patient's time window needs to be considered, but also the care worker's time window or other constraints. Masmoudi et al.[1] mentioned large-scale medical equipment may be needed to support nursing services during the care process. For example, some chronic disease patients need to use oxygen tanks to maintain their lives, while some heart disease patients need to use electrocardiographs to monitor heart function. The application of these devices in home care services has increased the complexity and difficulty of care service scheduling and planning. When large medical equipment is needed and nursing staff cannot carry it with them, transportation and scheduling of medical equipment and materials become important sub-problems in HHCRSP.

2. The description of HHCRSP

In an HHCSRP, a group of patients spread across a specific area are in need of care for varying durations and require specific qualifications to receive care at their homes. Care is provided by care workers who possess different skills and have varying availabilities, managed by an HHC agency. HHCRSP is actually a two-stage combinatorial optimization problem. The first stage is based on the patient's request to assign care workers, and the second stage is to plan the order of service and visit routes for the care workers. In assigning the order and routes of care workers to visit patients, it can be regarded as an extension of the Travel Salesman Problem (TSP) or Vehicle Routing Problem (VRP), which have been extensively studied, and their research results can be fully borrowed and somewhat extended according to the specificity of the problem. Therefore, HHCRSP can be described as follows: a HHC agency arranges matching care workers to provide services at patients' homes according to their needs, each are worker has a planned service route, and the service process needs to satisfy a series of constraints to achieve certain goals (e.g., minimizing service costs and maximizing service satisfaction) while completing the service.

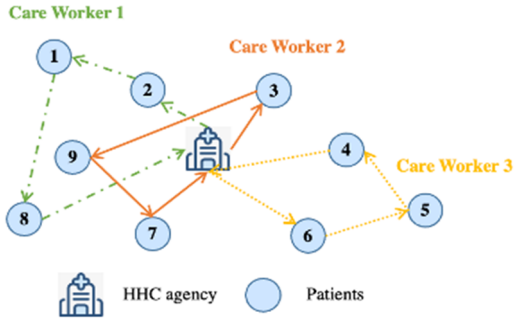

Figure 1. Example of an HHCSRP solution with 3 care workers and 9 patients.

An example of such a problem, with one HHC agency providing care to 9 patients and 4 care workers is given in the left part of Fig. 1. Typically, care workers start their travel from the HHC agency, utilizing a range of transportation methods such as cars, public transport, cycling or walking, and return at the end of their working period. The HHCSRP involves making decisions on which care worker should visit each patient at what time, while adhering to diverse constraints and optimizing specific criteria (such as cost or quality of services) over a given time period.

HHCRSP is a complex problem involving multiple constraints and requires consideration of the effects of many factors, including patient demand, care workers skill matching, and visit time windows. The type and number of factors considered can have an impact on the complexity of

the model. Depending on the focus of the study, HHCRSP can be classified into the following types:

Planning horizon

Single-period HHCRSP: care is carried out within the scope of one working day, i.e., caregivers are required to complete care services for assigned patients within one day, with attention to timeliness of care, skill matching.

Multi-period HHCRSP: Unlike the Single-period problem, the patient's care needs may be spread over a period of time, rather than the same day. Therefore, care workers may work multiple days and not necessarily have the same patients to visit each day; and patients may request multiple services at different times of the week or month, focusing on continuity of services.

Uncertainty

Deterministic HHCRSP: The patient's care service demand can be determined in advance, and the allocation of resources and the planning of the access path can be carried out in advance according to the predetermined time window of patient preference, demand and resource situation.

Uncertainty HHCRSP: Some uncertain situations may occur during the care workers service process, such as changes in the access time window, patient service length or demand due to unexpected events, which are solved by applying stochastic planning, opportunity constrained planning or robust planning methods.

Collaborative

Non-collaborative HHCRSP: The patient's service needs can be completed by only one care worker, and there is no other need for medication delivery or medical services that require home visits within the same time window.

Collaborative HHCRSP: The service process in which some patients' service content cannot be completed independently by one care worker, and requires the assistance of two or more care workers, at the same time can be called collaborative. In some situation patients with multiple needs within the same time window, such as meal delivery, injection treatment, and other service contents provided by different care workers.

3. The Literature

3.1. Some HHC reviews

Cissé et al. [2] analyzed constraints for different parties from the perspectives of HHC agency, customer, and care worker. The authors summarized commonly used mathematical expressions for four frequently used objective functions: minimizing travel costs, minimizing unallocated costs, minimizing care workers numbers, and maximizing satisfaction. Finally, provide an overview of methods developed to solve HHCRSP, and discuss future research directions.

Fikar and Hirsch [3] reviewed 25 single-period and 19 multi-period home health care papers from the perspective of service plan period. In single- period HHC papers, travel time, travel cost, and customer visit volume were the most common optimization objectives, while time window, skill requirements, and work duration were the most common constraints. Only a small number of papers considered uncertain customer demands and service times. In multi-period HHC papers, travel time and cost were still the most common optimization objectives, but more attention was given to service coverage, care workers work balance, and service continuity. The authors found that with the deepening of HHC research, more scholars began to focus on service synchronization and continuity, rest time, and customer and workers preferences. Some problems in uncertainty, multi-stages, and multiple modes of transportation still need further research.

Di Mascolo et al. [4] conducted a quantitative analysis and summary of 192 HHC-related papers as of November 2020, and summarized the constraints and objective functions for different needs. The authors found that minimizing travel time, distance, or cost remained the optimization objective for most papers, but the proportion of papers that used this standard has slightly decreased since 2017, and more attention has been paid to customer preferences. In addition, they reviewed 37 related papers on uncertainty and dynamic programming, which are less studied, and found that uncertainty of travel time, service time, and demand received more attention from scholars. In 67% of uncertain HHC papers, the objective function was similar to that of deterministic problems, while in the remaining 33% of papers, the objective function considered reducing deviations from the original plan caused by uncertainty problems, that is, minimizing deviations from the original plan.

3.2. Medical resource

Ricauda et al. [5] described the relevance of special equipment in home care services, taking elderly chronic obstructive pulmonary disease patients as an example. They pointed out that in addition to human resource arrangement, home bed services for these patients also require the supply of two types of materials: consumable medical supplies that are not renewable such as oxygen concentrators, and dedicated equipment that is renewable such as Doppler ultrasound and electrocardiograph machines. Reasonable scheduling and management of these devices and resources are necessary to ensure smooth care services. Therefore, the addition of medical resource routing planning and scheduling will increase the complexity and difficulty of care service scheduling.

Liu et al. [6] studied the scheduling problem of four types of demand requirements in HHCRSP, including nursing staff driving from the nursing center to the patient's home to deliver drugs and medical equipment, transporting blood samples collected from the patient to a medical laboratory, and collecting and taking back medical waste, unused drugs and medical devices to the nursing center. Two mixed integer programming models were proposed and solved using genetic algorithm and taboo search algorithm. Shi et al. [7] studied the problem of drug distribution in HHC services, assuming that the amount of drugs needed by each patient is uncertain, and treating this uncertain demand as a fuzzy variable. A fuzzy chance constraint planning was constructed based on the theory of fuzzy credibility, and the vehicle travel cost and distribution cost were minimized under the premise of satisfying patient time window constraints and fuzzy demand. A hybrid genetic algorithm was proposed for solution, which combined genetic algorithm, improved greedy algorithm and local search algorithm to obtain better solutions. Nasir and Kou [8] added three door-to-door services of drug delivery, blood collection and meal delivery within the nursing staff service time window in the HHC problem. The route of the nursing staff's door-to-door service is asynchronous with the other three door-to-door services, but the items must be extracted or delivered within the nursing staff service time window. A mathematical programming model was

constructed to minimize path cost and assignment cost.

In addition to drug and basic medical material distribution, there is another type of medical material involved in home bed care services, such as some chronic disease patients who need to use oxygen tanks to maintain their lives, while some heart disease patients need to use electrocardiographs to monitor heart function. Cappanera et al. [9] studied the path planning problem between nursing staff with different skills and demand patients, setting that some nursing operations may require special equipment, considering the asynchronous access of special equipment and nursing staff to the same patient. The paper proposed a lower bound estimation technique called BiGraphLB, which is based on the idea of bidirectional graph, representing tasks and vehicles as two independent sets of vertices, and using edges to represent relationships between tasks and vehicles. Then, the minimum cost for each task is calculated to estimate the lower bound of the problem. This technique can effectively improve the efficiency of the algorithm and achieve good results in experiments. Asghari et al. [10] studied the distribution and retrieval problem of home blood dialysis machines as shared devices in HHC. In the context of shared economy, individual owners who have the devices are added to the system of home bed care services, establishing a sharing network, allocating blood dialysis machines to different patients, and then formulating a delivery and recycling plan to achieve the goal of minimizing costs and carbon emissions. A self-learning non-dominated sorting genetic algorithm (SNSGA-II) was proposed for solution.

4. Summary

This paper has surveyed literature on HHCRSP, a field that has received increased attention in recent years due to multiple operational considerations and the high importance of such services to the public. The article provides a summary of the concept and related literature of HHCRSP, with a focus on considering healthcare resources. Currently, research on HHCRSP that takes medical resources into account is relatively limited and many issues still require further investigation.

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