Operations management applied to home care services: Analysis of the districting problem

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ABSTRACT

In this paper, we focus on a specific operations management related issue faced by home health care (HHC) services, namely the districting problem. Our contribution consists of formulating the HHC districting problem as a mixed-integer programming model by considering criteria such as the indivisibility of the basic units (i.e. locations where patients live), compactness, workload balance between human resources and compatibility. The formulations developed are based either on balancing the personnel care workload or minimizing the travel distance to reach the patients. Computational results obtained from the models show that they enable to improve the service quality towards HHC patients as well as caregivers by optimizing the compactness and workload balance criteria.

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1. Introduction

Recent developments in technological, social and economical environment have dramatically increased the need for improved service systems. Well designed service systems allow reducing costs and increasing customer satisfaction. This paper deals with a well-known type of service system, namely the home health care service. Home health care (HHC) which represents an alternative to the traditional hospitalization has been developed in France fifty years ago in order to solve the problem of hospitals' capacity saturation by providing to patients, at their home, complex and coordinated medical and paramedical care for a limited period which can be extended depending on patients' needs. This care is comparable, in terms of nature and intensity, to the one which would be delivered to the patient within a traditional hospitalization framework where the patient stays in the hospital to receive his/her treatment. HHC can be prescribed either by the family doctor or the doctor in charge of the patient in the hospital. Once admitted to a HHC structure, patients who suffer from pathologies such as cancer, nervous system diseases, circulatory system diseases, etc., receive medical and paramedical care based on one or several protocols/standards of care. The French HHC structures use twenty four protocols of care listed in the circular of May 30th, 2000 such as: the chemotherapy, radiotherapy, breathing assistance, palliative care, post-operation treatment, etc. [14]. Based on these protocols as well as on patients' social conditions, their age and their autonomy measured by the Karnofsky Performance Scale Index, a therapeutic project is then designed for each

patient so that the number and average duration of visits required during the treatment of the patient within the HHC as well as the type and number of human and material resources required for the care delivered can be determined. The diversity of human resources that can be involved in the care (e.g. physicians, nurses, physiotherapists, social workers, home support workers, pharmacists, etc.) explains, as it will be described in detail later in the paper, the necessity of assigning to each patient a reference caregiver who is in charge of coordinating the execution of the therapeutic project. At this level, it is important to mention that most of HHC structures classify patients' therapeutic projects into categories named "profiles". Indeed, patients whose therapeutic projects have similarities in terms of the expected duration of care, type, number and average duration of visits are grouped into the same profile.

During the last decade, HHC services have known an important growth. Indeed, the total number of HHC structures in France rose steadily from 68 structures in 1999 to 123 in 2005 and finally reached 271 structures in 2007. Despite the importance of the development of HHC services in practice, the amount of investigations dealing with operations management problems within the HHC context still remains modest, in comparison with earlier models developed for hospitals (e.g. [15,21,26], etc.). Most of the investigations considering HHC services mainly focus on either the problem of assigning caregivers to patients (or to visits) or the routing problem. Among the existing works developed so far, some models have been able to capture some of the specificities of HHC operations, i.e. what makes this care service different from the one delivered by hospitals, with respect to the way operations are managed. Hence, a first characteristic we can identify is the issue of the continuity of care in the HHC context defined by Shortell [29] as being the extent to which the medical

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and paramedical care are delivered by means of a sequence of coordinated and uninterrupted activities consistent with patients' needs, if possible by the same human resources. In practice, in order to guarantee the continuity of care in HHC, a patient is often assigned to only one caregiver, the reference caregiver, who follows the treatment of the patient during the time spent in the HHC structure. Most of time, the reference caregiver is the nurse who gives the paramedical care and coordinates the overall care with other caregivers such as the physician, social worker, etc. This is an important quality requirement of the HHC service due to the fact that it enables to preserve the service quality perceived by the patient since he/she receives the care from the same caregiver and thus does not have to continuously change his/her relationships with a new caregiver. A second characteristic of HHC operations is the necessity to integrate the patients' home within the care supply chain and hence to move the different flows of human and material resources needed for the care towards the patients' home. However, the diversity of human resources delivering the care and the variety of clinical and organizational decisions involved in the care delivery process need a tight coordination between different types of caregivers and material resources. Note that this coordination is especially difficult within this context since these resources are not grouped in the same health unit [12]. Another interesting problem which seems to us specific to HHC services concerns the consideration of human aspects while choosing the best organization for caregivers' teams. More specifically, if we consider one type of HHC caregivers, let's say the nurses, one may be interested in investigating the difference between two organizations: in the first organization, we assume that all nurses are grouped in a single team so that all the patients are treated by the same nurses' team independently of the basic unit where they live, while in the second organization, the area where the HHC structure operates is partitioned into several clusters (subareas), each of them being managed by a dedicated nurses' team. In our terminology, each cluster will be called a district. This second organization may enable not only to answer to a patient demand more quickly but also to increase the quality of service provided to him/her due to the diminution of the average time spent to reach him/her. Therefore, caregivers can spend more time in delivering care to patients. Furthermore, working in smaller areas, i.e. districts, within a smaller team may enhance caregivers' motivation since they can find a reinforced collaboration inside the team they belong to as well as a closer proximity with the HHC manager in charge of their team. Hence, the aim of a HHC structure in considering a districting approach may be to better manage its employees and, as a consequence, to satisfy patients more efficiently.

In this paper, we focus our attention on the districting problem due to the importance of such a decision in the achievement of HHC objectives in terms of improvement of the care delivery efficiency. Indeed, as explained above, the districting of a territory is a strategic HHC decision which aims at grouping basic units (a set of patients) into larger clusters, i.e. districts, so that these districts are "good" according to relevant criteria. These criteria can be related to the activity, demography or geographic characteristics of the basic units. Even if the districting approach can be viewed as time and resource consuming, it can have important impacts on caregivers' team structure and patients' satisfaction level.

This paper is organized as follows. In Section 2, we survey the literature related to our work: the first part of investigations reviewed concerns models that are developed in the operations management literature applied to HHC services while the second part is more related to the districting approach. In Section 3, we propose two mathematical formulations for the HHC districting problem. Results of computational experiments carried out on randomly generated instances to validate these two models are presented in Section 4. Finally, Section 5 presents some conclusions and perspectives that can be considered for future research.

2. Literature review

This part surveys two types of literature: operations management based models which have been proposed in the HHC literature and districting models developed in the operations research literature.

The three main issues treated in the existing HHC operations management literature are the problems of strategic resource dimensioning, districting and scheduling of human resources' activities. The first issue has been considered by Busby and Carter [9], who created a decision tool for the Simcoe County Community Care Access Center (SCCCAC) in Ontario. This tool enables to determine the trade-offs between three key factors: costs, service quality and patient waiting time. Based on these trade-offs, the SCCCAC could use this evaluation for determining the number of caregivers, with particular skills, and the quantity of different material resources necessary to satisfy the demand with the expected service quality level and minimum costs. De Angelis [16] has also addressed this problem for HHC structures providing services to AIDS patients. The author has developed a stochastic linear programming model which is linked to an epidemiological model and integrated the uncertainty in terms of patients' number and level of care required by each patient class.

The districting problem in the HHC context has been considered by mainly two authors. A multi-criteria approach have been first proposed in [6] for a local community health clinic in Montreal, Canada. This approach is based on criteria related to visiting personnel mobility and workload equilibrium which are combined into a single objective function but also on criteria related to the indivisibility of basic units, respect of borough boundaries and contiguity which are considered as hard constraints. The optimality of the method proposed in [6] has been reviewed in [24] by analyzing historical data which has underlined the fact that the approach proposed cannot forecast the fluctuation of the demand in each district. Furthermore, the model proposed in [6] has not been flexible enough in terms of assignment of caregivers to districts. In order to alleviate the overload of caregivers, [24] have proposed two solutions: the first one is a dynamic approach where the nurses are not assigned to a fixed district while the second consists of splitting the caregivers into two groups: the first one represents the caregivers assigned to a fixed district while the second one groups the caregivers that can work in all or a part of the territory.

Once the territory is divided into districts, the different resources must be assigned to the districts equitably. For this purpose, Boldy and Howell [7] have conducted a case study related to the allocation of home help resources to four geographical districts within the Devon Social Services Department.

A large amount of works in the HHC literature consider the scheduling of caregivers' activities which involves two hierarchical decisions. First, caregivers are assigned to patients or visits. Then, individual routes are constructed for each caregiver by determining at what time each visit must be done. To our knowledge, there is only one work that deals with the scheduling problem within the continuity of care context which has been conducted in [8]. The scheduling problem without considering the continuity of care has been treated by various authors. In this context, the patient is associated to a visit or a set of visits. The first decision support system has been proposed in [2] where the authors have presented a spatial decision support system that contains a special module for the daily scheduling of caregivers' activities. This module simultaneously assigns caregivers to patients' visits and generates the sequence in which the visits would be done. Cheng and Rich [13] have addressed the daily scheduling problem as a multi-depot vehicle routing problem with time windows and compatibility information. The objective of this daily scheduling is to minimize the total costs associated with the amount of overtime hours of the full-time nurses and the amount of hours of the part-time nurses. After that, another decision support system has been developed where the scheduling problem is formulated as