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Home Health Care Logistics Management Problems: Framework and Research Perspectives

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Abstract

Home Health Care (HHC) services are a growing sector in the medical service business. These services are based on a delivery network in which patients are hospitalized at their homes and health care providers must deliver coordinated medical care to patients. The fact that patients and medical staff's homes are considered as a component of the delivery network creates a difference from typical health care organizations and generates a greater complexity on logistics decisions. In this paper we provide a reference framework for HHC logistics management in order to identify research perspectives in the field. With this framework we present a brief review of the current literature in models and methodologies used to support logistics decisions and identify research gaps. In particular, we emphasize the need to develop and implement more integrated methodologies to support decisions at tactical and strategic planning levels and to consider key features from real systems.

Keywords: health care; home health care; logistics management.

1 Introduction

Home Health Care (HHC) services are a growing sector in the medical service business. Social and economic factors have accelerated the expansion of these services. On one hand the increase on life expectancy and the ageing of the population have influenced on the demand for health care (World Bank, 2011). This demand has increased not only in quantity but also in the diversification of pathologies and required medical treatments. On the other hand, resources for health care are limited and health care providers face the challenge to design and operate more efficient health care delivery systems (Brandeau, et al., 2005). In this context, HHC has appeared as an alternative to improve the performance of health care providers and the utilization of scarce resources. Having a patient receiving medical care at home instead of a hospital, results in a lower general cost for the health system (Borsani et al., 2006; WHO, 2000) and these services allow to improve life quality of patients and to reduce recovery periods (Ahlner-Elmqvist et al., 2008).

According to the U.S. Home Health Services Industry (Barnes Reports, 2011), the industry of HHC services comprises establishments primarily engaged in providing skilled nursing or medical care at home, under supervision of a physician. A HHC system can be viewed as a health services network that includes the patient; the person who asks for the home care (the patient, his family, the hospital or the physician); the people involved in the logistics implementation (coordinator in charge of the evaluation of material and human needs, pharmacy) or in the financial aspect of home care (health insurance); and the home care team (nurses, physicians, therapists, among others) (Bricon-Souf et al., 2005). The integration and coordination of this health service delivery network is a complex task and managers have to face many logistics decisions when designing, planning, and operating the system. HHC logistics management involves decision-making problems such as *network design*, *transportation*, *inventory* and *staff management* at the *strategic*, *tactical*, *operational* and *real-time* levels. Although these problems have been studied in the literature in different industrial contexts, few works report the use of models and methods to support logistics decisions in HHC services.

Most research found in the literature dedicated to HHC services refers to studies based on developed countries for operational decisions. Specifically studies have been conducted in Austria, Canada, Germany, Italy, Norway, Sweden, the Netherlands, the United Kingdom, and the United States. Brailsford and Vissers (2011) show the increase on the development of Operations Research techniques in health care in Europe, where HHC services have become a central element in the health policies. Despite these achievements, no scientific study focused on the design, planning, or operation of HHC has been carried out in developing countries. As stated by Doerner et al. (2007) and Flessa (2000), the majority of developing countries face severe health care crisis and the dilemma of very restrictive budget limitations for health care expenditures with a growing population. Health care systems vary among countries and the current state of the art on HHC cannot be generalized due to differences on health policies and funding structures. This suggests that models and methods for logistics management need to be studied and developed in order to reach more efficient HHC delivery networks.

In this paper we provide a reference framework for HHC management, focusing on logistics decisions. Based on this framework we review the existing literature on methodologies and models used to support logistics decisions and identify research perspectives on the field. In particular, we emphasize the need to develop and implement more integrated methodologies to support decisions at tactical and strategic planning levels and to consider key features from real systems. The paper is organized as follows. In Section 2 we define three different dimensions from which HHC management can be viewed: *planning horizon*, *management decisions*, and *services processes*. For each *management decision* and each *service process*, we present a brief overview of the existent literature of models and methodologies used to support logistics decisions. In Section 3 we present a summary pointing out important decisions that have received little attention in the literature and give directions for future research. Finally, we conclude the paper.

2 Home Health Care Characterization

In order to provide a characterization, in this section we discuss three different dimensions from which HHC logistics management can be viewed. First, we identify the *planning horizon* according to the duration and impact of the planning decisions. Second we differentiate the logistics functions by groups of *management decisions*. Finally, we describe the *services processes* defined as the set of steps performed when the HHC service is delivered to a patient.

We present an integrated scheme that illustrates the interaction of the three dimensions proposed in Figure 1. As it can be seen, the *strategy definition* corresponds to a set of decisions that determine in a long-term the structure of every logistics management function. This set of decisions define the service portfolio according to the market needs, the actions to undertake in order to push forward in the value chain and gain a competitive advantage, and the core competencies that will differentiate the HHC provider. Although we do not focus on models and methodologies to support the strategy definition, this planning process defines in every way how logistics functions should operate, and therefore should be considered in every management decision, for every planning horizon.

2.1 Planning Horizons

In HHC logistics management three levels of planning can be distinguished depending on the time horizon, namely *strategic*, *tactical* and *operational* (Ballou, 2004). The *strategic level* considers time horizons of more than one year and includes the design and allocation of long-lasting resources for long periods. Decisions at this level include the location and allocation of HHC central facilities, the patients districting, the fleet size and selection, the staffing levels, and the definition of service levels. The *tactical level* involves medium term decisions that are usually made for a year. The fleet assignment to patients' districts, the shift scheduling, and the definition of inventory policies are considered as tactical. The *operational level* is related to short time decisions that need to be made daily. These decisions include the staff assignment and routing as well as the inventory control. A fourth level has been recently recognized

as the *real-time level*, and it refers to decision making situations in which operations must be undertaken or altered in a very short time according to the actual execution of the *service processes* of the system.

For each of the logistics functions, the abovementioned levels define a hierarchy among management decisions that impose constraints in lower planning levels and influence the performance of the HHC delivery network. For example, in transportation management, the size and selection of the fleet used by medical staff to visit patients is a long-term decision that influences the way the fleet is then assigned to patients' districts at the medium-term. Equivalently, the fleet assignment to districts influences staff routing decisions at the short-term. This hierarchy suggests that models and methods used to support logistics decisions at the operational level will not have a significant impact on the system performance, if decisions made at upper levels are not based on proper methodologies to design the network and to assign resources.

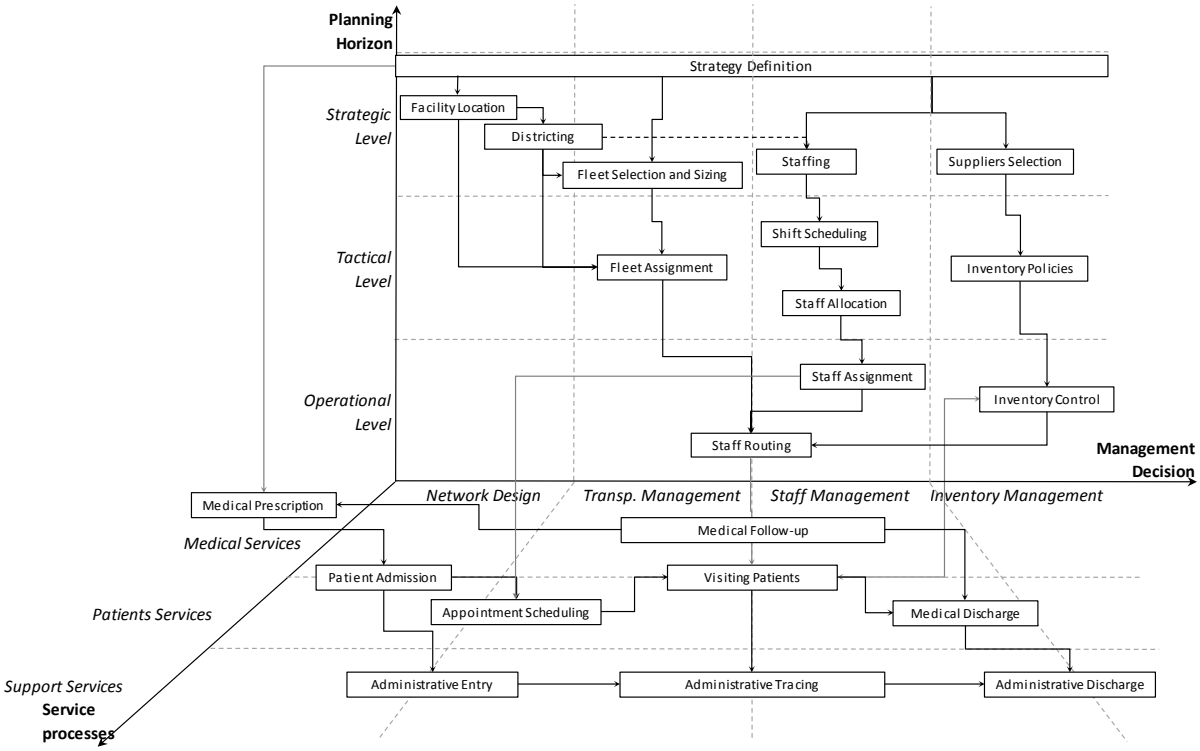

Figure 1: Home Heatlh Care Logistics Management Framework

2.2 Logistics Management Decisions

According to classical logistics functions, we can identify four groups of *management decisions* described as follows.

2.2.1 Network Design

This is a strategic function that requires managers to deal with two major issues. The first consists of locating HHC central facilities and then drawing their associated territory. This decision is known as the *facility location* problem and it consists of determining the number, location and capacity of HHC central facilities. As stated by Daskin and Dean (2005), this problem is critical in health care and its impact goes beyond cost and customer service considerations. If too few facilities are utilized or if they are not well located, it can result in increases in mortality and morbidity. Despite the large number of publications dedicated to this problem, the facility location seems to be of a minor importance in the case of HHC due to the inclusion of medical staff homes as departing points for service delivery and to the use of information technology. In fact, in our literature review we did not find published works that tackle this problem in the context of HHC.

On the contrary, the *districting problem*, which consists of partitioning each territory into suitable districts, is a major network design decision in HHC. The problem consists of defining districts made up of several territorial basic units in order to assure that the service is delivered to the patients location at the prescribed times, and to assign balanced workloads to the medical staff. Blais et al., (2003) study a practical districting problem in the management of public HHC services in Quebec, Canada. The authors model the situation as a multi-criteria optimization problem which is solved with a tabu search heuristic. Hertz and Lahrichi (2009) propose a patient assignment algorithm in the same context in Quebec, in order to improve the workload assignment to nurses and to avoid long travels to visit patients. The problem is addressed with a mixed integer programming model which is solved using tabu search. One of the improvements of this work is the differentiation of the workload in terms of the patient's categories according to the required type of care. Usually this feature is not included in the analysis, since the major population of current HHC services are elderly people, and the portfolio of services is quite small. However, due to the diversification of the service, a HHC provider could offer from 50 to 200 different references of service, which makes the workload measurement a complex task.

2.2.2 Transportation Management

Three main decisions are part of this logistics function: *fleet selection and sizing*, *fleet assignment* and *staff routing*. The *fleet selection and sizing* includes determining the transportation model used by the medical staff, the selection of modes and their respective sizes. The transportation model defines who is responsible to assure transportation to visit patients: the HHC provider or the medical staff. The selection of an optimal transportation mode is a key factor in logistics management since it is a large portion of the total logistics cost. The problem consists of finding a favorable combination of every transportation mode so transportation requirements are satisfied and a balance between speed and cost of transportation is achieved. Rendl et al. (2011) study a HHC scheduling problem in a real setting and consider different transportation modes. With the objective to minimize travel time and operational costs, the authors propose a hybrid meta-heuristic solution model based on a routing problem.

The second decision is *fleet assignment*, and it is valid when the HHC provider is responsible for transportation. Given the impact of fixed and variable transportation costs, managers should define the way the limited fleet is assigned to patients' districts in order to balance the work load and maximize the number of visits performed respecting medical requirements. Finally, the *staff routing* decision is directly related to the vehicle routing problem which consists on designing optimal delivery routes from a central location to a set of geographically distributed patients subject to various constraints (Toth and Vigo, 2002). In HHC, once patients have their medical treatment prescription and when time services, staff qualifications, frequencies and hours for each medical procedure are defined, the staff routing problem consists of building a schedule of activities for each staff member that must define the sequence of visits to the patients locations, so every medical procedure is performed within the given time interval, in the required frequency, in the prescribed sequence, and by the adequate staff member, while respecting work legal guidelines.

The major set of publications of transportation and staff management in HHC is found in routing decisions. Although the managed resource corresponds to the medical staff, more focused has been placed on the routing-scheduling component. This problem has been studied by Begur et al. (1997), Cheng and Rich (1998), Gurumurthy (2004), Bertels and Fahle (2006), Eveborn et al. (2006), Akjiratikarl et al. (2007), Steeg and Schröder (2008), Bredström and Rönnqvist (2008), Justesen and Rasmussen (2008), and Rabeh et al. (2011). In most of these works the objectives include the minimization of travel distance and staff costs combined with a quality assignment related to patients and staff preferences. Common considered features include time windows, precedence and synchronization conditions among visits, different staff qualifications, multi-depots and shift guidelines.

2.2.3 Staff Management

Staff decisions play a key role in the logistics performance of a HHC delivery network. Commonly, medical staff is limited and expensive, and their performance directly defines the quality of the health service. We identify four decisions in HHC staff management. The first one, known as *staffing*, is usually made

between the strategic and the tactical level, and it involves determining the number of personnel of the required qualification in order to meet estimated patients demand (Schneider et al., 1975; Smith-Daniels et al., 1988; de Vries, 1987) . This is a complex problem given factors to consider such as organizational structure and characteristics, personnel recruitment, skill classes of the staff, working preferences and patient needs (Burke, et al., 2004).

At the tactical level, the second decision is *shift scheduling*, which deals with the problem of selecting, from a potentially large pool of candidates, what shifts are to be worked, together with an assignment of the number of employees to each shift, in order to meet demand (Ernst et al., 2004). This problem becomes more complex when there is a large number of working rules, and when weekends, work stretches, vacation requests, and potential sick leaves have to be considered. Between the tactical and operational levels, the *staff allocation* decision refers to the need to employ temporary staff or to use float staff to handle unexpected large patient demands or staff shortages, during particular shifts and to assign individual staff to patients' districts. As it was stated for the transportation management function, the hierarchy restrict shorter-term decisions, and longer term staffing and scheduling decisions impact the extent to which temporary staff is required to be employed (Turner et al., 2010).

At the operational level the *staff assignment* decision is concerned with the assignment of visits among a given medical staff. In the staff scheduling literature the problem is known as task assignment and it is often tackled when working shifts have already been determined but tasks have not yet been allocated to individual medical staff (Ernst et al., 2004). In HHC this decision is influenced not only by the staffing and shift scheduling decisions made at upper levels, but also by the districting configuration given the geographical dispersion of patients. When a set of patients have been admitted in the system, the list of medical procedures is defined by the prescribed medical treatments, and procedures must be assigned to medical staff considering the patient location, the staff qualification and the medical requirements (e.g. hours, frequencies, precedences).

The staff assignment is closely related to the staff routing decision and for some cases both decisions might be taken simultaneously. However, this approach is not applicable for every HHC service and the assignment and routing decisions have to be taken sequentially. For example, in the case of Basic Nursing Care or Respiratory Therapy, many patients require that auxiliary nurses and respiratory therapist spend 12-hours shift at their location when monitoring vital signs is required. In this case, the assignment decision affects the performance metrics of the system in a higher level than the routing decision and therefore they are made separately.

2.2.4 Inventory Management

Inventory management is an important activity in the HHC delivery network and a complex logistics aspect of the health care sector. Investments in inventory are substantial and the control of capital associated with medicines and pharmaceuticals, supplies for medical procedures and devices, represent an improvement opportunity for the system, in which scientific methods for inventory control can give a significant competitive advantage (Axsäter, 2006). In HHC we identify three decisions related to inventory management.

At the strategic level, the *suppliers selection* refers to the process by which the HHC provider identifies, evaluates, and contracts with suppliers of medicines, supplies and devices (Beil, 2010). This decision generally depends on a number of different criteria and needs to consider both qualitative and quantitative factors. At the tactical level, the design of *inventory policies* implies determining when the inventory levels of each reference of medicines and supplies should be reviewed, how much of each reference must be ordered from the supplier and when (Gutiérrez and Vidal, 2008). At the operational level, the *inventory control* consists of controlling the flow of medicines, supplies and devices as medical treatments are delivered to patients. This is a complex daily task that implies the coordination of medical prescriptions, medical follow-up, administrative tracing and orders to suppliers.

To the best of our knowledge, the work presented by Chahed et al. (2009), is the first published paper that tackles the inventory problem in a HCC network. They studied the planning of operations related to

chemotherapy at home, focusing on the anti-cancer drug supply chain. The problem is tackled with an optimization model that seeks to minimize the production and delivery costs of medicines. The model also considers production scheduling and nurse routing decisions simultaneously and it is solved by an exact method.

2.3 Service Processes

We have defined *services processes* as the set of steps performed when the HHC service is delivered to a patient. In this set we identify five main processes classified into three types of services: *medical services*, *patients services* and *support services*. Our description of each service is presented as the sequential flow a patient follows when enters in the system.

2.3.1 Medical Prescription

The *medical prescription* is an entirely medical service, only restricted by the service policies declared at the strategic definition of the HHC provider. The medical treatment is prescribed by a medical staff, based on the patient pathology and the medical diagnosis. In HHC the prescription can be originated by two main types of patients: acute and chronic. The identification of the type of patient is a key task that directly influences on the estimation of the monthly workload and the required medical staff, as well as on inventory policies.

The medical prescription of an acute patient can be given directly by a medical professional through an outpatient appointment or by a medical institution or professional through an early medical discharge. In both cases, the patient requires a set of medical procedures, over a defined duration, which can be performed at the patient residence, in order to complete a medical treatment. Once the set of procedures is completed, the patient is discharged. On the other hand, the medical prescription of a chronic patient is usually provided by a medical institution or professional after a medical treatment and when the health condition is persistent and it requires long-lasting care. These patients include people with limited physical mobility or with terminal disease that require palliative care. Usually a chronic patient requires at least three months of health care at home. During this time, periodic *medical follow-up* is required and it determines each month, a new medical prescription (or medical discharge) and therefore a new admission into the system.

2.3.2 Patient Admission

Once the medical prescription is defined, the *patient admission* must be performed by the HHC provider. At this point the coverage policy and the administrative nature of the health insurance play a determinant role in the way the service is delivered and charged. In developing countries, most of health services are provided by private companies which limit the portfolio of services and their monetary value due to budget constraints and financial objectives. When a patient is to be admitted into a HHC service, the set of medical procedures defined in the medical prescription, and their respective number of repetitions, frequency and duration, have to be validated with the type of insurance policy that covers the patient.

Another criterion that has to be reviewed during the admission is the patient location according to the network design in which the patient districting has been defined. In urban settings, it is common that districting decisions limit the coverage of the service to certain areas or neighborhoods due to geographical or security reasons. Even for some urban areas, limits include hours of the day after entrance is not permitted. To finish the admission process, the list of medicines, supplies and devices has to be defined, according with each medical procedure.

When the patient admission process is completed, an *administrative entry* must be done into the HHC system. This process implies the definition of all information fields required during the admission process. These fields must be registered into the information system since they will be later used to *schedule appointments*, *assign medical staff*, perform *medical follow-up*, and complete all *support services* related with *administrative tracing* and *administrative discharge*, which implies generating bills and performing payment collection process. Although these support processes are commonly seen as secondary ones, they play a key role in the operative and financial performance of the HHC system.

2.3.3 Appointment Scheduling

The *appointment scheduling* process consists of determining for each medical procedure of each treatment of each patient, when the visit will be performed and by whom. This process is directly related to the *staff assignment* decision, and it must consider the districting configuration, the patient location, and the information fields of each medical procedure considered in the medical prescription process, as well as the medical procedure duration. All the information fields related to the medical staff (staff member location, qualification, and shift assignment) and the delivery date of medicines and supplies must be also considered. The appointment scheduling is a complex process since several factors defined in the network design, the transportation and the staff logistics functions have to be considered simultaneously. Moreover, the sequential set of decisions made in this process directly influences on the quality of the service and on the quality of workload assignment to medical staff.

2.3.4 Visiting Patients

Once all medical and administrative factors have been defined, and the appointments are scheduled, the medical staff is responsible for *visiting the patients*. This process is the actual performance of the medical procedures at the patient location, which must be executed according to the established medical protocols. In operative terms, the quality of the visits is defined by the accomplishment of the appointments according to the medical prescription, the scheduled days and hours and the performance by a qualified medical staff.

2.3.5 Medical Discharge

During the time the medical treatment is delivered to the patient location, a physician has to visit the patient at least once to do a *medical follow-up*. This visit has the objective to evaluate the evolution of the treatment and determine if new medical procedures are required or if a *medical discharge* can be prescribed. In the same way, during this period an *administrative tracing* has to be performed by the visiting and the administrative staff in order to keep an updated report or the medical procedures delivered. If a medical discharge is prescribed, an administrative discharge process has to be undertaken based on the reports made during the administrative tracing, in order to close the case, generate bills and perform the payment collection process. If new medical procedures are required, the physician must write a new prescription and the admission process should be performed again, starting a new cycle of the service processes.

3 Summary, Conclusions and Research Perspectives

In this paper we have presented a three-dimension framework to characterize HHC logistics management problems. The first dimension deals with the duration and impact of the planning decisions through three *planning horizons*: *strategic*, *tactical* and *operational*. The second dimension differentiates the logistics functions by groups of four *management decisions*: *network design*, *transportation management*, *staff management* and *inventory management*. The third dimension describes five main *services processes*, defined as the set of steps performed when the HHC service is delivered to a patient: *medical prescription*, *patient admission*, *appointment scheduling*, *visiting patients* and *medical discharge*. For each dimension we provide a sampling of the available literature of models and methodologies used to support logistics decisions.

Three perspectives of future research emerge from this review. First, due to the limited nature of resources and the very restrictive budgets for health care, especially in developing countries, most of the critical management problems faced by HHC providers are not related to short-team or real-time scheduling decisions. Instead, the location and allocation of long-lasting resources at strategic and tactical levels are key decisions that determine in a large proportion the performance of the health delivery system. As life expectancy continue to increase, demands for health care will grow in quantity and diversification, and HHC providers will continue to face the challenge to design and operate more efficient health care delivery systems. These management problems do not rely only on short-term decisions to schedule

medical staff visits to patients. Therefore, more research attention should be placed on methodologies and models to support decisions of resources location and allocation.

Second, few researches have focused on the inclusion of real features in the modeling process of HHC logistics management problems. The major interest observed in the literature consists of designing efficient solution methods to short-time decision problems. However, key real features as the diversification of patients' pathologies and HHC service references, as well as work legal regulations for medical staff have received little attention in the research literature. The inclusion of these features in districting problems and staff management problems such as staffing and shift scheduling can provide significant improvements in HHC systems.

Finally, more research attention should be placed on the study of the hierarchical integral structure of logistics management decisions in HHC. For example, at the staff management dimension, the staffing decisions and their allocation to districts are long-term decisions that are influenced by the distribution of patients' demands. Nevertheless, these demands are dynamic over time and thus new hiring decisions and staff configurations for districts might be required in a medium-term. This suggests that an integrated analysis of logistics decisions among different decision levels can provide a better support, if the impact of long-term and medium-term decisions is integrally evaluated.

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