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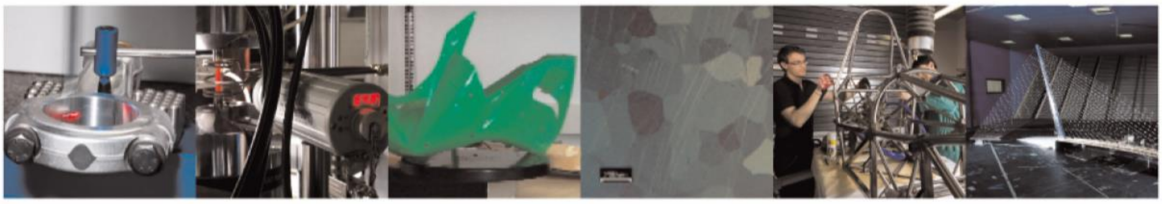

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A contribution to operations management-related issues and models for home care structures

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1. Introduction

Due to ageing of population and prolonged life expectancy, the number of beneficiaries of the French health system increased significantly from year to year. Hence, the expenditure for health care reached 11.7% of the French gross domestic product (GDP) in 2009 (INSEE 2010), which places it at the second rank, after the USA. Conventional health institutions such as hospitals, pivots of the health system, must ensure their service while demand is growing and funding levels are reduced. The increased demand for care and the pressure from the government to reduce costs resulted in closing some institutions, reducing the number of available beds, postponing costly interventions or transferring patients to other institutions that are alternative to classical hospitals such as Home Care (HC) providers.

Hence, health professionals are encouraged to develop ambulatory surgery operations and strengthen the links between 'city medicine' and hospital practice (Sourty-Le Guellec 1997). Alternatives to classical hospitalisation are relevant for patients suffering from certain chronic diseases, those requiring heavy nursing care that does not need a technical platform, or elderly

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and dependent patients needing continuous care. Such alternatives include outpatient or emergency treatments in hospital (e.g. chemotherapy in hospital), day hospitalisation, ambulatory surgery, etc. Another alternative designed to shorten/avoid hospital stays and to prevent unnecessary re-admissions is being developed in the recent years by HC providers. Defined in a broad sense, HC services consist of providing coordinated medical and paramedical care for a limited period which can be extended depending on the patient's needs. HC services include and are not limited to home health care (often called hospital-at-home services), nursing care or hospice care that makes it possible for terminally ill patients to receive pal-liative and supportive care during the final stages of their lives at home or in home-like settings.

During the last decade, HC services have known a significant growth in the majority of European countries. WHO (2008) reported that public spending on HC accounts for more than 30% of the resources spent on long-term care in many OECD (Organization for Economic Co-operation and Development) countries, ranging from 0.2% of GDP in Spain to 2.75% in Sweden. Over one-third of people over 75 received HC (Litwin and Attias-Donfut 2009). The rise of HC services in recent years has been accelerated by several factors such as the ageing of the pop-ulation (from 4% in 2010 to nearly 10% in 2050 in OECD countries Colombo et al. [2011]), the increase in chronic pathologies and physical disabilities (WHO 2008), the introduction of innovative technologies such as monitoring devices, telemedicine, fall detectors, etc. as well as advances in medical science (Reyes, Li, and Visich 2012; Xin, Yeung, and Cheng 2010), the continuous pressure of governments to contain health-care costs (Chevreul et al. 2004; WHO 2010) and the social changes observed over the last decades (Ehrenfeld 1998). Thus, in France, the number of beds in hospitals and private clinics tends to decrease (6.8 beds/1000 inhabitants in 1980, and 3.8 beds/1000 inhabitants in 2005, i.e. a 40% reduction), while at the same time, the number of patients with chronic or degenerative pathologies increases due to longer average lifetime (Eurostat 2008).

Despite the importance of their development, in most current HC practices, we observed that the performance of clinical processes receives more attention than logistics- and organisation-related issues, which is clearly impacting the efficiency of the care service. Furthermore, in the academic literature, the actual lack of a general framework that would enable a better understand-ing of HC operations does not help to develop efficient, high quality and responsive organisation models for HC. As pointed out recently by Genet et al. (2011), most of the existing papers analyse only one specific aspect of the system without addressing the whole picture.

This paper aims at filling this gap. In contrast with earlier studies such as Genet et al.(2011), Burau, Theobald, and Blank (2007) or Hutten and Kerkstra (1996) that studied the HC system from medical, financial or sociological perspectives, our motivation lies in con-sidering operations management-related issues in HC. In particular, our aim is to contribute to answer three research questions: (1) what does operations management consist of in HC organisations and what are the factors that contribute to make it complex, (2) what does the existing scientific literature has to say about HC operations and (3) what might be the most relevant (and challenging) issues that would be interesting to look at from an operations man-agement perspective. The paper is organised as follows. Section 2 aims at underlining the key characteristics of health-care service systems (Section 2.1.) and those of HC (Section 2.2.). An example on the chemotherapy at home practice is provided for illustration. Section 3 first identifies the types of factors that may cause complexity in managing operations in HC (Section 3.1.) and based on these factors, we propose a framework that pinpoints the main oper-ations management-related decisions in HC (Section 3.2.). Section 4 concentrates on a review of the literature associated with operations management applied to HC. Finally, Section 5 presents some concluding remarks and suggests new topics of interest for operations management researchers.

2. HC service characteristics

To present issues and challenges associated with operations management in HC systems, we describe the characteristics of health-care services in general (cf. Figure 1). We then give a presentation of the specificities of HC services.

2.1. *Health-care services characteristics*

The service delivered by a health-care system (such as a physician office, a hospital or a HC service provider) consists of performing care activities which can be described over three stages (*specification*, *production* and *delivery* stages) in order to transform (*improve, preserve* or *stabilise*) the patient state (*physical* or *psychological* state) by using various types of human and material resources (Sahin 2008). Hence, the service delivered to the patient can be of different types, medical, paramedical and psychological, and might include some social aspects, especially in the case where the service is delivered at patients' homes. Furthermore, the main service may include some additional services such as good delivery (e.g. drugs used for treatment and supply of medical equipment).

The *specification* stage of the service aims at identifying the patient's care needs and the therapy to provide. Most of the time, this process is realised in two steps: making an appointment with the care giver in order to request an access to the care service followed by a consultation. The *production* stage is the realisation of care activities (e.g. diagnosis, patient sample analy-sis and radiotherapy application). The *delivery* stage is the release of the care service, it mainly consists of transmitting to the patient information regarding the therapy being used, the expected impact on his/her health and undesirable effects, etc. based on care activities realised in the production stage. It may require a direct or indirect interaction (e.g. mailing laboratory test results to the patient) between the care giver and the patient. In some cases, production and delivery stages can be realised simultaneously, e.g. a consultation with a psychologist where production and release activities are merged.

Health-care service is often qualified as being a complex process, requiring both integrative and adaptive approaches to deal with this complexity (Tien 2008). Indeed, whether realised with a curative objective in response to a request for care (e.g. a prescription of treatment) or on a

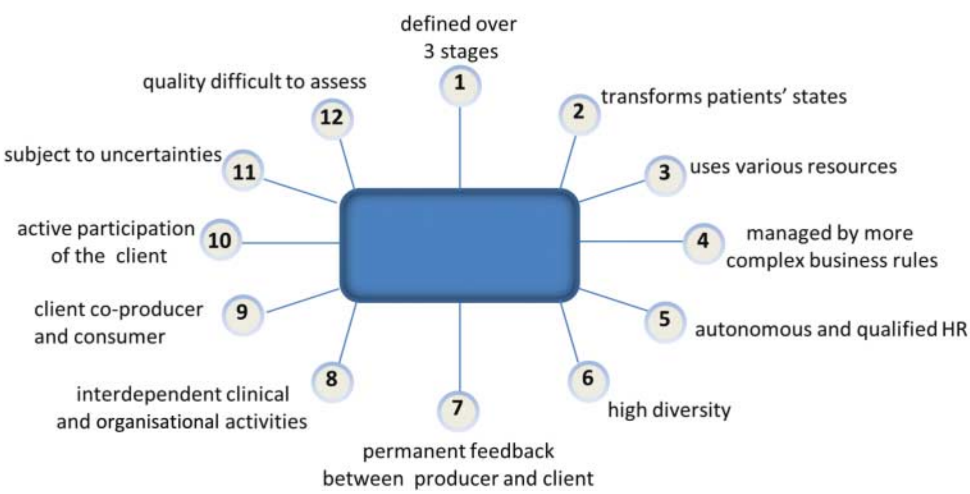

Figure 1. Main characteristics of the health-care service.

preventative mode (e.g. screening and monitoring via sanitary programmes), the care service involves several stakeholders (i.e. patients, doctors, hospitals and insurance companies) which constitute a care production chain where flows of goods and services circulate (Stock, McFadden, and Gowen 2007). The system's purpose is hard to define, given the many stakeholders involved, the multiple objectives (i.e. wellness care, emergency care and palliative care) of each stake-holder, and the overarching business model (i.e. revenues, costs and target service quality levels).

While in production systems, human resources required for an elementary activity (task) rarely exceed one to two operators, up to seven or eight operators can be involved in the same medical activity managed with more complex business rules (e.g. management of preferences and prior-ities) (Gourgand 2008). Human resources are subject to constant change in knowledge related to medical research and technological advances (e.g. the use of telemedicine requiring new techni-cal skills and new forms of relationships with patients). Indeed, these highly qualified resources have an important autonomy level and decision-making power over the care production process. In contrast with manufacturing systems, it seems unimaginable that technical care activities can be entirely controlled by HC managers as may be the case of a qualified operator in an industrial production line.

The health-care system is characterised by the diversity of the services provided. Indeed, the care delivered to a patient is unique. Phelps (1995) reports that 'hospitals and doctor offices are like multi-task workshops producing a wide range of various products, each of which is shaped specifically for a particular patient'. The care is thus adapted to the needs of the patient not only regarding medical aspects but also in terms of specific attributes (e.g. age, weight, level of dependency, personal preferences, psychological situation and financial capability). Providing quality service to patients depends on the ability and willingness of the practitioner to combine his knowledge of medicine with information he/she has on each individual patient. Hence, care service is by nature a very customised 'product' although it is often based on a combination of rel-atively standardised elementary protocols. This is a significant difference with products for which even if customisation is present, it lies usually at catalogue level (e.g. choice of options within a catalogue). In the context of care services, two patients will never be completely identical, which would generate partial differentiations in the treatment of individuals.

In contrast with goods manufacturing, all over the care service production process, there is a permanent feedback loop (or a bi-directional relation as reported by Sampson and Froehle [2006]) between the patient and the care producer. For instance, the patient would provide a blood sample to his/her direct care giver who transfers it to a biological laboratory. The laboratory returns results to the physician, who, on the basis of these results, can ask the patient to take up further examinations in order to develop a diagnosis. Hence, the diagnosis (and care) provided to the patient may either be based on a standard protocol requiring a single examination or can be developed progressively over multiple examinations and medical procedures, which leads to a continuous design and execution of the service activity.

Care delivery is supported by organisational and logistics processes. As reported by Gourgand (2008), care systems consist of entities that provide logistic or medical services that interact. These two categories of process are interdependent: the prescription of a treatment and the specification of the frequency of administration of the treatment imply the dates of availability of drugs used and, vice versa, the occurrence of an organisational issue requires a change in the mode in which care will be administered. Hence, these two processes have to be coordinated.

The patient plays a unique role in the care service. His/her condition (physical and psy-chological) gives direct information on the result produced by the service (e.g. pain eased or disappeared and allergy developed during treatment). The care service is one of the few ser-vices that people need but are not necessarily motivated to benefit from, unlike other services such as entertainment (Berry and Bendapudi 2007). The patient can, therefore, be in a state of discomfort, anxiety, irrationality or stress, which in turn will affect the expected result of the service.

The patient is at the same time producer and consumer of the care service, which is a characteristic adding complexity to service design and organisation. Hence, he/she participates in the service by providing the necessary information to care givers either by directly describing his/her aches or by contributing to measure his/her state (e.g. blood analysis and scanner).

Due to the human presence and behaviour involved in the process, one can rarely (totally) control the events and anticipate eventual reactions. Furthermore, more and more patients want to be actor of the care service they receive, either regarding decisions that concern the choice of treatment or those related to the manner in which it will be realised. Patients' commitment to and participation in the treatment depend on various factors such as his/her level of knowledge concerning the disease which he/she suffers from and the treatment received, his/her emotional state, the progress of the disease, etc. (Vermeire, Hearnshaw, and Royen 2001). The influence of the patient on service realisation (during specification and production stages) is also related to the co-productive nature of the service: some patients may make a self-diagnosis of their pathologies, patients are physically present during service production in varying degrees and based on different modalities, they have their own values, expectations and knowledge (Tien and Goldschmidt-Clermont 2009) and develop their own interactions with the care produc-tion system (Brailsford and Schmidt 2003). Thus, patient's commitment plays a key role in all stages of service realisation: in the specification stage, he/she may decide to ask for care, answer (or not) honestly and in a comprehensive way questions of the care giver and approve (or not) treatments proposed by the latter; in the production stage, he/she provides samples necessary for analysis, respects (or not) medical protocols used for therapy, etc. This is sig-nificantly different from goods production which involves the customer mainly at the design stage.

Another source of complexity in managing health-care services stems from uncertainties. Indeed, the participation of the patient represents a source of variability which is inherent to the care service. This can generate delays or additional costs to the care givers; patients can sometimes provide incomplete information during the specification of care, have problems in expressing clearly and totally their problems or be slower than expected to perform tasks related to the production of care. Additionally, demand for care is also uncertain. Although one can consider that demand has a predictable or deterministic part (seasonal pathologies, planned activ-ities, etc.), it contains a random part which concerns the nature (e.g. patient profiles), the volume and frequency of demands (e.g. level of care required for each patient profile and occurrence of an emergency or natural disaster). Furthermore, resources involved in care delivery can be unavailable from time to time, causing perturbations in the planning and execution of activities. Different levers can then be used to balance demand for care and capacity: making capacity flex-ible by using temporary external staff, developing staff skills so that they become multi-skilled, using new technologies such as telemedicine to increase productivity or using pooling or capac-ity sharing policies among several institutions, deploying appointment systems and other demand smoothing approaches. As explained before, another possible lever is to encourage approaches such as co-production of the service by involving the patient and his/her family more in the administration of the service.

Complexity of health-care services is also related to the perishable nature of the production capacity. Indeed, health-care systems are expected to create an added value based on the availability and expertise of human (and material) resources. When they are left unused, the value that could be created is lost forever since care services cannot be produced before demand is expressed. Hence, the perishable capacity characteristic is not different from manufacturing systems. What is different for services is that unlike standard goods manufactured in a Make to

Stock mode provided to customers immediately, care services cannot be produced before receiv-ing the requests of clients. Such specificity implies having a flexible capacity upon receipt of the request to produce the service. This mode of operation is similar to the manufacturing of high diversity products on a Make to Order mode.

Whereas in manufacturing, physical parameters, statistics of production and quality can be more precisely quantified, since a service operation depends on the interaction between the recip-ient and the production process, the quality is necessarily more subjective. Indeed, quality is a complex notion to define and assess health-care services. Many investigations have addressed the issue of performance and quality for such services (Campbell, Roland, and Buetow 2000; Dagger, Sweeney, and Johnson 2007; Li and Benton 1996). A widely adopted classification is the one of Donabedian (1980) who identifies various dimensions of quality of care such as the following: (i) quality of care provided which is mostly related to the results of the care provided, technical skills and interpersonal skills of care givers, (ii) quality of facilities and equipment to ensure comfort, safety and respect patient privacy, (iii) quality of the accessibility of care (service access time, responsiveness of staff, etc.) as well as equality regardless of geographical, economic and social conditions. The quality of results associated with the care service is very difficult to measure in practice due to issues encountered in defining and measuring the impact of a medical act on a patient. This difficulty is related, according to Choi et al. (2005), to the long period of time between the production of care and the observation of the outcomes associated with the service. This is why for many authors, the result of the care service is considered as being the consequence of the quality of service and not one of its components, which refocuses the quality of care on the processes and the means deployed to achieve it.

2.2. *Specificities of HC operations*

The concept of HC was initiated in 1947 in the USA. In France, the first HC structure was created in Tenon Hospital in 1951; then the total number of HC structures rose steadily from 68 in 1999 to 123 in 2005 to finally reach 271 structures in 2007.

The care service in a HC system is organised according to several steps such as the following: HC prescription, admission, diagnosis development, sojourn in HC and patient discharge. HC service can be prescribed after a hospitalisation period, a consultation in hospital or upon a private physician's ('family doctor' or general practitioner) request. Whatever the prescriber is, in the pre-HC phase, the candidate patient goes through some evaluations (on his/her health status and care needs, living environment, etc.), leading to the validation or refusal of his/her admission in HC. It is also in this phase that the development of the therapeutic (care) project begins, i.e. the personalised treatment plan of the patient which is jointly elaborated by the prescribing physician and the HC medical team and defines over several weeks all clinical, psychological and social requirements that the patient needs. Hence, the therapeutic project specifies in detail care activities, their duration and frequency, the associated human and material resources necessary to achieve the therapeutic goals. Since the patient's condition can change at any time, the therapeutic project requires a continuous and collaborative design throughout the period of treatment of the patient in HC.

Care production consists of direct care activities, the associated patient status monitoring and measurement (control) activities and transport activities. Care activities are supported by organisational activities aiming at ensuring the availability of human and material resources.

HC operations have often been qualified as complex operations to be managed in evolving health environments (Chesteen et al. 2005; Fone et al. 1987). In order to illustrate HC operations, we briefly describe below an example of process in the HC context, namely the chemotherapy at home practice.

2.2.1. *Illustrative case: the chemotherapy at home process*

Patients suffering from cancer can be treated by surgery, chemotherapy or radiotherapy. Chemotherapy treatments can be administered in hospital (either in classical or in outpatient hospitalisation) or at home, by the HC provider. The protocol is defined based on the type, nature and location of cancer. The prescription of the chemotherapy is on a cycle basis. Anti-cancer agents can be administered orally, by blood or intramuscularly or, in most cases, intravenously. The duration of injections is highly variable, from a few minutes to a few hours, or over several days. Medicines used, protocols, the rhythm of administration as well as dosages depend on each type of cancer and the state of each patient (Berman 1999). Anti-cancer products are adminis-tered one after the other. For instance, the protocol may define a session of chemotherapy every 21 days for breast cancer: during each session, the patient will receive 500 mg/m^2 of 5-Fluoro-Uracil, 500 mg/m^2 of Cyclophosphamide and 50 mg/m^2 of Adriamycin (Boothroyd and Lehoux 2004).

In France, the development of chemotherapy at home practice was one of the goals of the 2003–2007 Cancer Plan. As detailed in (Chahed et al. 2009), the chemotherapy at home process consists of complex and demanding tasks performed by several actors belonging to various structures such as hospital, hospital internal pharmacy, HC service provider and other resources such as family doctor, private nurses, biology laboratories and logistics service providers.

The process starts at the time when the patient and the hospital medical team (e.g. oncologist and physician) agree to do the chemotherapy at home and ends when the treatment is over. The hospital team then addresses a request for admission to the closest HC structure. Upon receipt of the request, an investigation is done by the HC coordinating nurse. The admission decision is validated based on the result of this verification process which also serves to regulate demand (admissions planning process) for the HC system. For any patient admitted, a home visit is done by the coordinating nurse to identify his/her specific needs and the associated human and material resource requirements. This first evaluation leads to the establishment of a patient care project which specifies the types and number of human and material resources required for the care delivery, while respecting the sequence of cures predefined by the hospital oncologist. More precisely, the patient care project identifies the types of care givers necessary to deliver the care, the drugs to administrate, the frequency and average duration of visits, the additional home helps the patient needs as well as the modalities of discharge from HC. This project is defined for a limited and reviewable period and can be modified depending on the patient's health status. It ends when the fixed therapeutic objectives are reached or when the patient is dead. The nurse also determines a plan for visits in accordance with the care project. This mainly consists of (i) informing the nurse planning all visits for HC patients so that she can organise the supply of human resources and material necessary for the cures, (ii) seeking the approval of the patient's physician (i.e. family doctor) for the proposed care project and (iii) contacting a private nurse who has the skills necessary for chemotherapy, if the realisation is not expected to be assigned to a nurse employee of the HC structure.

The first session of the cure is systematically realised in hospital where the internal pharmacy supplies the cytotoxics, i.e. anti-cancer drugs, necessary to the cure. Hence, the Georges Pom-pidou European Hospital (HEGP, France) we worked with produces about 20,000 preparations of cytotoxics per year for both hospitalised patients and those cared for at home (Vidal et al. 2010). The production process requires substantial investments in terms of equipment (insulators), facilities (sterilised) and staff (qualified). Therefore, since the early 2000s, the production of such drugs has been gradually centralised in the internal pharmacies of big hospitals. Such pharmaceutical units enable thus to ensure drug production while providing the necessary conditions of security and sterile environment, such requirements being only partially met before within the HC context. Besides, from the HC perspective, the outsourcing of cytotoxics production needs a tight coordination and a rigorous securisation of the preparation and distribution stages of the process between the hospital-based prescriber, the preparing pharmacy and the HC system.

The diversity of cytotoxics prepared is important. Indeed, products differ in volume, stability, cost and administration duration. In addition, such drugs are sterile and each drug is prepared for a specific patient. Indeed, doses necessary to prepare the drugs are determined exclusively by parameters such as the weight and size of the patient and the clearance of creatinine. These parameters are updated very regularly, and a significant change in one of them makes the drug useless or even dangerous for the patient. Thus, cytotoxics are perishable.

The following sessions of the chemotherapy cure are realised at home with an implantable venous device and portable pumps or broadcasters. A large number of activities must be carried out within a very short timeframe (two to three days) in a sequential order, by either various internal or external resources (cf. Table 1).

Hence, the first day is devoted to the validation of the cure and the production of cytotoxics essentially. Patient blood analysis must be carried out either by the HC nurse or in an external laboratory if the patient's condition allows him/her to move easily. The sample is then analysed in a laboratory, and the results sent to the HC structure, the family doctor and the hospital of origin of the patient. The family doctor then interprets the results and checks for the possible existence of anomalies. If results are abnormal, the family doctor informs the HC provider and confirms the cancellation of the planned treatment which is rescheduled at a later date. Otherwise, the doctor signs the 'green light document' which is sent to the HC structure. After validation of the HC nurse and physician and eventually the pharmacist, a production order is send to the hospital pharmacy in charge of preparing the necessary cytotoxics. In parallel, the HC pharmacy prepares the additional support medicines necessary for the realisation of the cure. Ideally, the production of the cytotoxics should be made at the end of the first day or early second day since these products are highly perishable. Afterwards, cytotoxics and support medicines are delivered at the patient's home, usually by a logistic service provider. The administration of medicines (cytotoxics and support medicines) is realised the third day where the nurse in charge of the realisation does also the follow up of the patient during the same day.

To conclude, the management of chemotherapy at home process is made over a distributed network where the coordination of various activities is performed at HC level. Indeed, coordination activities are present everywhere during the chemotherapy at home process: (i) at upstream level, the HC coordinating nurse establishes the link between the hospital of origin of the patient and the HC system, (ii) during the realisation phase, the nurse also coordinates the activities of several actors by transferring information and following carefully the progress of activities, (iii) at downstream level, the nurse ensures that HC service takes place under satisfactory conditions for the patient. The overall objective of the coordination is the quality of care services including the security aspect. Meanwhile, some external actors involved in the process may have strong local incentives which can be economical (e.g. external private nurses) or not (e.g. public hospitals). Resources participating in the process are in general overloaded by their usual activities, and should also integrate constraints coming from realising the chemotherapy at home in order to achieve the overall objective of quality.

3. A hierarchical decision framework for HC operations management

In this section, we propose a decision framework for HC systems which aims at classifying the main decisions pertaining to operations management. For this purpose, we first identify the different complexity factors that would impact decisions in an HC environment (Section 3.1) and then present the framework proposed (Section 3.2).

Table 1. The realisation process of chemotherapy at home.

Activities	Actors							
Make a nurse consultation	Nurse (HC employee or external)		Biological laboratory					
Sample patient blood	Nurse (HC employee or external)							
Transmit the blood sample	Nurse (HC employee or external)							
Analyse the blood sample and transfer the results			Biological laboratory					
Evaluate the results				Family doctor	Hospital doctor			
Conduct a medical consultation at patient home or physician office				Family doctor				
Validate the chemotherapy at home		HC coordinating nurse		Family doctor	Hospital doctor	Hospital Pharmacy		
Produce cytotoxics						Hospital Pharmacy		
Produce complementary drugs							HC Pharmacy	
Deliver drugs at home	Nurse (HC employee or external)							Logistics service provider
Dispense the drugs	Nurse (HC employee or external)							
Monitor the patient after dispensation	Nurse (HC employee or external)	HC coordinating nurse						

3.1. *HC operations' complexity*

Different factors generate complexity in managing operations in HC. The term complexity factor is employed to refer to any characteristic of the HC system that may contribute to generate difficulty in formulating the expected behaviour of the system and to induce unpredictable divergences between the planned activities and their realisations.

The very large number of complexity factors in the HC context can be classified over five groups. The first group gathers factors that are relative to the size of the HC system. The second one gathers those that generate variety in the HC system. The third one concerns factors that are relative to the interdependencies and interrelations within the system. The fourth one identifies factors generating uncertainty in operations. Finally, the fifth group deals with the context-dependence of HC system complexity.

Hence, *factors related to size* are either related to the sizes of elementary objects which exist within the HC system or the sizes of elements that have an impact on an individual patient's care project. Sizes are likely to be assessed thanks to appropriate quantitative measures (e.g. time scale and cardinal scale). This aspect of size then appears to be a necessary condition for complexity as stated by Corbett, Brockelsby, and Campbell-Hunt (2002) that any organisational system should be over a minimum critical size to be considered as a complex system. *Factors related to vari-ety* concern either the diversity of elementary objects which exist within the HC system or the diversity of elements impacting an individual care project. *Interdependency factors* are either related to the existence of relationships between elementary objects within the HC system or the existence of relationships between elements regarding an individual project. Interdependencies and all notions related with them such as interactions, interrelationships or interfaces are likely to be the greatest drivers of system complexity. Additionally, various sources of *uncertainties* may perturb the efficient management of operations. Finally, as stressed by Chu, Strand, and Fjelland (2003), *context* dependence appears to be another category of factors generating complexity in health-care systems.

Table 2 gives a summary of the different components of complexity in HC, so that one can better understand stakes involved in managing operations in such systems. As can be seen from this Table, the various complexity factors can impact either the whole HC system or the individual HC patient's care project. As such, Table 2 gives a base for the decision framework presented in the next section.

3.2. *HC hierarchical decision-making framework*

The existing hierarchical decision-making framework developed for managing supply chains of goods consists essentially of four levels: long-term or strategic decisions known as *Supply Chain Strategy & Design*, mid-term or tactical decisions known as *Supply Chain Planning* or *Sales & Operations Planning*, short-term or operational decisions known as *Flow Man-agement and Inventory Control* and very short-term or detailed operational decisions known as *Detailed Supply Chain Scheduling* (Sahin 2008). These decisions are arranged in such a way that the decisions having impacts at a further horizon are placed at a higher level in the framework and generate the constraints to be taken into consideration at lower levels. Furthermore, to guarantee that decisions at lower levels are taken within the scope defined at higher levels and do not deviate from the fixed targets, indicators are defined to mea-sure their performances on a continuous basis. A first version of such a framework has been proposed by Anthony (1965), based on which Vissers, Bertrand, and Vries de (2001) have also developed a production control framework for hospitals. Our aim is to adapt it to HC services.

Table 2. The HC operations complexity factors framework.

Complexity factor	HC organisation complexity		HC patients' therapeutical project (care project) complexity	
	Identified factor	Description	Identified factor	Description
Size-related factors	Number of stakeholders	Stakeholders can be numerous, among which are patients, human resources, HC managers, insurance companies, etc.	Number of HC human resources to be coordinated in the care project	Several human resources can be involved in realising the patient's care project defined when he/she is admitted in HC
	Number of institutions/ companies that the HC collaborates with	HC interacts with several institutions such as hospitals, nursing homes, pharmacies, logistics service providers, etc.	Number of institutions/ companies involved in a patient care project	Patients cared in HC can need access to other care structures such as physical re-adaptation centres, hospitals, etc. This involves the transportation of the patient from home to the place where the measure activity will be performed
	Number of HC human resources to be managed	Various human resources include care givers, administrative personnel, etc.	Average number of activities in a care project	A care project involves three types of activities: care, measure and transport activities. When activities (or tasks) in a patient care project are numerous, then the project is more complex since numerous activities require higher coordination and finer analysis to formulate the whole evolution of the patient
	Number of HC care givers to be coordinated	A large number of care givers is involved in care delivery	Number of intermediary results/ objectives to achieve in a patient care project	Patients' care projects define intermediary treatment goals to be reached on a continuous basis
	Number of HC care teams to be coordinated	When HC consists of several care giver teams (assigned to districts), HC operations become more complex to coordinate	Average duration of a care project	The longer a care project lasts, the more complexity sources will influence it and the more difficult it is to predict its evolution. But the shorter a care project, the more it is constrained, resulting in higher pressure and difficulties to manage it
	Number of admitted patients	Patient number is related to the annual number of admissions (either first admission or readmission of patients to the same HC organisation in the year)		
	Average number of patients existing in the HC	These values have to be declared to the health governmental institutions		
	Maximum number of patients that the HC provider could support at the same time			
	Average distance separating HC patients	HC systems provide services to patients living within service regions that often span over large metropolitan or rural areas		

(*Continued*)

Table 2. Continued.

	HC organisation complexity		HC patients' therapeutical project (care project) complexity	
Complexity factor	Identified factor	Description	Identified factor	Description
	Number of investors	For commercial HC providers		
	Number of technologies/information systems used in the care process	Various technologies and information systems are used to collect and share information in the HC context. The increasing number of systems used would generate complexity to monitor information flows		
Variety-related factors	Diversity of interests of the stakeholders and HC (quality) objectives	HC objectives are numerous (economic objectives, quality of the service provided, security and comfort of patients, etc.), their coordination and control are complex because conflicting interests are likely to appear	Diversity of components considered in a care project	A patient care project considers all aspects relative to his/her clinical, social and psychological status (and care needs) as well as conditions related to the home and family environment
	Diversity in the corporate status of HC providers	A large variety of HC structures exists, including monopolist agencies providing comprehensive services, agencies for specific services (such as nursing), competing commercial and non-commercial private HC providers and public HC providers	Diversity of human resources types needed in the care project	The more diverse the needed resources (and skills) are, the harder the care project is to predict and control, which makes it more complex to manage
	Diversity of services delivered by the HC	HC offers different services such as medical and paramedical services, psychological support and coaching of patients, health promotion, disease prevention and education of the patients and their families, social services such as housekeeping, meal preparation, personal care and assistance at home	Diversity of material resources types needed in the care project	
	Diversity of the care type (patient care profile) to be provided	Care delivered to HC patients can be classified into several categories: punctual care, continuous or palliative care, follow-up and rehabilitation care	Diversity of technologies used in the care process	
	Diversity of the geographical locations of other institutions/companies the HC is working with	When stakeholders of HC are far from one another in terms of geographic location, then operations coordination is harder (loss of information during information exchange, lack of information sharing due to their mutual disaffection, etc.)	Diversity in the definition (and the scope) of a patient care project	Patients' care projects definition processes differ from one HC structure to another. Care project elaboration differs according to the HC prescriptor, the HC coordinating nurse practices, etc.
	Diversity of HC care givers of different types to be coordinated	HC care givers can differ by their category (physician, nurse, social worker, etc.), skills, and contract type (internal/external and part time/full time)	Diversity in the update of a patient care project	The way care projects are updated (frequency of update, who does the update, who validates, etc.) can differ from one care giver team to another

Diversity of staff characteristics (experience, motivation, etc.)	When the staff is varied, notably in terms of work experience, motivation or culture, then operations coordination and control appear to be more complex
Diversity of human resources quality requirements	Care givers have also some expectations in terms of quality of service, among which: balancing of the workload, improvement of working conditions, satisfaction of personal preferences, etc.
Diversity of material resources	Material resources can be consumable (drugs, single-use material, dietetic products, etc.) or non-consumable (fleet vehicles, medical and paramedical equipment, information system, etc.)
Diversity of the geographical locations of patients	In HC, practitioners' activities have to be coordinated among several decentralised patient care points, either in rural or in urban areas. Since patients are not hospitalised in the same care unit, they need to be treated individually. The reactivity to patients' requests is then reduced compared to hospitals, where patients are grouped within care units
Diversity of patients	In terms of gender, degree of dependency, home conditions, family presence or not, etc.
Diversity of patient quality requirements	The quality of service towards HC patients depends on several parameters such as the technical quality of care, average waiting times, satisfaction of patients' personal preferences, satisfaction of the continuity of care constraint, existence of a trusting relationship with care givers, etc.
Diversity of operations management-related decisions in a HC setting	HC structures deal with several different issues related to operations management: capacity planning and dimensioning human resources, partitioning a territory into districts, assigning care givers (i.e. operators) to visits or to patients, defining the schedule of visits and the routing of operators, etc.
Diversity of organisations in terms of management regarding organisational/logistics activities	Organisational and logistics activities are managed by the HC Logistics/Operations Department, if such a department exists. In other cases, many supply chain functions (planning, materials order placement, order picking and delivery) are realised by nurses
Diversity in planning and executing patients' care projects	Some organisations have adopted a decentralised therapeutic project planning. After the assignment of the patient to the nurse, this last creates his/her short plan of visits. Thus, the short-term planning of therapeutic projects is charged to professionals that develop their own routings

(*Continued*)

Table 2. Continued.

	HC organisation complexity		HC patients' therapeutical project (care project) complexity	
Complexity factor	Identified factor	Description	Identified factor	Description
	Diversity of tools used to measure and analyse the performance of HC systems	Several HC performance indicators can be used including suppliers' performance in terms of delays and costs, human resource performance in terms of patient waiting time, the quality of the relationship established with patients, etc. In practice, performance metrics, tools and measurement protocols are not standardised		
	Diversity of information systems used	When information systems used in HC are varied, then the compatibility and conjoint use of these information systems appear to be a complexity source		
Interdependence- and *coordination-* related factors	Interdependence between the patient health status and the production of the service	Care production cannot be standardised and foreseen since it has to be adapted in real time to the patient health status and needs. Actions of the care giver have impact on patient's health status and vice versa. A continuous multi-dimensional assessment of patients' care projects is therefore necessary in order to capture the evolving needs	Level of interrelations between a patient's care project phases	A patient care project consists of several phases that are the design, planning, implementation and control phases. The more project phases are interrelated, the more decisions made during a phase may impact the following ones, and the more a failure occurring during a phase is to be cured by rework in other phases. As a whole, predicting the project evolution is therefore more difficult.
	Clinical and organisational processes interdependence	Clinical and organisational activities of the care delivery process have to be coordinated so that to synchronise human and material resources involved in the care delivery process	Level of interrelations between a patient's care project components	Components concern clinical, social and psychological aspects.
	Interdependencies between care givers schedules	Human resources intervening in several care projects make it all the more complex to manage the overall patients' care projects portfolio. The delay or unavailability of resources can cause shifting, delaying or not realising the activity. In this case, the schedules of the other resources would be affected	Number of interfaces in care projects coordination	Interfaces needed to coordinate a patient care project (debriefing between day and night/week and weekend teams) are potential sources of complexity.
	Interdependencies between districts of the HC	Similarly, interdependence between HC districts' (i.e. coordination requirements) care activities makes it more complex to manage the care delivery process	Care givers team cooperation, management and communication	Low team cooperation, poor management and communication make it all the more complex to manage patients' care projects since decisions, objectives and processes may for instance be shared less effectively by the care giver team.

	Interdependencies between other health structures such as hospitals	One part of HC activities (such as anti-cancer drugs preparation) is performed in hospitals which the HC works with. In such a setting, the activity of HC is strongly dependent on the reliability of the hospital activity	Care givers' relations with permanent processes	Care givers often need to be involved in several patients' care projects and one or several permanent processes (training, staff meeting, etc.). Relations with permanent organisations make it more complex to manage a given care project since these permanent structures may exert constraints on resources' availability
	Interdependencies between the different operations management-related decisions	As for good manufacturing, the different decision-making processes over the different horizons are interdependent: the result of one decision is an input or a constraint for the other	Dynamic and evolving care givers team structure	The care project team structure is to be evolving during the execution of the care services. Changes in the team structure over time imply difficulty to analyse, predict and control the behaviour of the whole care project
Elements of *Uncertainty*	Aggregate patients' demand characteristics	This is related to the total number of patients who need care, the level of care required and the time when demands would arise. Hence, demand uncertainty would have an impact on the number and the length of stay of patients in the HC system. Uncertainties stem from seasonal features, epidemiogical factors, sudden changes in patients social evolution, etc.	Individual patient demand characteristics	This is related to the level of care required by each patient (at individual patient level) and the timing when the demand would arise. They are related to sudden changes in a patient's clinical, psychological or social status (which requires an urgent request or an increased duration of patient visit)
	Availability of human and material resources	The uncertainty regarding material and/or human resources availability can be due to the inventory shortage of consumable material resources, equipment breakdowns, eventual absences of human resources (disabilities and illness) or due to the sharing of capacity with other institutions (e.g. liberal nurses).	Availability of human and material resources	Care givers are involved in several care projects. Non-availability of resources required by a care activity would make its management more complex
Elements of *Context*	Immediate environment complexity	Environmental factors such as social movements, road construction projects, traffic conditions, meteo conditions, etc. impact HC operations and generate complexity. Hence, such factors can have a direct impact on care givers' travel times		
	Demographic, technological, economic and social changes	The activity of HC is impacted by several factors, such as the ageing of the population, the increase in chronic pathologies, the introduction of innovative technologies, the continuous pressure of governments to contain health-care costs and the social changes		
	Policy priorities and funding priorities	A range of policy changes and priorities create pressure on HC. Home-based solutions are advanced not only for health, social and emotional benefits but also because of the potential reduction in public expenditure, as HC provision has been demonstrated to be more effective and efficient than institutionalised care		
	New laws and regulations	New laws and regulations (in both organisational and technological aspects) can increase operations complexity since they may result in the need for changes in the processes/outcomes, given the requirements of new laws and regulations (such as security norms, patient privacy, etc.)		
	Local laws and regulations	Regional laws and regulations (in both organisational and technological aspects) can increase complexity since they may impact notably some differentiation in processes/outcomes according to the geographical zone where they are performed/created		
	Competition	A competitive context is a more demanding and complex one since the targeted business is to choose the best care service offerings, processes, etc. in terms of expected values		
	Cultural elements variety	A HC system with a variety of cultures (social, organisational, etc.) among patients, human resources and external partners which need to be managed altogether appears to be more complex. Cultural configuration and variety can appear within the HC structure or in its environment		
	Significance of HC on public agenda	Significance on public agenda increases complexity since overall pressure increases (due to necessary delays respect and possible impacts of failing in delivering the care service), making the HC system more complex to analyse and manage		

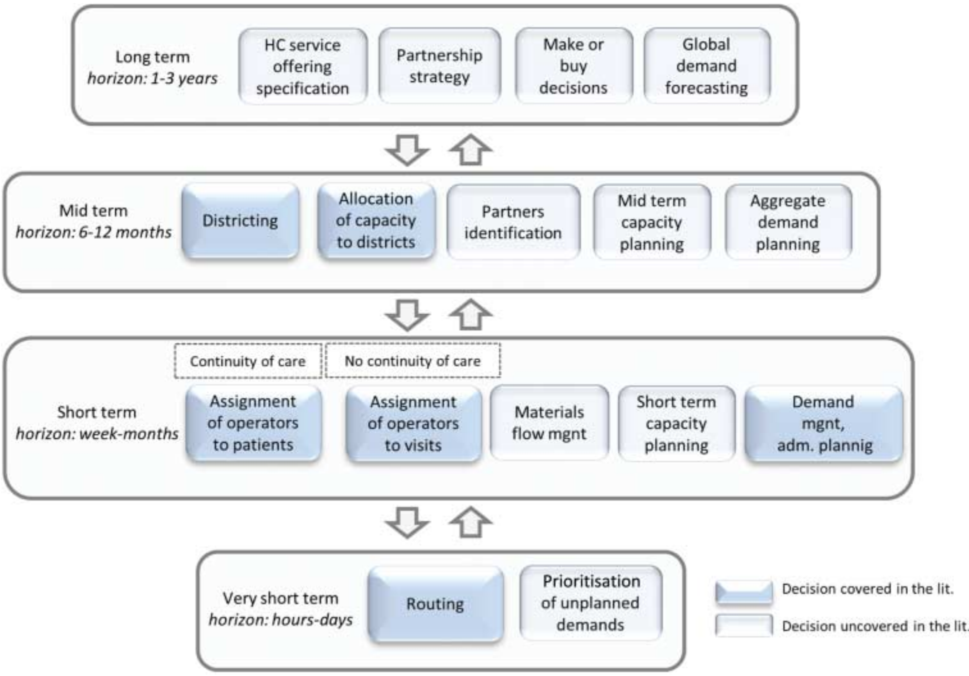

Figure 2. Operations management decisions in HC structures.

Based on an analogy with the framework described above, the hierarchical decision framework for HC systems would be made of four interdependent decision stages (cf. Figure 2):

- long-term decisions (*horizon:* 1–3 *years*) that would define: HC service offering specification (e.g. addressing questions such as which types of care services will be delivered, for which type of patients, based on which target service quality measures over which geographical coverage?) based on a global demand estimation (e.g. annual patient care volumes), make or buy decisions that refer to the integration level of the HC system (i.e. which part of HC activities is realised by internal resources and which part is outsourced?), long-term manpower planning, definition of partnership strategies and collaboration mechanisms to be deployed with external institutions, partners identification and partnership formation,
- mid-term decisions (*horizon:* 6–12 *months*) that would include: districting decision and care teams formation, demand planning and forecasting, capacity planning including resource dimensioning, contracting (e.g. defining agreements with suppliers of consumables and hospitals and specifying renting/maintenance conditions related to medical equipment) and partnership management,
- short-term decisions (*horizon: weeks to months*) that would specify more precisely human resource capacity decisions based on more accurate (short-term) forecasts of patient demands, eventually adjust the capacity by hiring external resources, assign admitted patients to operators, define materials replenishment policies and manage flows (e.g. placing orders according to a specified inventory policy and order picking) and demand (e.g. planning for patients' admission dates, re-orientation of patients towards other health-care structures and reservation of capacity at the end of patients' sojourns in HC),
- very short-term decisions (*horizon: hours to days*) that would include patients' visits scheduling and routing, managing unplanned (urgent) demands or unavailable operators leading to the re-definition of operators' routes.

4. Review of literature related to HC operations management

Despite the growing importance of HC services, the number of investigations dealing with operations management-related problems within the HC context is actually modest in comparison to the ones developed for hospitals. Among challenges facing HC operations management mod-els is the lack of a consensus that would enable to define and classify services provided by HC providers and the associated processes. Efforts such as process mapping or service blueprinting-based approaches are indeed fewer in such settings compared to hospitals. Studies aiming at better qualifying HC processes are also rare. Among exceptions is the work of Matta et al. (2012) proposing a first IDEF0 process model for representing the main processes involved in an HC system. We note that the actual lack of studies is very similar to the earlier development of hos-pital centric operations management models where research issues were initially found to be not structured, multi-dimensional and complex (Roth and Menor 2003).

The classification upon which we built the existing literature review is based on the hierarchical operations management decision framework presented in Section 3. Based on this framework, this section aims at presenting how the highlighted areas in Figure 2 have been approached in the studies published so far. The databases used were Web of Science, Sciencedirect, Scholar Google, Elsevier and the keywords were home (health) care, operations management, decision making, human resources planning and materials planning.

As such, in contrast with other services such as retail, we did not find papers that deal with the above-mentioned *long-term decisions*. In practice, most decisions such as service offering are closely related to national or regional health policies and funding mechanisms as well as the corporate status of HC systems. Similarly, we did not find studies considering collaboration or coordination issues in the HC context, neither at the long- nor at the mid-term horizon. In practice, efforts are made on a continuous basis to increase the coordination between HC providers and hospitals in order to guarantee the continuity between the discharge of patients from hospital and their admission into HC. The success levels of such efforts are various depending in general on whether the HC system considered is hospital affiliated or not.

Regarding *mid-term decisions*, there is a recent attempt in the literature to adopt a structured approach to develop districting models for HC systems. Since the productivity of operators is influenced by the size of the region which they operate in, districting models aim at dividing the service region into sub-regions (or districts) according to some pre-defined criteria. Applied earlier to the fields of politics, sales, police, etc., this problem consists in grouping small geographic areas, i.e. basic units where patients live (typically zip codes), into larger clusters called districts in a way that these latter are 'good' according to relevant criteria (e.g. workload balancing, tolerable maximum distance between two patients that belong to the same district). Hence, districts are designed such that each zip code is assigned to exactly one district, and the workload of each district must be within the allowable workload bounds of the operator or team of operators serving the district. In HC, the workload cannot be measured as a simple count of the number of patients in each district and would include visit load and travel load, i.e. time spent visiting patients and time spent travelling between patient locations (both metropolitan and rural areas should be considered). To limit travel times between patient visits, districts should be geographically compact and contiguous.

Among districting models developed so far in the literature, Blais, Lapierre, and Lapierre (2003) partition the territory by balancing equitably the workload of nurses (measured as the time spent with patients and the time spent travelling to reach patients' homes) over the six different districts of a Canadian territory. The approach is not only based on criteria related to visiting personnel mobility and workload equilibrium which are combined into a single objective function but also based on criteria related to the indivisibility of basic units, respect of borough boundaries and contiguity which are considered as hard constraints. The problem is solved by means of a Tabu search technique. Benzarti, Sahin, and Dallery (2013) develop two formulations of the districting problem by considering different patient profiles. These two mathematical formulations integrate the compactness and care workload balance criteria as either hard con-straints or objective functions. The optimality of the method proposed in Blais, Lapierre, and Lapierre (2003) is reviewed by Lahrichi et al. (2006) based on the analysis of historical data and leads to the conclusion that fluctuations in patients' care needs may have considerable impacts on the performance, resulting in inequities in terms of service quality between districts. In order to alleviate the overload of care givers, Lahrichi et al. (2006) proposes to adopt a more 'dynamic' assignment approach which divides nurses into two groups: the nurses from the first group are assigned to a specific district, while each nurse of the second group can work over the whole territory, or in a fixed subset of districts. Since the population needs fluctuate from one district to another, this gives the possibility to reassign nurses to different districts in order to maintain the balance of workloads.

Once the territory is divided into districts, the different resources must be equitably assigned to the designed districts so that the workload of care givers and the quality of services delivered to patients are roughly the same. Hence, the study developed in Boldy and Howell (1980) involves two steps: the assessment process, in which the nature and level of services required per patient are evaluated, and the allocation procedure, which aims at defining the appropriate geographical splitting of a set of HC human resources (home helpers) among several districts over a territory, i.e. dimensioning the districts. Criteria such as the number of persons/area, age, disability, hous-ing conditions and the availability of other services in each district are considered. This is a case study type work based mainly on survey information. Hence, the development of quantitative models is not the objective of the study.

At mid-term level, HC capacity planning is realised for essentially human resources. This includes resource dimensioning, i.e. definition and specification of the aggregate capacity needed to match the expected total care demand with the satisfactory service quality level and minimum cost over the specified territory. This would also concern material resources if the HC has not subcontracted this part of the activity. Then, at short-term level, capacity planning is refined by determining (for each district and at global level) the number of human resources of each type (considering nurses, physicians, home assistants, etc.) needed over several weeks/months based on more precise forecasts of patient demands. In some cases, the organisation can also decide to adjust capacity by hiring external professionals for delivering care. At each level of decision, the capacity planning decisions are based on an estimation of the uncertain demand for services over the territory. Generally, most operations management decisions such as districting, resource dimensioning, assignment, patient admission planning, etc. rely on (accurate) forecasts of patients' demands. We found several works that consider issues related to patients' admission planning under uncertainties and demand forecasting. Hence, De Angelis (1998) has developed a stochastic linear programming model which aims at producing an optimal schedule for admitting new patients to the HC system over a 12-week planning period, subject to constraints on available resource and-budgets. The objective is to maximise the number of patients who can be admitted to HC each week. The model takes into account the minimum standard of service as well as the uncertainty regarding the level of service request associated with each type of patient patients are classified into classes of dependency between which transition rates are defined) requires. In the same vein, Busby and Carter (2006) developed a queuing theory-based model enabling the calculation of patients' expected wait times to be admitted in the HC system based on inputs regarding demand and available capacity to provide care services. Based on the model, patients can be informed of their expected waiting time for service and may be able to decide whether to wait for public service or to purchase it privately. The model permits not only to quantify waiting times but also helps to prioritise patient classes to receive care service, determines the impact of budget changes on wait times and serves as a basis to negotiate with the government regarding the funding levels necessary. More recently, Lanzarone, Matta, and Scaccabarozzi (2010) proposed a patient model which entails two parts: a care pathway model related to the stochastic evolution of patients' needs and a cost model which describes resources required by the patient according to his/her pathway. The care pathway model is based on a Markov chain in which states correspond to the care profile of patients. Transition matrices between care profiles are defined based on historical data. The model provides estimations of future demands, in the form of empirical probability density functions. A topic very complementary to demand forecasting is related to the specification of patients' therapeutic projects, i.e. the design and modelling of operations management-related aspects in such projects; e.g. what type of information regarding patients' future requirements is to be included in therapeutic projects, in what form such information is desired (e.g. forecasts vs. firm demands, horizon, granularity and accuracy levels of forecasts), when does the information need to be available (specifying earliest/latest dates for information availability), for which actors, etc. No paper was found on this topic.

Regarding *short-term decisions*, assignment problems are of particular interest in HC settings. This problem consists of allocating each newly admitted patient to one or several operators chosen among a set of possible operators. Assignment of nurses to patients is the most com-mon assignment problem in HC. Developing districting models enables to simplify the resource assignment problem: patients are first assigned to a district and then assigned to operators chosen among the ones available in the same district (in the independent districts organisation scheme) or other close districts (in the coordinated districts organisation scheme).

In general, the assignment problem is formulated with an objective of balancing the workload (between operators, districts or care giver teams) by considering several aspects such as the travel time needed to reach the patients, the availability of operators, the higher pay for extra time in the case the standard working time is exceeded, skills of operators or coordination between districts that affect the patient visit times. Workload can be measured as visit load (which depends on the heaviness of the visit compared to a witness visit), case load (which depends on the number of patients assigned to a nurse in each category) and travel load. Again, the continuity of care objective, when pursued, stipulates that the patient be assigned to only one operator and that the assignment not be changed for a long period. In practice, in order to guarantee the continuity of care in HC, a patient is often assigned to a care giver, the reference operator, who follows the treatment of the patient during the time spent in the HC structure (Shortell 1976). Most of the time, the reference care giver is the nurse who gives the paramedical care and coordinates the overall care with other care givers such as the physician, social worker, etc. This is an important quality requirement of the HC service (Haggerty et al. 2003) known as consistency of service provider. Such a consideration enables the patient to receive service from the same care giver and thus does not have to continuously change his/her relationships with a new care giver. Studies have shown a correlation between continuity of care, increased patient satisfaction and decreased hospitalisations and emergency room visits (Cabana and Jee 2004).

Hence, different complexity factors can be considered while modelling assignments: conti-nuity of care constraint, interdependencies of assignments between districts, stochastic patient demands, etc. In the literature, the assignment problem is solved by including some, by using approaches based on mathematical programming or structural policies. In the first group, Borsani et al. (2006) combine a simple assignment model and a scheduling model: the output of the assignment model serves as input to the weekly operators' scheduling model. The objective of the assignment model is to ensure workload balance among operators while respecting some constraints such as qualification requirements and geographical coherence constraints. Hertz and Lahrichi (2009) propose two mixed integer programming models for assigning operators to patients. One model includes linear constraints and a quadratic objective function, while the other includes nonlinear constraints. The objective is to balance operators workloads while respecting constraints related to maximum acceptable loads and assigning each patient to exactly one nurse of each type. The possibility of assigning a patient to a nurse who does not belong to the patient's district is also considered. Tabu search technique is used to solve the problem. A more complete modelling framework of the possible variants of the assignment problems encountered in HC is developed in Lanzarone, Matta, and Sahin (2012) where authors develop a set of mathematical programming models to balance the workloads of operators within specific categories. The mod-els consider several peculiarities of HC services, such as the continuity of care constraint, the skills of the operators and districts which patients and operators belong to, under the assump-tion that patients' demands are either deterministic or stochastic. For stochastic demand case, the assignment problem is solved under the expected value, here and now and wait and see approaches.

Lanzarone and Matta (2012) argue that building up on the knowledge about the structure of the optimal assignment policies could be helpful in developing the patient assignment literature in HC: providers could easily apply simplified policies without requiring expensive software appli-cations; analytical policies can solve the problem with a limited computational effort, allowing to include the variability of the demand; the structure of the optimal policy could be used to help research the optimum in the heuristic-based algorithms that have to be adopted for large-scale problems faced by large HC providers. Hence, they develop a structural policy for assigning one newly admitted patient to an HC operator (e.g. nurse, physician and physiotherapist) under uncer-tain workload (stemming from uncertain amount of care needed by the patients) and respecting the continuity of care. More specifically, their goal is to minimise a stochastic cost function based on the time for visits provided by the nurses above their capacities.

The reader interested in further details regarding studies presented so far can refer to Table 3 where we provide a synthesis of existing models developed for long-, mid- and short-term decisions.

Very short-term decisions are the most frequently addressed issues in the existing HC models literature. If the constraint of continuity of care is not required and patients can be cared for by several operators, at very short term, human resources are assigned to the activities of patients' therapeutic projects (e.g. care visits and goods delivery) rather than to individual patients. Hence, the assignment planning and the routing (scheduling) problems are the same, i.e. they are solved simultaneously to define the sequence of care activities each operator has to execute in the spec-ified period, generally a week. A common assumption is that the weekly visits for each patient occur according to a pre-specified visit day combination (i.e. a pattern) for that patient. For exam-ple, allowable combinations for a two visit per week patient could be Monday and Thursday or Tuesday and Wednesday. Several parameters can add complexity in solving this problem: skills of operators and interdependencies of districts would affect visit durations, two operators may be requested at the patient home for a specific visit, patients can have preferences (e.g. being visited by the same operator from week to week or constraints regarding the earlier/latest visit times), there may be precedence constraints between activities, uncertainties inherent to the HC system create perturbations in the planned routes, the HC may want to design optimal routes so that these are repeatable from week to week in terms of visit days, etc. Regarding the objective function considered, there are several variants such as the minimisation of travelling times, oper-ators' overtime costs, the number of uncovered visits or the maximisation of patient satisfactions or nurse productivity in terms of number of patients serviced for instance.

The reader can find a detailed presentation of the literature associated with HC routing mod-els in a previous work, i.e. Yalcindag, Matta, and Sahin (2011), from which Table 4 is adapted. Hence, four criteria families are used to classify models: (i) study type, (ii) modelling charac-teristics, (iii) network characteristics and (iv) data characteristics. Hence, in the first category, each study is classified according to the type of model used Travelling Salesman Problem (TSP), Vehicle Routing Problem (VRP), the solution approach applied and whether the implementation of the model exists or not. The next category group aspects are related to the time window

Table 3. Long-, mid- and short-term planning decisions-related literature in HC.

Article	Decision type considered	Objective(s) of the problem	complexity factors considered: Elements related to the size of the problem analysed	Diversity of patients considered	Diversity of care givers considered	Interdependencies considered	Uncertainties considered	Other complexity factors considered	Research type	Application of the model	Involvement of physicians in the list of authors
Blais, Lapierre, and Lapierre (2003)	Districting problem	Design districts to respect: the indivisibility of basic units, connectivity, personnel mobility and district	Numerical examples solved for 2 districts to be designed for 10 basic units				Deterministic problem parameters	Care providers' quality expectation depends on workload equilibrium	Multi criteria optimisa-tion model	The model has been implemented in Montreal Canada	No
Benzarti, Sahin, and Dallery (2013)	Districting problem	Design districts to respect: the indivisibility of basic units, district workload equilibrium and maximum distance between two patients		Different profiles of patients are considered			Deterministic problem parameters	Care providers' quality depends on workload equilibrium and patients' quality depends on the continuity of care and the reactivity of care providers	Mathematical program-ming	Not applied on a real case	No
Lahrichi et al. (2006)	Districting problem	Evaluate the performance of a districting model based on historical data	Territory of 125,000 in habitants, among which 5200 are regular HC users. 6 districts		External nurses, case manager nurses and nurse technicians. Nurse technicians are assigned to short-term patients or long-term patients needing punctual nursing	The design of a surplus team which can be assigned to any district at any moment (district interdependencies) is considered	The impact of demand fluctuations on the districting problem is assessed a posteriori	Care providers' quality expectation depends on workload equilibrium	Case study	The work is based on a districting model applied in Montreal Canada	Yes
Boldy and Howell (1980)	District dimension-ing: allocation of resources to districts	Define the appropriate geographical splitting of a set of HC home helpers among several districts over a territory		Different patients' profiles (elderly, patient with disability, . . .), population structure of the territory		The approach involves the consideration of two interdependent decisions: patients' future demand estimation and dimensioning of existing districts		Patients' quality depends on the reactivity and availability of care givers	Case study	The developed approach has been implemented in a Home Help Service organisation	Yes

(*Continued*)

Table 3. Continued.

Article	Decision type considered	Objective(s) of the problem	Elements related to the size of the problem analysed	Diversity of patients considered	Diversity of care givers considered	Interdependencies considered	Uncertainties considered	Other complexity factors considered	Research type	Application of the model	Involvement of physicians in the list of authors
De Angelis (1998)	Admission regulation	Define an admission schedule for patients to maximise the number of patients that can be admitted each week; patients in different classes may be given different weights to express priority		AIDS patients (divided over five groups depending on their dependency levels) are considered	Nurses, doctors and social workers considered	Two interdependent models are developed: epidemiological model for patients' demands forecasting, a model producing an optimised admission schedule for a given planning period	The level of service patients require is uncertain	The transition of patients from one class to another is modelled by transition rates	Stochastic linear programming model which is linked to an epidemiological model	Model implemented for one HC provider in the city of Rome	No
Lanzarone, Matta, and Scaccabarozzi (2010)	Patients' demand forecasting	Develop a stochastic model to represent the patients' care pathways in order to predict how many patients are followed up in the course of time and, for each of them, the duration of care and the amount of required visits	14 Care pathways identified			Forecasts obtained in the model are helpful for several decisions: estimate the number of care givers necessary to satisfy demand, schedule efficiently the care givers' activities, to assign care givers to the new patients, etc.	The patient care duration, the number of cared patients and the number of requested visits within a time frame are uncertain		The model consists of a Markov chain whose state variable is the care pathway coupled with the number of visits distribution for each state	The developed approach has been tested in one Italian provider	No
Borsani et al. (2006)	Operator assignment and routing problem	Two models are developed for deciding: (1) which human resource should be assigned to which patient and (2) when to execute the service during the planning horizon, in order to satisfy the care plan for each patient	Test on 2 providers: (1) Provider A: 382 patients and 25 operators, and (2)Provider B: 87 patients and 6 operators		Operators qualifications differ (the ability to carry out or not palliative cares or the duration for cares given)	Consideration of an assignment model serving as input to the scheduling model		Care providers' quality depends on workload balance, the respect of the times windows and their burn out level. Patients' quality depends on the continuity of care and respect of preferential days	Mathematical programming	The model was tested on two Italian providers	No

Hertz and Lahrichi (2009)	Operator assignment problem	The aim is to balance the workload of the nurses (assessed based on three measures) while avoiding long travels to visit the patients	19 case manager nurses, 7 nurse technicians, 1413 patients and 36 basic units	Several patient profiles: (1) short-term patients that do not require case management, (2) short-term patients that need post-hospitalisation or post-surgery care, (3) long-term patients needing punctual nursing care, (4) patients with loss of autonomy and (5) palliative patients	Two types of nurses considered: (1) nurse technician and (2) manager nurse. A major part of nurses are already assigned to districts, while the surplus team consists of nurses that can work in any district			Two assignment policies are compared: a first policy immediately assigning a new patient admitted and a second policy considering making the assignment a few days later. By waiting a little bit, this policy has the possibility to perform the assignment of several patients at the same time and can thus better control the balance of the workload of the nurses	A mixed integer programming model with some *n* on-linear constraints and a non-linear objective which is solved using a Tabu Search algorithm	The model has been implemented in Montreal Canada.	No
Lanzarone, Matta, and Sahin (2012)	Operator assignment problem	Assign operators to patients so that the workload of operators is well balanced				Districts can be managed in a coordinated way so that they share the same resources (i.e. operators)	Patients' demands are either deterministic or stochastic	Continuity of care is considered	Mathematical programming (deterministic and stochastic)	Model implemented for an Italian HC provider	No
Lanzarone and Matta (2012)	Operator assignment problem	Minimise a cost function for each operator that depends on the amount of time for visits that he/she supplies in surplus to his/her capacity and balance workload among operators	The analysis is for the largest division of a HC organisation. Six independent districts and 22 nurses are considered	Palliative and non-palliative patients are considered			Patients' demands are uncertain	The goal of the assignment is to allocate the newly admitted patient to only one reference operator, among the *n* compatible ones, characterised by the lowest increment of the expected cost	A structural analytical policy is developed	Model applied for a HC provider in the north of Italy	No

Table 4. Criteria used to classify very short-term planning literature in HC.

1.	**General characterisation of the study**	2.3.2.2.	With material resource	3.2.1.1.	Single
1.1.	*Model based*	2.4.	*Patient covering*	3.2.2.	Multiple
1.1.1.	TSP	2.4.1.	Always	3.2.2.1.	General depot
1.1.1.1.	Deterministic	2.4.2.	Uncovered	3.2.2.2.	Operators' houses
1.1.1.2.	Stochastic	2.4.3.	Precedence and coupling	3.3.	*Time window type*
1.1.2.	VRP	2.4.4.	Qualification required	3.3.1.	Patient dependent
1.1.2.1.	Deterministic	2.4.5.	Disjunctive events	3.3.2.	Operator dependent
1.1.2.2.	Stochastic	2.4.6.	Care continuity	3.4.	*Contract type of the operator*
1.2.	*Solution approach based*	2.4.7.	Exclusion	3.4.1.	Full time
1.2.1.	Exact approach	2.5.	*Service providing*	3.4.2.	Half time
1.2.1.1.	State-of-the-art solver	2.5.1.	Single	3.4.3.	External
1.2.1.2.	Simulation	2.5.2.	Multiple	3.5.	*Operators' skill type*
1.2.2.	Heuristic approach	2.6.	*Provider type*	3.5.1.	Identical
1.2.2.1.	New approach	2.6.1.	Nurse/Doctor visiting	3.5.2.	Different qualifications
1.2.2.2.	Existing approach	2.6.2.	Drug delivery	3.6.	*Quality of the system*
1.2.2.3.	Simulation	2.7.	*Objective*	3.6.1.	Patients' point of view
1.3.	*Implementation*	2.7.1.	Single criterion	3.6.2.	Operators' point of view
1.3.1.	Applied	2.7.1.1.	Min. total distance travelled	3.7.	*Travel time*
1.3.2.	Not applied	2.7.1.2.	Min. visiting outside districts	3.7.1.	Deterministic
2.	**Modelling characteristics**	2.7.1.3.	Min. cost of overtime and part time hours	3.7.2.	Stochastic
2.1.	*Time window structure*	2.7.1.4.	Min. unshared visits	3.8.	*Demand*
2.1.1.	Soft time windows	2.7.1.5.	Min. shared visits	3.8.1.	Deterministic
2.1.2.	Hard time windows	2.7.2.	Multiple criteria	3.8.2.	Stochastic
2.1.3.	Both soft and hard time windows	2.7.2.1.	Min. uncovered visits	3.9.	*Service time*
2.2.	*Time horizon*	2.7.2.2.	Max. patient and operator satisfaction level	3.9.1.	Equal
2.2.1.	Daily	2.7.2.3.	Min. total distance travelled	3.9.2.	Variable
2.2.2.	Weekly	3.	**Network characteristics**	3.9.2.1.	Deterministic
2.2.3.	Monthly	3.1.	*Geography*	3.9.2.2.	Stochastic
2.3.	*Visiting structure*	3.1.1.	Single district	4.	**Data characteristics**
2.3.1.	Unshared visits	3.1.2.	Multiple districts	4.1.	*Real-world application*
2.3.2.	Shared Visits	3.2.	*HC centre*	4.2.	*State-of-the-art data*
2.3.2.1.	With human resource			4.3.	*Randomly generated data*

structure, the time horizon considered, visit characteristics, patient covering, service providing, provider type and study objective. Network characteristics refer to the HC geography structure, HC centre, time window type, contract type of operator, operator homogeneity, quality of the system, travel times, demand and service times. Finally, concerning data used, a distinction is made between real-life instance, randomly generated instance or widely applied state-of-the-art instance data.

In addition to the classification provided in Table 4, a brief description of each work is given here. Hence, Begur, Miller, and Weaver (1997) develop a daily scheduling model of operators' activities, which simultaneously assigns visits to operators and generates the sequence in which visits have to be provided. This is based on a heuristic approach that combines a set of procedures (e.g. *k*-optimal procedure, sweep algorithm and insertion procedures) to build routes for each nurse for each day of the planning horizon. The objective is to minimise the total travel time while respecting constraints related to route construction, operators' time windows and skills requirements. Cheng and Rich (1998) address the daily scheduling problem as a multi-depot VRP with time windows and compatibility information. The objective is to minimise the total cost associated with the overtime hours assigned to full-time nurses and the hours given to part-time nurses. The problem is formulated as a mixed integer linear programming model and solved by a two-phase heuristic. Bertels and Fahle (2006) propose a combination of linear programming, constraint programming and heuristics to assign operators to visits and to optimally sort the visits assigned to each operator. The goal is to minimise the total transportation cost and maximise the satisfaction of both patients and operators, while considering a variety of soft constraints (e.g. patient–operator affinities, preferences for certain visits and care givers' time preferences). Eveborn, Flisberg, and Ronnqvist (2006) develop a decision support system, named Laps Care, in which the scheduling problem creates initial *m*-Travelling Salesman Problem with Time Window solutions that maximise the number of patients served and minimise distance travelled subject to hard constraints for critical time windows and soft constraints for patient provider preferences. Schedules are determined by applying a heuristic solution approach to a set partitioning model, and schedulers can make new solutions by adding staff members or relaxing constraints. The objective is to minimise total cost related to travel time, scheduled hours, preferences, etc., while respecting criteria such as time windows for visits, operators' skill requirements and accomplishment of each visit by one operator. In Eveborn et al. (2009), the improvements of Laps Care on the home health-care system in Sweden are summarised. Thomsen (2006) formulates the daily scheduling problem as a VRP with time windows. The objective is to minimise the total travel time, the number of shared visits (carried out by two oper-ators) and unlocked visits (carried out by non-reference operators), while respecting patients' and operators' time windows, assigning at least one visit to each operator and beginning and ending shared visits at the same time. This problem is solved by an insertion heuristic and the Tabu search technique. Similarly, Akjiratikarl, Yenradee, and Drake (2007) address the daily schedul-ing problem as a VRP with time windows and solves it with the particle swarm optimisation meta-heuristic. The objective consists of minimising the total distance travelled while respecting constraints related to patients' and operators' time windows and assignment of each visit to only one operator. Ben Bachouch et al. (2008) developed a VRP model with time windows as a mixed linear programming model which aims at minimising the total distance travelled by nurses. This model considers several constraints: nurses' meal breaks, continuity of care, maximum distance between two consecutive visits by the same nurse and each nurse's route beginning and ending at the HC facility. Ben Bachouch et al. (2009) address the daily drug delivery problem as a VRP with time windows. The objective is to minimise the total distance travelled. They assign carriers to specific regions so that each tour is realised by the same carrier. In addition, they develop four different strategies: starting deliveries when a specified number of deliveries is received, starting deliveries if a specified distance is reached regarding the planned deliveries, starting deliveries on a fixed number of deliveries per carrier and starting deliveries on fixed hours. They com-pare results for each strategy in order to identify which one is the most efficient to solve the drug delivery problem. Elbenani, Ferland, and Viviane (2008) developed a model for determin-ing routes for operators, which incorporates constraints of the VRP with medical and continuity of care constraints. Each patient and each nurse are assigned to a region. A nurse is allowed to visit a different region with a certain penalty. They also add blood sample-related constraints (called medical constraints) and they consider an objective of minimising the total travelling cost of operators. As a final step, they solve this problem with a meta-heuristic approach based on Tabu search. Chahed et al. (2009) and Chahed et al. (2011) consider the routing problem for the chemotherapy at home practice, where the production and distribution problems are dependent because the anti-cancer drugs produced at hospital and distributed to patients' homes have limited lifetimes. They identify six models based on three criteria: the respect of patients' time windows, the objective function considered (to minimise the distribution cost or to maximise the earnings achieved per patient visited) and the distribution of drugs by HC personnel or by an external logistic service. They develop solutions for one of these models. Kergosien, Christophe, and Billaut (2009) formulate the routing problem to an m-TSP problem with time windows. The objective is to minimise the total travelling cost while respecting visits' and operators' time windows constraints, the assignment of each patient to one operator, synchronised (some visits require more than one operator) and disjunctive (some operators cannot work together) services constraints. They test the model on randomly generated instances with Cplex solver. Bennett and Erera (2011) developed a static variant of the nurse routing problem to understand the impact of fixed appointment times on routing and scheduling decisions. A first distance-based heuristic is shown to have limitations for appointment time problems. Then, a rolling horizon capacity-based heuristic is developed. It considers interactions between travel times, service times and the fixed appointment time menu when inserting appointments for currently revealed patient requests into partial nurse schedules. Trautsamwieser, Gronalt, and Hirsch (2011) developed a model for daily planning. The goal is to secure the HC service in times of natural disasters. They develop a VRP model with state-dependent breaks, the objective being to minimise travel times and waiting times, and also the dissatisfaction levels of patients and operators subject to the assignment con-straints, working time restrictions, time windows and mandatory breaks. More recently, based on a generalisation of the VRP with time windows, Rasmussen et al. (2012) modelled the routing problem as a set partitioning problem with side constraints and developed an exact branch-and-price solution algorithm. They used a multi-criteria objective function which includes the min-imisation of uncovered visits, the maximisation of operator-visit preference and the minimisation of the total distance travelling costs. They assign a higher priority to the uncovered visit part than the other parts. Constraints of the model include: each visit can be covered exactly once or left uncovered, operators can only handle allowed visits, patients' and operators' time windows and precedence relations of visits. Nickel, Schrder, and Steeg (2012) use constraint programming and adaptive large neighbourhood search to construct a set of schedules for each day of the week, which satisfies visit day combination constraints for patients which are known in advance. The paper also partially addresses problem dynamics by developing a Tabu search algorithm that can be used to incorporate periodic visits for a new patient into partial schedules. One com-mon characteristic of investigations presented here is that none of the models considers demand uncertainty. Yalcindag, Matta, and Sahin (2012) proposed a two-stage approach for assignment and routing decisions. The main goal was to analyse the interaction between the assignment and routing processes. Specifically, they evaluated how different assignment models can change the routing policy. At assignment level, they used a mathematical programming model and two different structural policies; all the approaches are subject to balancing the workloads among operators. After solving the assignment problem, a TSP model is formulated for the routing problem. The output of the assignment problem is incorporated as an input into the routing problem.

5. Conclusions

This paper aims at contributing to a better understanding of the relatively new area of HC services, a field in which operations management-based approaches need some adaptations to the specificities of such a service activity that is provided at patients' homes. Hence, we conducted a structured review of the scientific literature dealing with HC operations management in the past few years. We also proposed a framework that represents in a comprehensive way the potential factors of complexity in HC settings.

Our analysis highlights the lack of research regarding operations management models for HC. Although the practical interest is widespread, the level of theoretical and empirical work does not really reflect this. We see that as a call for further research in this area.

The papers analysed have provided a great deal of information but none of them provides a complete picture of HC operations management issues and challenges. Although HC systems appear to be different between and within countries, international scientific studies aiming at comparing the differences (which may stem from pathologies covered by the HC provider, fund-ing differences, cultural aspects, etc.) are still rare. Besides, integrated studies handling the HC system operations as a whole are non-existent, to the best of our knowledge. A large part of studies focuses on operational type decisions such as human resource assignment and routing models, without putting in perspective the interactions/impacts of such models with the other levels of decisions and the complexities associated with such interactions.

Many studies are conducted as case studies and therefore results are obtained for a specific geographical area (metropolitan or rural), different types of HC having different sizes, for a set of specific patient pathologies, etc. As a consequence, different outcomes are observed in different studies. More generic models suitable for HC systems may be valuable for practitioners.

Our review shows also that there still exist several relevant topics to investigate for those interested in operations management models applied to HC. Without pretending to be exhaustive, the following paragraphs aim at illustrating some of these directions.

An integrated care system is a system in which care services are provided in both hospitals and the community. The care network consists thus of several care facilities having different status and objectives that participate to giving care to patients. Decision-making models are needed regarding the best choices to make when building up patients' care pathways, i.e. how to manage and dispatch patients through a health network which consists of entities such as hospitals, HC providers, clinics, nursing homes, how to prioritise patient demands by respecting the available capacities? The development of such models can also help to clarify the eligibil-ity criteria that would be relevant to use when admitting patients in HC where admission and discharge decisions are not often based on objective decision-making tools. For instance, the improper acceptance of a highly intensive patient can saturate some key critical resources, thus delaying the admission of other patients that will wait longer to be accepted into the service. Admission management and resource planning are thus fundamental problems which require the definition of strategies to effectively manage care services ensuring optimum utilisation of resources. The complexity associated with the regulation of patient admissions stems from factors such as the uncertainty underlying the patient arrival process, the uncertainty relative to the length of stay in HC, different modes of coordination and heterogeneous information sharing pro-cesses between the upstream institutions supplying patients for HC and downstream institutions recruiting from HC, respect of an equity among patient classes arriving from different institu-tions, patient pathologies and specific care preferences and HC available capacity. Multi-criteria decision models would be helpful in addressing this issue.

HC systems evolve in a (collaborative) health network involving actors from different entities which may have disparate incentives and direct impacts on HC operations. Although win–win agreements between entities are underlined, there is actually a lack of studies providing a better qualification and quantification of the potential advantages gained from these partnerships and the possible modes in which partnerships can be established. Among topics of interest, the development of models enabling to measure the value of collaboration, identifying conditions for a profitable collaboration, defining the possible organisational forms of collaboration seems to be relevant. Supply chain models developed for decentralised chains that seek to answer questions of sharing values generated by a system having multiple players, which are based on contract management and game theory as coordination mechanisms (Cachon 2003) can represent an interesting starting point to address this issue. A second, related research interesting to look at would be the investigations developed in the field of collaborative clusters (collaborative network, virtual teams, etc.) by adapting them to the specific context of health systems (Camarinha-Matos and Afsarmanesh 2007).

At operational level, resource planning and assignment as well as materials management prob-lems encountered in HC systems are similar to those observed in hospitals but are more complex since patients and resources are geographically distributed. Similarly, routing problems resemble problems observed in freight transportation services but differ from them by the fact that patient care projects are unique and often subject to random perturbations. Therefore, the need for mod-els enabling an efficient coordination between different types of flows is even stronger in the HC context. Hence, first, models should be developed towards the specification (i.e. design) of patient care projects by considering clinical as well as logistical aspects when providing an esti-mation of patients' future care needs. Second, further models enabling the planning of activities that require different types of care givers from different organisations who have to cooperate for delivering a complete care are necessary. As stressed before, the coordination of human resources lies in the fact that some care activities may require resources from different human resource pro-files and that these activities are interconnected. Such models are needed at assignment as well as routing levels.

Supply chain management-based approaches have still to be introduced to the HC context. As such, flow management models enabling the sourcing and synchronisation of material resources from different suppliers located at different locations delivered for different patients geographically dispersed by reducing costs while maintaining the target quality of service are required. Such models are subject to constraints: non-consumable resource providers (i.e. special medical bed, assisted ventilation equipment) and logistics service providers in charge of delivery may have availability constraints, other supplies (i.e. drugs, cytotoxics, single-use sterile medical devices) may have lifetime constraints. In addition, flow management models should include emergency scenarios and/or equipment failure situations. Models should also integrate the management of return flows from patients to suppliers generated by supplies not consumed and/or outdated, waste associated with the drugs used, etc.

More generally, another appealing and challenging research stream for HC would be the consideration of human behaviour models in quantitative models supporting decision making for HC operations management. Discussions we had with HC professionals helped us to identify several human aspects impacting operations management in HC systems. First, the production of care services relies on humans whose behaviour may depend on the organisation in terms of management (e.g. size of care givers' teams, management style and coaching of these teams, and motivation incentives). Such an observation has also been made earlier for other types of services. An illustrative example is that of telephone call centres. In this area, the production of service, that is the response to the request of a client, is produced by operators. The mode of organisation and management of a call centre structure has a strong impact on the perfor-mance of operators, in terms of rapidity in answering the call as well as quality of the response. It is therefore particularly interesting to integrate behavioural models in staffing and assignment optimisation models to be more realistic while choosing the best scheme to organise the call centre structure. Another example concerns the more explicit consideration of operators' stress levels in decision-making models. In practice, HC providers try to integrate such considerations when assigning nurses (e.g. not assigning a stressed and saturated operator to a heavy pathology or terminal patients or on night shifts). Such practices aim to prevent operators from the burn out syndrome. Including the stress of operators in assignment problems would be a challenging result. Other behaviours at patient level would also impact operations. Since the patient is explicitly involved in producing the service, the way the production of care is organised can impact a patient's behaviour and in turn this has an impact on the service. Hence, it would be interesting to evaluate and compare possible modes of organisation by including patients' behavioural impacts. It is important to emphasise that here the aim is not to develop new models of behaviour (as defined in behavioural science literature) but to integrate existing behavioural models in operations management models. This can be compared (from the logical view of the approach) to taking into account a model of behaviour of a machine in manufacturing models (e.g. how does the failure rate increase when we increase the speed of a machine).

References

Akjiratikarl, C., P. Yenradee, and P. R. Drake. 2007. "PSO-Based Algorithm for Home Care Worker Scheduling in the UK." *Computers and Industrial Engineering* 53 (4): 559–583.

Anthony, R. N. 1965. *Planning and Control Systems: A Framework for Analysis*. Boston, MA: Harvard University.

Bajo, J., A. J. Fraile, P.-L. Belén, and M. J. Corchado. 2010. "The Thomas Architecture in Home Care Scenarios: A Case Study." *Expert Systems with Applications* 37 (5): 3986–3999.

Begur, S. V., D. M. Miller, and J. R. Weaver. 1997. "An Integrated Spatial Decision Support System for Scheduling and Routing Home Health Care Nurses." *Interfaces* 27 (4): 35–48.

Ben Bachouch, R., M. Fakhfakh, A. Guinet, and S. Hajri-Gabouj. 2008, "Planification de la tournée des infirmiers dans une structure de soins à domicile." Conférence Francophone en Gestion et Ingénierie des Systèmes Hospitaliers (GISEH), Switzerland.

Ben Bachouch, R., M. Fakhfakh, A. Guinet, and S. Hajri-Gabouj. 2009, "A Model for Scheduling Drug Deliveries in a French Homecare." International conference on industrial engineering and systems management (IESM), Montreal, Canada.

Bennett, A., and A. Erera. 2011. "Dynamic Periodic Mixed Appointment Scheduling for Home Health." *IIE Transactions on Healthcare Systems Engineering* 1 (1): 6–19.

Benzarti, E., E. Sahin, and Y. Dallery. 2013. "Operations Management Applied to Home Care Services: Analysis of the Districting Problem." *Decision Support System* 55 (2): 587–598.

Berman, A. J. 1999. "Supporting the Home Care Client Receiving Chemotherapy." *Home Care Provider* 4 (2): 81–85.

Berry, L. L., and N. Bendapudi. 2007. "Health Care: A Fertile Field for Service Research." *Journal of Service Research* 10 (2): 111–122.

Bertels, S., and T. Fahle. 2006. "A Hybrid Setup for a Hybrid Scenario: Combining Heuristics for the Home Health Care Problem." *Computers and Operations Research* 33 (10): 2866–2890.

Blais, M., S. D. Lapierre, and G. Lapierre. 2003. "Solving a Home-Care Districting Problem in an Urban Setting." *Journal of Operational Research Society* 54 (11): 1141–1147.

Boldy, D., and N. Howell. 1980. "The Geographical Allocation of Community Care Resources: A Case Study." *Journal of the Operational Research Society* 31 (2): 123–129.

Boothroyd, L., and P. Lehoux. 2004. La chimiothérapie basée au domicile: Les enjeux pour les patients, les soignants et le réseau de la santé, Rapport pour l'AETMIS (Agence d'Evaluation des Technologies et des Modes d'Intervention en Santé).

Borsani, V., A. Matta, G. Beschi, and F. Sommaruga. 2006. "A Home Care Scheduling Model for Human Resources." Proceedings of ICSSSM06 (international conference on service systems and service management), 449–454. Troyes, France.

Brailsford, S., and B. Schmidt. 2003. "Towards Incorporating Human Behaviour in Models of Health Care Systems: An Approach Using Discrete Event Simulation." *European Journal of Operational Research* 150 (1): 19–31.

Burau, V., H. Theobald, and R. Blank. 2007. *Governing Home Care: A Cross National Comparison*. Cheltenham: Edward Elgar Publishing.

Busby, C. R., and M. W. Carter. 2006. "A Decision Tool for Negotiating Home Care Funding Levels in Ontario." Home Health Care Services Quarterly 25 (3–4): 91–106.

Cabana, M. D., and S. H. Jee. 2004. "Does Continuity of Care Improve Patient Out-Comes." *The Journal of Family Practice* 53 (12).

Cachon, G. P. 2003. "Supply Chain Coordination With Contracts." In *Handbooks in Operations Research and Management Science: Supply Chain Management*, edited by S. Graves and T. et de Kok. Amsterdam: Elsevier.

Camarinha-Matos, L. M., and H. Afsarmanesh. 2007. "A Comprehensive Modeling Framework for Collaborative Networked Organizations." *Journal of Intelligent Manufacturing* 18 (5): 529–542.

Campbell, S. M., M. O. Roland, and S. A. Buetow. 2000. "Defining Quality of Care." *Social Science & Medicine* 51 (11): 1611–1625.

Chahed, S., D. Feillet, E. Sahin, and Y. Dallery. 2011. "The Anti-Cancer Drug Supply Chain: A Coupled Production-Distribution Problem." *Supply Chain Forum* 12 (1): 22–30.

Chahed, S., E. Marcon, E. Sahin, D. Feillet, and Y. Dallery. 2009. "Exploring New Operational Research Opportunities Within the Home Care Context: The Chemotherapy at Home." *Health Care Management Science* 12 (2): 179–191.

Cheng, E., and J. L. Rich. 1998. *A Home Health Care Routing and Scheduling Problem*. Technical Report, CAAM TR98-04. Rice University.

Chesteen, S., B. Helgheim, T. Randall, and D. Wardell. 2005. "Comparing Quality of Care in Non-Profit and for-Profit Nursing Homes: A Process Perspective." *Journal of Operations Management* 23 (2): 229–242.

Chevreul, K., L. Com-Ruelle, F. Midy, and V. Paris. 2004. “The Development of Hospital Care at Home: An Investigation of Australian.” *British and Canadian Experiences*, Questions d’Economie de la Santé 91.

Choi, K. S., H. Lee, C. Kim, and S. Lee. 2005. “The Service Quality Dimensions and Patient Satisfaction Relationships in South Korea: Comparisons Across Gender, Age and Types of Services.” *Journal of Service Marketing* 19 (3): 140–149.

Chu, D., R. Strand, and R. Fjelland. 2003. “Theories of Complexity – Common Denominators of Complex Systems – Essays & Commentaries.” *Complexity* 8 (3). Wiley Periodicals.

Colombo, F., A. Llena-Nozal, J. Mercier, and F. Tjadens. 2011. *Help Wanted? Providing and Paying for Long-term Care*. Paris: OECD Publishing.

Corbett, L. M., J. Brockelsby, and C. Campbell-Hunt. 2002, “Tackling Industrial Complexity.” In edited by G. Friozelle and H. Richards, 83–96. Cambridge: Institute for Manufacturing.

Dagger, T. S., J. C. Sweeney, and L. W. Johnson. 2007. “A Hierarchical Model of Health Service Quality: Scale Development and Investigation of an Integrated Model.” *Journal of Service Research* 10 (2): 123–142.

De Angelis, V. 1998. “Planning Home Assistance for AIDS Patients in the City of Rome, Italy.” *Interfaces* 28 (3): 75–83.

Donabedian, A. 1980. *Explorations in Quality Assessment and Monitoring, Vol. 1. The Definition of Quality and Approaches to its Assessments*. Ann Arbor, MI: Health Administration Press.

Ehrenfeld, M. 1998. “Nursing and Home Care in Europe.” *International Nursing Review* 45 (2): 61–64.

Elbenani, B., J. A. Ferland, and G. Viviane. 2008. “Mathematical Programming Approach for Routing Home Care Nurses.” Proceedings of the 2008 IEEE.

Eurostat. 2008. *Europe in Figures: Eurostat Yearbook 2008*. Luxembourg: Office for Official Publications of the European Communities.

Eveborn, P., P. Flisberg, and M. Ronnqvist. 2006. “Laps Care-An Operational System for Staff Planning of Home Care.” *European Journal of Operational Research* 171 (3): 962–976.

Eveborn, P., M. Ronnqvist, H. Einarsdottir, M. Eklund, K. Liden, and M. Almroth. 2009. “Operations Research Improves Quality and Efficiency in Home Care.” *Interfaces* 39 (1): 18–34.

Fone, D., S. Hollinghurst, M. Temple, A. Round, N. Lester, A. Weightman, K. Roberts, E. Coyle, and E. C. Garvey. 1987. “Current and Future Nursing Issues in the Home Administration of Chemotherapy.” *Seminars in Oncology Nursing* 3 (2): 142–147.

Genet, N., et al. 2011. “Home Care in Europe: A Systematic Literature Review.” *BMC Health Services Research* 11: 1–14.

Gourgand, M. 2008. “La modélisation, la simulation et l’optimisation des flux dans les systèmes hospitaliers.” *Bulletin de la Société Française de Recherche Opérationnelle et d’Aide à la Décision (ROADEF)*, N°21 – Automne - Hiver 2008: 8–12.

Haggerty, J., R. Reid, G. Freeman, B. Starfield, C. Adair, and R. McKendry. 2003. “Continuity of Care: A Multidisciplinary Review.” *British Med Journal* 327: 1219–1221.

Hebert, M. A., B. Korabek, and R. E. Scott. 2006. “Moving Research Into Practice: A Decision Framework for Integrating Home Telehealth Into Chronic Illness Care.” *International Journal of Medical Informatics* 75 (12): 786–794.

Hertz, A., and N. Lahrichi. 2009. “A Patient Assignment Algorithm for Home Care Services.” *Journal of the Operational Research Society* 60: 481–495.

Hutten, J. B. F., and A. Kerkstra. 1996. *Home Care in Europe: A Country-Specific Guide to Its Organization and Financing*. Aldershot: Ashgate.

Kergosien, Y., L. Christophe, and J. C. Billaut. 2009. “Home Health Care Problem: An Extended Multiple Traveling Salesman Problem.” Multidisciplinary international conference on scheduling: theory and applications (MISTA), Dublin, Ireland.

Lahrichi, N., S. D. Lapierre, A. Hertz, and A. Talib. 2006. “Analysis of a Territorial Approach to the Delivery of Nursing Home Care Services Based on Historical Data.” *Journal of Medical Systems* 30 (4): 283–291.

Lanzarone, E., and A. Matta. 2012. “A Cost Assignment Policy for Home Care Patients.” *Flexible Service and Manufacturing Journal*. doi:10.1007/s10696-011-9121-4.

Lanzarone, E., A. Matta, and E. Sahin. 2012. “Operations Management Applied to Home Care Services: The Problem of Assigning Human Resources to Patients.” *Transactions on Systems, Man, and Cybernetics–Part A: Systems and Humans* 42 (6): 1346–1363.

Lanzarone, E., A. Matta, and G. Scaccabarozzi. 2010. “A Patient Stochastic Model to Support Human Resource Planning in Home Care.” *Production Planning Control* 21 (1): 3–25.

Li, L. X., and W. C. Benton. 1996. “Performance Measurement Criteria in Health Care Organizations: Review and Future Research Directions.” *European Journal of Operational Research* 93 (3): 449–468.

Litwin, H., and C. Attias-Donfut. 2009. “The Inter-Relationship Between Formal and Informal Care: A Study in France and Israel.” *Ageing & Society* 29 (1): 71–91.

Matta, A., S. Chahed, E. Sahin, and Y. Dallery. 2012. “Modelling Home Care Organisations from an Operations Management Perspective.” Working paper, Ecole Centrale Paris.

Nickel, S., M. Schrder, and J. Steeg. 2012. “Mid-Term and Short-Term Planning Support for Home Health Care Services.” *European Journal of Operational Research* 219 (3): 574–587.

Phelps, C. E. 1995. Les fondements de l’economie de la sante, Editions Publi Union.

Rasmussen, M. S., T. Justesen, A. Dohn, and J. Larsen. 2012. “The Home Care Crew Scheduling Problem: Preference-Based Visit Clustering and Temporal Dependencies.” *European Journal of Operational Research* 219 (3): 16, 598–610.

Reyes, P. M., S. Li, and J. K. Visich. 2012. "Accessing Antecedents and Outcomes of RFID Implementation in Health Care." *International Journal of Production Economics* 136 (1): 137–150.
Roth, A. V., and L. J. Menor. 2003. "Insights to Service Operations Management: A Research Agenda." *Production and Operations Management* 12 (2): 145–164.
Sahin, E. 2008. Contributions à la Gestion des Opérations de biens et de services, Habilitation à Diriger des Recherches, Université Lyon 1.
Sampson, S. E., and C. M. Froehle. 2006. "Foundations and Implications of a Proposed Unified Services Theory." *Production and Operations Management* 15 (2): 329–343.
Shortell, S. M. 1976. Continuity of Medical Care: Conceptualization and Measurement." *Medical Care* 14 (5): 377–391.
Sourty-Le Guellec Marie-Jo. 1997. L'avenir de l'hôpital: quelles alternatives ? Biblio n°1183, ISBN: 2-87812-211-9.
Stock, G. N., K. L. McFadden, and C. R. Gowen. 2007. "Organizational Culture, Critical Success Factors, and the Reduction of Hospital Errors." *International Journal of Production Economics* 106 (2): 368–392.
Taylor, B. J., and M. Donnelly. 2006. "Risks to Home Care Workers: Professional Perspectives." *Health, Risk and Society* 8 (3): 239–256.
Tien, J. M. 2008. "On Integration and Adaptation in Complex Service Systems." *Journal of Systems Science and Systems Engineering* 17 (4): 385–415.
Tien, J. M., and P. J. Goldschmidt-Clermont. 2009. "Healthcare: A Complex Service System." *Journal of Systems Sciences and Systems Engineering* 18 (3): 257–282.
Thomsen, K. 2006. "Optimization on Home Care." Thesis Report, Informatics and Mathematical Modeling, Technical University of Denmark.
Trautsamwieser, A., M. Gronalt, and P. Hirsch. 2011. "Securing Home Health Care in Times of Natural Disasters." *OR Spectrum* 33 (3): 787–813.
Vermeire, E., H. Hearnshaw, and V. Royen. 2001. "Patient Adherence to Treatment: Three Decades of Research. A Comprehensive Review." *Journal of Clinical Pharmacy and Therapeutics* 26 (5): 331–342.
Vidal, L. A., E. Sahin, N. Martelli, M. Berhoune, and B. Bonan. 2010. "Using the AHP to Select Anticancer Drugs to Produce by Anticipation." *Expert Systems With Applications* 37 (2): 1528–1534.
Vissers, J. M. H., J. W. M. Bertrand, and G. Vries de. 2001. "A Framework for Production Control in Health Care Organizations." *Production Planning and Control* 12 (6): 591–604.
WHO (World Health Organization). 2000. *Home-Based and Long-Term Care: Home Care Issues and Evidence*. WHO Technical Report Series.
WHO (World Health Organization). 2002. *Community Home-Based Care in Resource-Limited Settings: A Framework for Action*. WHO Technical Report Series.
WHO (World Health Organization). 2008. *Home Care in Europe*. WHO Technical Report Series.
WHO (World Health Organization). 2010. *The World Health Report: Health Systems Financing: The Path to Universal Coverage*. WHO Technical Report Series.
Xin, J. Y., A. C. L. Yeung, and T. C. E. Cheng. 2010. "First to Market: Is Technological Innovation in New Product Development Profitable in Health Care Industries?" *International Journal of Production Economics* 127 (1): 129–135.
Yalcindag, S., A. Matta, and E. Sahin. 2011. "Human Resource Scheduling and Routing Problem in Home Health Care Context: A Literature Review." Proceedings of the 37th conference on operational research applied to health services, 8–22. Cardiff, UK.
Yalcindag, S., A. Matta, and E. Sahin. 2012. "Operator Assignment and Routing Problems in Home Health Care Services." Proceedings of CASE 2012.