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Home Health Care Logistics Planning: a review and framework

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Abstract

Home Health Care (HHC) is a growing industry in the medical services business, mainly in Europe and North America. These care services are provided at patients' home by a multidisciplinary team using a distribution network. In this paper, an overview of the HHC services in Portugal and Brazil is presented. Additionally, a review is also presented to identify the main logistics problems associated with HHC services such as districting, routing and inventory management and the lack of integrated approaches to address them, as well as the best practices of management in the area. A framework is proposed to represent the main elements and characteristics of HHC services and their relationships. The framework suggests the use of a Decision Support System (DSS) based on optimization models and simulation approaches to overcome some of the main challenges associated to integrated approaches to address main problems, filling the gaps in the current literature. With the development of this DSS it will be possible to assist in the logistic planning of HHC teams, especially in countries like Brazil and Portugal.

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Keywords: Home Health Care; Logistics; Districting; Routing and Scheduling; Inventory Management.

1. Introduction

Home Health Care (HHC) services consist in attending patients in their own homes, by a multidisciplinary team. Teams are composed by workers, such as doctors, nurses, among others. Because resources for health care are limited, HHC services are nowadays viewed as a challenge in what concerns the design and the efficient operation of health care delivery systems, reducing global costs and relieving congestions in the access to hospitalization.

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The sector has high investments, mainly in developed countries, such as Denmark, which has allocated about 1.6 % of its GNP (Gross National Product) in 2005 (about $4 billions) for the care of 200 thousand patients [1]. In European countries, around 1% to 5% of the public health budgets are spent on HHC services [2]. The number of people dependent on HHC services in Germany has already reached 1.6 million in 2012 and is still increasing [3]. In developing countries, HHC is more recent and its evolution is still slow due to economic problems, disorderly population growth, lack of infrastructure, security and constant illnesses (dengue fever, yellow fever, zika virus, and others). As an example, in Turkey, the public HHC system is targeted only at priority groups, namely patients bedridden with respiratory problems, muscular diseases, newborns and the terminal stage of cancer. The remaining population, which does not fall into the priority groups, need to join private HHC services [4]. In Colombia, peripheral areas of large cities with high crime rates do not receive this type of service due to lack of security as a way to preserve the physical integrity of health workers [5].

The planning effort required to manage these services is of great complexity, because it involves questions at different levels of decision, such as districting (strategic level), inventory management (tactical), routing and scheduling (tactical/operational level). In HHC literature, the largest contribution is in the area of vehicle routing and scheduling. For these types of problems, the goal is to minimize the costs of travel between patients and maximize teams scheduling to perform daily work [1]. Attention to materials' management problems in the context of HHC has been scarce. Main topics that have been identified include suppliers' selection, inventory policies and control [6]. Districting problem is of great importance, because aims at organizing areas, creating compactness in team's workload and minimizing travel time. For example, in Colombia, about 50% of HHC providers face districting problems [5].

In this work, the objective is to develop a review and framework that allows understanding the main logistic problems (of different levels of decision) in the HHC context, how they relate to each other, and the possibility of solving them in an integrated mode. The framework recommends the use of a Decision Support System (DSS) based on optimization models and good practices suggested in the literature. Most relevant contributions in these areas (which can contribute to the DSS) were used to develop the framework. It will include a sequence of phases concerning the design steps of such a system, identifying the different decision levels, restrictions, resources and stakeholders.

This paper is organized as follows. Section 2 reports HHC characterization and a brief description of the Portuguese and Brazilian services; Section 3 presents the literature review; Section 4 presents a proposal of a framework; Section 5 ends the paper with the conclusions.

2. Home Health Care Characterization

Home health care services are characterized by logistical problems such as districting, routing, scheduling, and inventory management. For each type of problem, a decision level is assigned, which is directly related to the duration and impact on planning decisions, as can be seen in Figure 1.

The decisions at strategic level consider a time horizon of over one year [5], including problems such as facility location, districting, staffing and fleet selection. The facility location aims to determine the best location for service deployment, as well as determining the location of each team's facilities. The next planning stage will be clustering (districting) the geographical area, aiming the balance of workload among health workers. Strategic problems, such as fleet selection, staffing and supplier selection, aim to determine which ones meet the requirements at the lowest possible cost.

These processes are approached differently in each country, especially in public HHC. As an example, in Austria, HHC solutions have been proposed to reduce vehicle fleet costs, having more sustainable solutions such as the use of multimodal public transport and the division of vehicles between workers [7], [8]. However, in developing countries such as Brazil and Colombia, vehicle use is extremely important due to the low quality of public transport services and the lack of safety in certain districts, making it impossible to use these solutions.

The tactical level has a time horizon of up to one year [5], and in this context problems such as fleet assignment, staff dimensioning, shift scheduling and inventory policies have to be addressed. The first problem is to define the number of vehicles to be made available by district and team. The staff dimensioning is the allocation process of workers by district, according to local demand. The shift scheduling deals with the problem of selecting, from a potentially large pool of candidates, what shifts are to be worked, together with an assignment of the number of employees to each shift, in order to meet demand [6]. Finally, the inventory policy aims to determine the number of orders or purchase of materials made in each period, aiming at minimizing costs and avoiding the lack of materials.

Operational level decisions are focused on tasks to be performed in a short period of time, most of the times on a daily base [5]. The staff assignment is the process of scheduling patients per team. These decisions can be performed daily or weekly by the local manager. The control of inventories is carried out daily by the workers. This is done through the inputs and outputs of the materials and drugs used by services. Teams prepare medication kits and materials necessary for each patient on the team's premises; in the return, all materials and drugs used are reported in the information system. Finally, daily routing is assigned, with the objective of minimizing total distance to be traveled by the teams to provide patients care. Better solutions for this problem can be determined by using routing software.

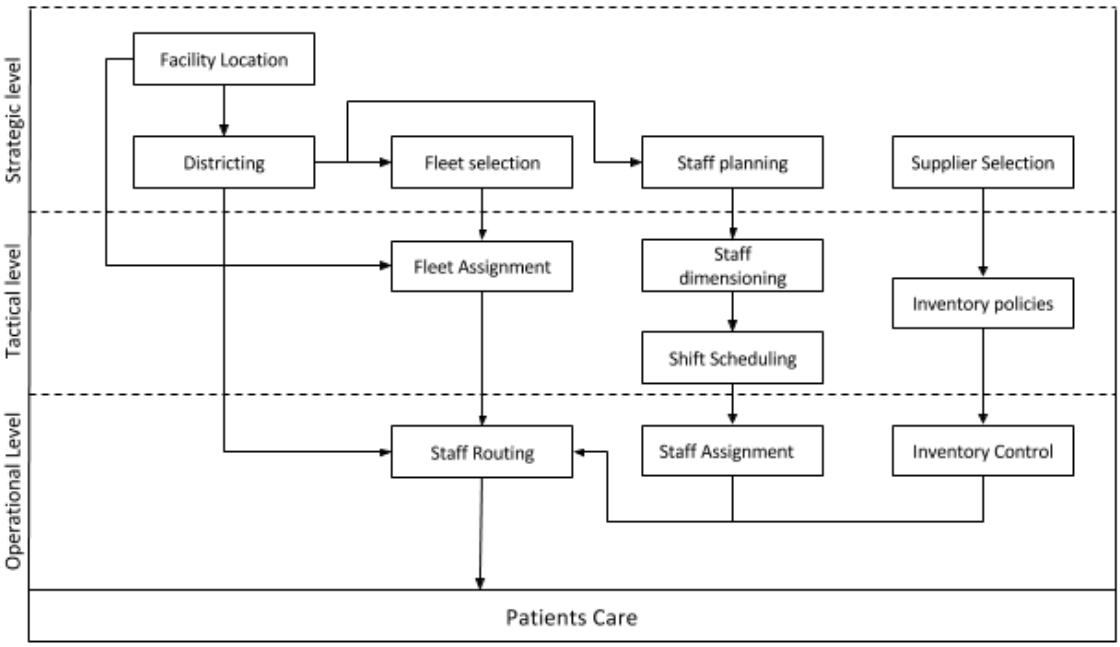

Fig. 1. Home Health Care planning activities.

2.1. The cases of Portugal and Brazil

In this section, a brief description of two public HHC services are presented, namely the Portuguese case and Brazilian case. The first was formally created in 2006, and the second in 2011.

The process of admission to the National Network for Integrated Continuous Care (RNCCI) in Portugal (Figure 2) is done by the Local Coordinating Team (ECL), through a proposal from a hospital or health Center. After the analysis of the proposal, the ECL may not admit the patient, if the disease is in the acute phase, there is only need of social support or if the patient needs hospitalization for diagnostic. The patient to be admitted to Integrate Continued Care Team (ECCI) needs to be in a situation of dependency and under the responsibility of a caregiver further to satisfy some other requirements. Patients admitted should wait for a vacancy in the ECCI, if necessary. Soon after the appearance of a vacancy, the patient is allocated to one team with skills as per their needs. This process is done by the local coordinator. The frequency of visits is also according to the needs of each patient. After a period of time, the patient may recover and be discharged, or worsen their situation by being referred to a hospital or palliative team. If the patient's hospitalization period is less than 12 days, the vacancy in the team is reserved. Otherwise the patient should again wait for a vacancy.

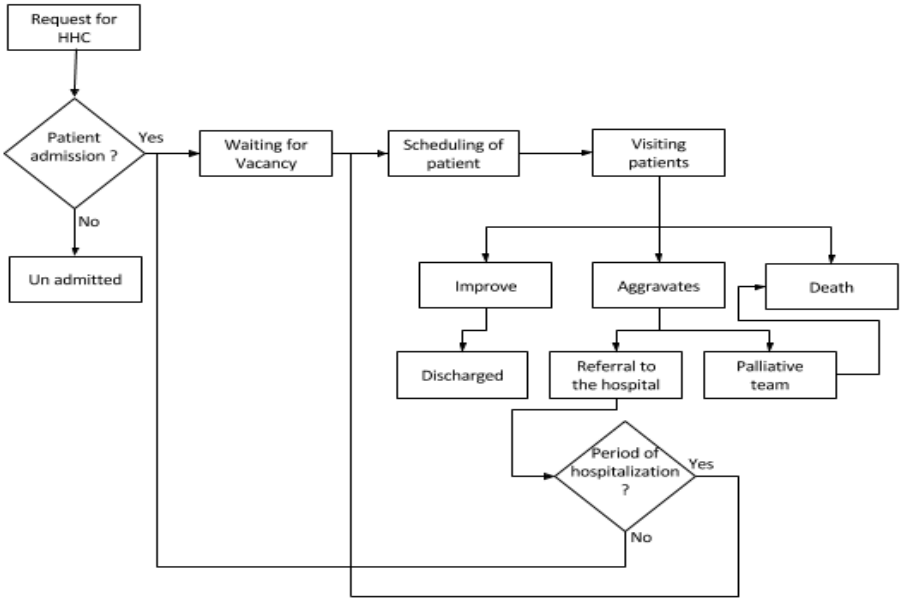

Fig. 2. Portuguese HHC admission and transferring processes.

In the Better at Home program in Brazil (Figure 3), the patient should come from a hospital or health center and have a recommendation for inclusion in the HHC services.

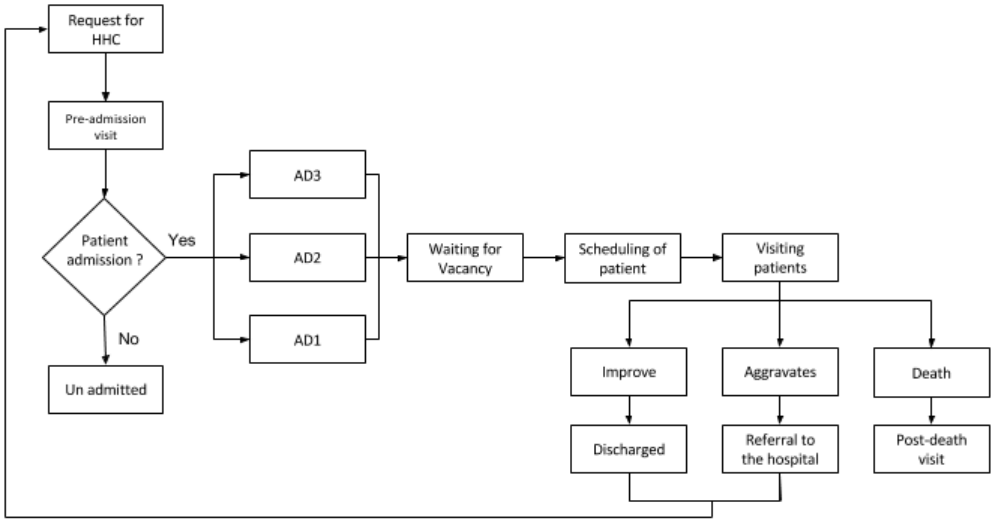

Fig. 3. Brazilian HHC admission and transferring processes.

Patients may be admitted if they are unable to travel to the health services, that their residence has the minimum conditions as required by ANVISA (National Health Surveillance Agency), and have a caregiver for daily assistance, as also required in the Portuguese case. However, in HHC Brazilian, it is necessary a pre-admission visit. The purpose of this visit is to assess the degree of patient complexity, local infrastructure and caregiver participation. This visit is performed by a doctor. After the evaluation, the local coordinator will define the modality or type of home care to be provided, according to the degree of complexity of the patient informed by the doctor. Unlike the Portuguese HHC,

in Brazilian HHC have three types of home care: AD1, AD2 and AD3. The AD1 modality is intended for patients who have controlled or less intense health problems. The AD2 modality is to users with difficulty or physical impossibility for getting to a health unit and who require a greater frequency of care, health resources and continuous monitoring. The AD3 modality is intended for users similar to AD2, but who make use of specific equipment. After choosing the modality, relevant information is sent to the local team where the patient is assigned to a team. This process is also done by the local coordinator. Finally, the processes for cases of discharge, aggravates and death of the Brazilian HHC also differ in relation to the Portuguese HHC. In cases of recovery, the patient is referred back to the requests for admission of HHC, because it will be necessary to analyze if the patient will need a home care of inferior modality or if the patient is discharged from the HHC services. If it is sent to a hospital or emergency center, it will also go through the same process as in the previous case. Unlike the Portuguese HHC, it returns directly to the HHC services without the need for a new admission process. In addition, in the Portuguese HHC cases of aggravation, patients can be referred to a specialized team in palliative care, which is not in the Brazilian HHC. In cases of death, a post-death visit is performed by a doctor and aims to assist the family and provide the death certificate.

When analyzing domiciliary services of both cases, it was possible to identify differences and similarities in some processes. In addition, it was detected through a brief inquiry applied in both cases, the non-use of optimization models or software in the decision making involving logistical problems. This may adversely affect operations, especially with the emergence of material and drug inventory problems, as well as the lack of compactness and balance among the workloads of the teams, as detected in the study by Gutierrez and Vidal [5]. In order to avoid this, logistical problems such as districting, routing and scheduling, and inventory management should be analyzed and solved frequently, as presented in the current literature.

3. Literature review

A literature review was carried out focusing the most relevant papers published in scientific journals and conferences available online by November 2016. Book chapters, reports and these are not considered. Based on the literature survey developed in this study, the logistics problems related to HHC services are: districting, routing and scheduling, and inventory management. All articles were analyzed and separated according to the types of problems.

The district problem is to group small geographical areas, called basic units (postal code areas, streets and others) into larger geographic clusters, called districts, provided that they maintain balance, contiguity and compactness. The types of models, approaches and methods presented in the literature differ according to the type of problem. These areas range from problems of political districting (the first to be addressed) to problems of distribution of goods and others and HHC problems.

The studies related to Districting Problems in Home Health Care (DPHHC) aim to organize territories, seeking to minimize the time of displacement between the different households and allowing a significant increase in the time of service or face to face. The main characteristics of HHC districting are the indivisibility of the basic units (group of patients located in streets, parishes, among other places), accessibility of the districts (formed by a set of basic units), besides the compactness and workload balance teams.

The first districting study for HHC applied with real-world data was developed by Blais et al. [9]. This study was developed for a health center in the community of Côte-des-Neiges, Montreal, Canada. To solve the problem of zoning, a Tabu Search (TS) metaheuristic developed by Bozkaya et al. [10]. After obtaining the results, they found that the district plan generated by metaheuristics was as good as one developed manually by a specialist group.

In the study by Benzarti et al. [11], two Integer Programming (IP) models were tested for districting problems in HHC. Both models were based on the balance of the workload of the technicians. For this case, randomly generated data were used. Both models were analyzed in four different scenarios, with different combinations of constraints. The results show that for improving the workload balance in the Model 1, we should reduce the number of districts to design. On the contrary, for reducing the distances traveled within each district in the Model 2, it is better to partition the territory as much as possible [11].

A multi-objective optimization model was applied to a districting problem in the rapidly growing population of Cali, Colombia [5]. The goal of the study was to maximize face-to-face, and minimize travel time. To solve this model, a lexicographic algorithm was used, ensuring that decision-makers interactively incorporate the preferences of how decision criteria are optimized under a lexicographic order. The results presented improvements in relation to the previous districting strategy, and the computational time to solution of each objective function ranged from 86 seconds

to 72 minutes.

The problems related to routes and scheduling in HHC services have been frequently addressed in the literature and can be solved individually or integrated. Routes are generally treated as problems of computational complexity, and are characterized as Vehicle Routing Problems (VRP), Traveling Salesman Problem (TSP), and Dial-a-Ride Problem (DARP). The solution is based mainly on the application of heuristics or metaheuristics. Only in cases of small instances the exact methods are used, as can be analyzed next.

In HHC services, TSP is often used for routing problems, such as in Braekers et al. [12], where it is proposed a multi-objective optimization model. The objective functions of this model were to minimize the total cost and inconvenience of the customer. The algorithm used in the metaheuristic is based on the Multi-Directional Local Search (MDLS) and uses the LNS as a sub-heuristic. Results were compared with some exact solutions in small instances and demonstrated that this meta-heuristic provides good performance.

Decerle et al. [13] proposed a two-phases meta-heuristic to deal with a scheduling and routing problem, characterized as an extension of TSPTW (Travel Salesman Problem Time Windows). In the first phase the nurses scheduling and routes were solved, and in the second phase only the unlicensed professionals were considered. The goal was to minimize the cost of transportation and working hours. The results showed that this metaheuristic is capable of obtaining good results with resolution time equal to or less than one hour, only in small and medium instance problems.

A routing problem was formulated as VRP by En-Nahli et al. [14], with the inclusion of time windows and the synchronization of visits. To solve this problem, a Mixed Integer Programming (PIM) model was proposed, whose objective was to minimize the travel time of technicians. The solution strategy was divided into three phases, initially a solution is obtained by means of a constructive heuristic, and in the second phase a neighborhood descent variable is applied to improve the initial solution. Soon afterwards the interactive local search heuristic goal defines the best current solution and starts with the interactions. For this case, 15 instances with different time windows (small, medium and large) were considered, with only about 10% of visits synchronized. Finally, it was possible to observe that the neighborhood variable moves the best insertion, helping significantly at run time.

In Liu et al. [15], two meta-heuristics (Genetic Algorithm and Tabu Search) were applied to a vehicle routing problem with simultaneous deliveries and time-stacks (VRPSDPTW). This study examined a problem of daily scheduling of vehicles from a home health care company to the delivery of medications, medical devices, biological samples, medical waste or unused drugs. The goal was to minimize the total cost of the vehicle to meet the demands of patients. The two methods were tested in different instances. By means of the obtained results, it was found that these two methods provided good solutions in a reasonable period of time, and clearly superior to those in the literature.

A DARP problem was proposed in Fikar and Hirsch [8], whose objective was the sharing of vehicles, aiming to reduce costs and obtain sustainable solutions for a healthcare operator in Austria. For this case, a heuristic goal was developed and executed in two stages. In the first stage, the possible routes to be walked by technicians are defined by a set-partitioning (SP) model. In the second stage, the savings heuristics of Clarke and Wright [16] together with a meta-heuristic (taboo search) were used to determine the delivery and collection routes of technicians. The computational time was around 58 minutes per district. In addition, the results showed that it is possible to reduce the number of vehicles without affecting the quality of service.

A model was implemented for problems related to the inventories management and routing in HHC [17]. The objective was the planning of production, inventory management and distribution of drugs to combat cancer, besides the routing and scheduling of nurses. This study was developed shortly after the French health organization required that anti-cancer drugs be produced within a specific place and no longer in the patients' homes. As a result, there was a need to create a plan for the production, storage and distribution of medicines before their expiration. Then, for this case, a Whole Linear Programming (PLI) model was developed to solve a Production Programming Problem (PSP) coupled to the Traveling Salesman Problem (TSP). The results showed three fields of solutions. In the first field, there is no solution for the production and delivery problem. In the second one, there is an optimal solution which is different from the optimal solution to the routing problem treated separately. In the third one, the optimal solution coincides with the optimal solution of the routing problem treated separately.

The different solution methods proposed for these types of problems can be used to aid decision making in real cases, such as Portuguese and Brazilian, increasing the level of service and minimizing operational costs. A far as the authors of this paper know, the existing literature does not present models nor solutions for all the reported problems (in the different decision levels such as districting, routing and inventory management) in a completed integrated manner. The only types of HHC integration reported involve inventory management and routing in Chahed et al. [17],

and routing with scaling as in Decerle et al. [13] and Liu et al. [15]. For this reason, the present study seeks to present a framework capable of integrating these different types of problems and solving them.

4. Framework proposal

Logistic problems with different levels of decision were integrated, as shown in the framework proposed in Figure 4.

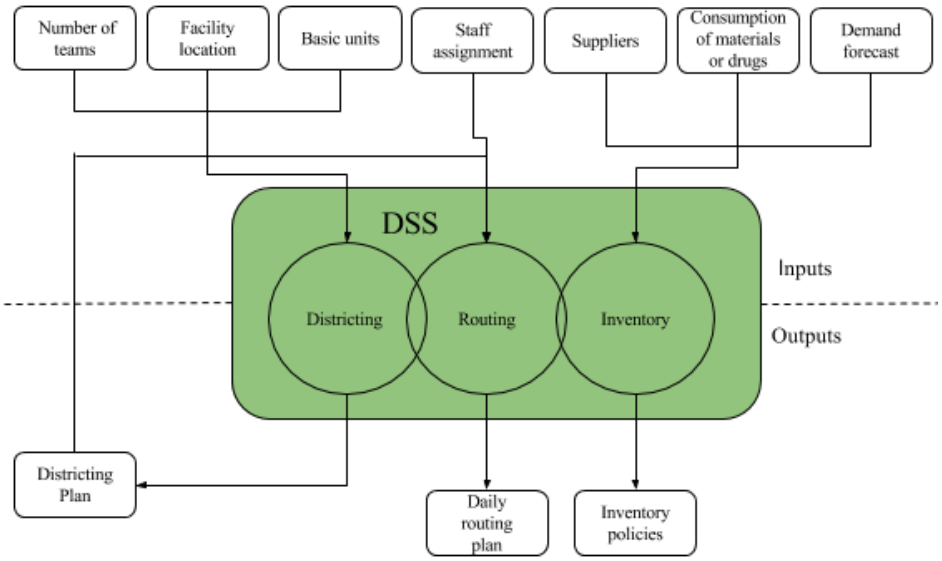

Fig. 4. Decision support system for HHC.

For this case, the scheduling problem will not be solved in this framework. This will be under the responsibility of the teams that should provide these inputs. The districting problem in HCC will require inputs such as the location of the city to be analyzed, the basic units (neighborhoods), and the number of locally assigned teams. The number of teams assigned in the Portuguese and Brazilian HHC is according to the number of inhabitants of the municipality, that is, each team assigned is responsible for about 100 thousand inhabitants. This will generate output, the districting plan, which is summarized in the grouping of basic units, whose purpose is to reduce the time of movement between patients and maintain a balance between the workload of the workers. This output will be used as input for the routing problem, which will also require the staff assignment, or the daily list of patients per worker. The output will be the daily routes plan per worker, aiming the minimization in the time of travel. Finally, the inventory management problem requires inputs such as suppliers' knowledge to obtain information such as production capacity, delivery time, product quality and price. In addition, it will be necessary to obtain the consumption of materials or/and drugs by type of service, and also to develop a demand forecast based on historical data. With this information, it will be possible to obtain as output an inventory policy capable of dealing with supply problems, levels of safety stock and costs.

Districting problems in HHC were solved differently in the three studies presented in the literature review. Initially, with the application of IP in the study Benzarti et al. [11], it was possible to obtain good results, but only in scenarios with a small set of 4 districts. In the study by de Blais et. al. [9] and Gutiérrez and Vidal [5] a metaheuristic of Tabu search and multi-objective optimization with lexicographic algorithm were used respectively. In both cases, good results were obtained, but the Gutiérrez and Vidal model [5] seems to be more adequate for this framework, because it can handle more data for instance generation, such as type of medical activity, annual demand for visits, average time of care, type of patients and level of safety in the districts. For inventory management problems, the main objective is to propose optimal strategies that can contribute to the supply and inventory control processes, aiming at minimizing costs, as shown in Kelle et al. [18] will be considered in this framework. This is because some drugs and materials have expensive price and must be controlled, such as the anti-cancer drugs presented in Chahed et al. [17].

The routing problem must be solved with heuristics or metaheuristics, since this type of problem depends on the patients to be visited, the computational time may increase significantly [12]. The method used by En-Nahli et al. [14] presented good results, being possible to synchronize about 10% of the visits. Other method for routing problems would be the solutions presented by Fikar and Hirsch [8] may be a good choice, especially with the use of the savings heuristic of Clarke and Wright [16], which provides good solutions in a short time. This heuristic can be applied in this framework due to its easy application and to provide good results, especially in cases of large instances. These models will be integrated in a future, enhanced, framework, under development by the authors of the present paper, and would be used for the development of a decision support system (DSS) for the Brazilian and Portuguese cases.

5. Conclusions

The present study developed a literature review and framework that allows understanding the main logistic problems in the HHC context, how they relate and the possibility of solving them in an integrated mode. The main contribution of this study is the development of a framework capable of integrating logistical problems of different levels of decision. In the literature review several models and methods were identified, however, none of them considers a complete integration of problems of different decision levels, as suggested in the proposed framework. In addition, it is proposed the use of this framework for the development of a DSS to assist local home health coordinators in Brazilian and Portugal cases.

Acknowledgements

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