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INVITED SURVEY

Home health care routing and scheduling problems: a literature review

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Abstract
Home health services arise from the need for hospitals to care for patients and/or dependent persons who, due to special conditions, require hospitalisation and/or care at home. The organisation of this service impacts the quality and cost of health services, which implies the programming of medical and social staff and the design of their daily routes. This literature review presents a description of the problem and a taxonomy of its characteristics and restrictions. It summarises the state-of-the-art decision-making solutions to deal with the home health care routing and scheduling problem and studies related objectives and constraints.

Keywords Home health care · Routing · Scheduling · Operations research · Decision-making

Mathematics Subject Classification 90-00 · 90-03 · 90-11

1 Introduction and methodology

Considerable efforts have been made in the business world to reduce operations costs and improve global performance. In this context, healthcare systems, which are among the most complex production systems, followed this optimisation direction several years after the industrial world did, even though it had been considered a non-profit

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service for a long time. In this work, we shed light on a home care and healthcare service that presents an efficient alternative to classical hospitalisation and a growing business to face the ageing population. This sector is still witnessing numerous evolutions according to demographic, political, and economic factors.

Home healthcare (HHC) is an idea that has gained support in society and has undergone many changes to the structures we know today. The care provided by HHC structures is less expensive than, more convenient than, and just as effective as the care provided by a hospital or a skilled nursing facility.

The home (health)-care structures belong to the social and medico-social fields. The home (health) care covers food preparation, hygiene and mobility care of patients, delivery of medicines, and control of medical treatments, emergency services, and home medical appointments, among others. Medical activity concerns patients who need medical assistance, such as infusion handling and administration of medications. The required staff comprises therapists, doctors, psychologists, nurses, and nursing assistants. Nonmedical care concerns people with physical or mental limitations living on their own and needing any kind of medico-social support.

The home care problem refers to the provision of community care services by local authorities to their constituents (Gould 2018; Euchi 2019). The difference in the value propositions and hence strategic plans between structures has repercussions on the organisational structure and particularly the characteristics, objectives and constraints (hard and soft) considered at the operational level. Home healthcare (HHC) is facing strategic problems, such as the partitioning of the territory, the allocation of resources to the district, and the dimensioning of internal resources, in addition to tactical and operational decisions related to the delivery of drugs, the logistics of equipment necessary for care, and the construction of rounds for caregivers.

This article addresses an in-depth bibliographic study of the home (health) care routing and scheduling problem: scheduling caregivers to provide care tasks within a window of time while reducing travel time. The timing of the visits should be respected as much as possible, as patients should not be kept waiting. Care givers can leave their homes or the health centre. Different skills and qualifications generally exist among caregivers, while the use of highly qualified nurses should be limited to tasks that require these skills.

The HHC involves helping people for a relatively short period to recover after hospitalisation. Home care, however, generally refers to helping the elderly and/or disabled carry out their daily activities, such as shopping, swimming, cleaning, and cooking. Once a person begins to receive home care support, this care will likely remain for a long time. Although there are not as much as in HHC, there are skills and qualifications required in home care when caring for others, such as, health and safety.

For many years, researchers in operations research (OR) and management science (MS) have dealt with the organisation of care inside hospital institutions, in addition to related logistics activities. They provided OR tools and techniques to reduce the activity costs while also placing great importance on the people's satisfaction, needs, and the improvement of their living conditions. The programming of medical and social staff and the design of their daily routes to visit patients and/or dependents are important decisions that impact the time and cost of home healthcare, as well as the quality of the service (Pillac et al. 2013; Van den Bergh et al. 2013). This problem

is mainly called the *home health care routing and scheduling problem* (HHCRSP). It interests researchers in OR/MS industrial engineering (IE) from both the theoretical and practical perspectives. A recent study shows a considerable increase in the number of papers in OR/MS/IE fields dealing with HHCRSP from 1996 until today (Dimascolo et al. 2021). This problem is mainly seen as an application of the *Multi-Travelling Salesman Problem* (MTSP) or the *Vehicle Routing Problem* (VRP) with Time Windows, Multi-Depot, in addition to some additional concepts related to the characteristics of the Home Healthcare service (Frifita and Masmoudi 2020), and thus it is NP-Hard and challenging for OR researchers (see Nickel et al. 2012). In addition, it has become one of the top optimisation problems in the healthcare domain due to the continuous growth of the home healthcare business and its considerable impact on the hospitalisation costs and the whole patient pathway performance.

The purpose of this paper is to provide a literature review on the characteristics of the *home health care routing and scheduling problem* and to discuss how researchers in OR/MS/IE have dealt with these problems from both theoretical and practical perspectives. Based on a comprehensive methodology, the current literature is reviewed, analysed, and summarised. To provide a real contribution in comparison to literature review papers in this field, we focus on the characteristics of the problem, in addition to the objectives and the constraints.

This literature review aims to identify several lines of research related to HHCRSP, discussed at the end of this article. It allows practitioners in home healthcare services to see whether the real daily planning problem that they encounter has given rise to the development of efficient solutions in the literature. Moreover, it helps researchers to identify challenging issues and to direct their research towards tailored solutions according to the constraints, objectives, and other characteristics of the studied problems.

This study summarises the state-of-the-art works dealing with the HHCRSP and provides a set of comprehensive tables. An integrative literature review is chosen, with the elaboration on the guiding question to show how broad the HHCRS problem is with its different variants, the database definitions, the establishment of inclusion and exclusion criteria for studies and sampling or documentary research, the definition of the information to be extracted from the selected studies, the evaluation of studies included in the integrative review, and the interpretation of the results and presentation of the review and synthesis of knowledge.

The studied papers are identified through a bibliographic search, where the attention is restricted to papers published from January 2016 to December 2021. This particular period has been selected to restrict our study to the most recent up-to-date and most relevant articles that address this issue.

The databases of the most important publishers were used: Science Direct, Springer, Taylor and Francis, Wiley online library, MEDLINE accessed via PubMed and Web of Science. The following keyword combinations were used: ("**Health" OR "healthcare") AND ("Home healthcare" OR "home care hospital services") AND ("routing" OR "scheduling")**. Table 1 describes the searches carried out.

Initially, a total of 5,276,976 publications were found. By reading titles and abstracts, it was possible to exclude duplicate studies in the different databases and studies that did not meet the inclusion criteria and/or the proposed themes. As a result,

Table 1 Searches

Database	Date	Search terms	Found items
Science Direct	2016–2021	"Health" OR "healthcare"	819,640
		"Home healthcare" OR "home care hospital services"	587
		“Routing” OR “scheduling”	462,531
Springer	2016–2021	"Health" OR "healthcare"	934,290
		"Home healthcare" OR "home care hospital services"	532
		“Routing” OR “scheduling”	341,156
Taylor and Francis	2016–2021	"Health" OR "healthcare"	405,985
		"Home healthcare" OR "home care hospital services"	241
		“Routing” OR “scheduling”	21,316
Wiley online library	2016–2021	"Health" OR "health care"	630,418
		"Home health care" OR "home care hospital services"	401
		“Routing” OR “scheduling”	25,277
(MEDLINE), accessed via PubMed;	2016–2021	"Health" OR "health care"	278,359
		"Home health care" OR "home care hospital services"	2515
		“Routing” OR “scheduling	593
Web of Science	2016–2021	"Health" OR "healthcare"	1,292,586
		"Home healthcare" OR "home care hospital services"	419
		“Routing” OR “scheduling	60,130
Total			5,276,976

139 articles were selected. Out of the selected articles, 67 papers answered the guiding question, and thus, constituted the final sample of this examination.

2 Home healthcare routing and scheduling characteristics

The first studies of HHCRSP are attributed to Begur et al. (1997), who developed a heuristic approach for daily nurse scheduling and routing for a real case of home-healthcare (the Visiting Nursing Association (VNA) of Birmingham, Alabama, which

provides services to residents in several counties of central Alabama encompassing an area of 2727 square miles). The HHCRSP involved mobilising staff to perform work-related activities at different locations. Staff members used a professional car or various other means of transport, e.g., walking, private car, public transport, bicycle, etc. In addition, there was more than one activity to be performed in a day at a dependent's home (Taniguchi et al. 2020; Euchi 2020a, 2021; Kandakoglu et al. 2020; Ozeki et al. 2021, Frifita and Masmoudi 2020). The HHCRSP integrated the assignment of medical staff to patients (Rahimian et al. 2017; Lin et al. 2018; Hassani and Behnamian 2021) and the design of the routes with visits to patients with different variants of the VRP (Euchi 2017; Režnar et al. 2017; Domínguez-Martín et al. 2018; Mor and Speranza 2020). The most studied VRP variant in HHCRSP is VRPTW (Errico et al. 2018; Expósito et al. 2019; Hoogeboom et al. 2021; Euchi et al. 2021). Other variations of VRP have been applied to HHCRSP, such as the *Multi-Travelling Salesman Problem with Time Windows* (MTSPTW) (Lahyani et al. 2017; Defryn and Sörensen 2018; Bretin et al. 2021), the *Vehicle Routing Problem with Multi-Depot* (VRPMD), which aimed to characterise the multiple points at which the personnel started and ended routes, the *Vehicle Routing Problem with Multi-Period* (VRPMP) dealing with periodic planning (Li et al. 2019; Al Chami et al. 2018), and the use of drone delivery for medical supplies in the healthcare system problems (Euchi and Sadok 2021b; Euchi 2021).

The *Vehicle Routing Problem* (VRP) is among the most studied problems in the OR field. The classical goal of VRP is to minimise the total distance travelled by a set of vehicles serving customers in different locations, while each customer must be visited once by a vehicle. Many variations of VRP exist and have been studied in the literature. We can mention, for example, the *Vehicle Routing Problem with Time Windows* (VRPTW) (Solomon 1987; Euchi 2020b), where a vehicle must arrive at the customer within a specified time window. If the vehicle arrives before this time window, it is necessary to wait before making the delivery. Extensions of the VRPTW include other features, such as multiple trips, multiple resources, multiple depots, and vehicle synchronisation. In the VRPTW extension, which covers several depots, the vehicle fleet is spread over several depots, allowing each vehicle to be returned to the nearest depot once all deliveries of this vehicle have been completed. In the VRPTW extension with multiple trips (Brandão 1999, Cattaruzza et al. 2016), the employees could make several trips in a day to visit patients. A trip in this context involves a series of tasks before returning to the depot. For the extension of the VRPTW with vehicle synchronisation, the routes are dependent on one another. Thus, changing one tour has an impact on others and may even make them infeasible (Afifi et al. 2016, Frifita et al. 2017). There are several types of synchronisation: service, e.g., a service is performed in a city by one or more vehicles, and the synchronisation of resources, e.g., the presence of resources to transfer a load from one vehicle to another.

Paraskevopoulos et al. (2017) provided a comprehensive study on resource-constrained routing and scheduling. The latter revealed the characteristics of the problem in terms of the qualifications required for the resources, service requirements, and objectives of the problem. Guericke and Suhl (2017) recommended an adaptive large neighbourhood search to solve the HHC with working regulations. To test the competitiveness of the proposed solution methodology, the authors used benchmark instances taken from the literature.

In Shi et al. (2018), the authors proposed a stochastic programming model with recourse and a simulated annealing-based heuristic to solve the home healthcare routing problem with stochastic travel and service times. An Italian home palliative care service was given as a practical study in Scaccabarozzi et al. (2019). The authors provided a report of the data on the activities and care in Italy, and a Best Practice Panel was proposed to measure a selected panel in a healthcare system. A practical case study in Canada to solve the *home healthcare routing and scheduling problems* was provided in Grenouilleau et al. (2019). A hybrid heuristic algorithm based on set partitioning was proposed. The authors confirmed that the solution methodology provided an improvement in terms of minimising the travel time and in the processing time to solve a real case study.

In Euchi et al. (2020), an HHC with time windows with a single structure and synchronised visits were included in the problem. A two-phase approach was used. First, a clustering algorithm (CA) with a k-mean was given to find several caregiver routes. Second, an ant colony system (ACS) was applied as a distributed optimisation form (Hybrid ACS-CA) to solve the problem. A new method for optimising the allocation of visits to patients based on automatic learning and a search method was described.

To concentrate on ageing people, Nasir and Kuo (2020) proposed a hybrid genetic algorithm for home care logistics planning with synchronised visits and multiple nurses.

Nikzad et al. (2021) suggested a two-stage procedure for resource planning in-home healthcare problems in a stochastic environment. A metaheuristic procedure to solve the model was given. Through progressive hedging and Frank and Wolf systems, the authors described their improvement technique to reduce the computational time. Numerical results proved the aptitude of the solution procedure to solve large examples.

Li et al. (2021) introduced a new variant of the home healthcare routing and scheduling problem that considered an outpatient service. Wellness and prevention, diagnosis, treatment, and rehabilitation are considered outpatient services. This includes a medical test that can be done in a medical structure without staying. A hybrid genetic algorithm with the outer-approximation method was developed to find a global ε-optimal solution for small and large sets of problems.

Table 2 describes work related to home healthcare routing and scheduling with year, reference, publication, and problem characteristics. Table 3 displays the solution methodology used to solve each type of problem together with benchmark instances.

3 Objective functions

The optimality criteria that have been considered in the HHCRSP literature can be divided into three classes: competition time-based, patients' preference, and staff member preference (see Table 4). The objective function is defined in consultation with different HHC services to make a high-quality solution, low operational cost, and improved satisfaction of patients and workers. Those costs are balanced in several papers using weight parameters. Each of these three classes of objective functions is presented in this section, and Table 5 presents the objective function considered in different papers dealing with the HHCRSP.

Table 2 Literature on home healthcare routing and scheduling

Year	References	Publication		Type of study		Horizon		Uncertainties
		Journal	Affiliation	Theoretical	Practical	Short	Long	
2016	Ait Haddadene et al. (2016)	ESWA	France	–	×	–	×	–
2016	Braekers et al. (2016)	EJOR	Belgium	×	–	×	–	–
2016	Fikar et al. (2016)	Eur. J. Ind. Eng	Austria	×	–	–	–	×
2016	Lin et al. (2016)	ESWA	Hong Kong	–	×	–	×	–
2016	Redjem and Marcon (2016)	FSM	France	–	–	×	–	–
2016	Rest and Hirsch (2016)	FSM	Austria	–	×	×	–	–
2016	Wirnitzer et al. (2016)	ORHC	Germany	–	×	–	×	–
2016	Yalçındag et al. (2016)	C&OR	Turkey	×	–	–	–	×
2017	Cissé et al. (2017)	ORHC	France	×	–	–	–	×
2017	Du et al. (2017)	Sustainability	Turkey	×	–	×	–	–
2017	Fikar and Hirsch (2017)	C&OR	Austria	×	–	×	–	–
2017	Frifita et al. (2017)	ENDM	France	×	–	×	–	–
2017	Guericke and Suhl (2017)	OR Spectrum	Germany	×	–	–	×	–
2017	Liu et al. (2017)	IJPR	China	–	×	–	×	–
2017	Luna et al. (2017)	Clustr. compu	Spain	–	×	–	×	–
2017	Quintana et al. (2017)	Appl. Inte	Spain	–	×	–	×	–
2017	Yuan and Jiang (2017)	Sustainability	China	–	×	–	×	–
2017	Rahimian et al. (2017)	EJOR	UK	×	–	–	×	–
2018	Cappanera et al. (2018)	Omega	Italy	–	×	–	×	–
2018	Lin et al. (2018)	C&IE	Taiwan	×	–	–	×	×

Table 2 (continued)

Year	References	Publication		Type of study		Horizon		Uncertainties
		Journal	Affiliation	Theoretical	Practical	Short	Long	
2018	Shi et al. (2018)	ESWA	France	×	–	×	–	–
2018	Carello et al. (2018)	ORHC	Italy	–	×	–	×	–
2018	Decerle et al. (2018)	ORHC	France	–	×	×	–	×
2018	Demirbilek et al. (2018)	HCMS	UK	×	–	–	×	×
2018	Fathollahi-Fard et al. (2018)	J. Clean. Prud	Iran	×	–	×	–	–
2018	Fikar and Hirsch (2018)	FSM	Austria	–	×	×	–	–
2018	Liu et al. (2018)	Com. App. mat	China	×	–	–	×	–
2018	Mosquera et al. (2018)	Omega	Belgium	–	×	–	×	×
2018	Nasir and Dang (2018)	Sustainability	China	×	–	–	×	×
2018	Sinthamrongruk et al. (2018)	Int. J. Agile Systems and Management	UK	×	–	×	–	–
2018	Szander et al. (2018)	Sustainability	Slovenia	–	×	–	×	–
2018	Yuan et al. (2018)	IJPR	China	×	–	×	–	×
2018	Zhan and Wan (2018)	C&OR	China	×	–	×	–	–
2018	Meyer-Massetti et al. (2018)	Int. J of Clinical Pharmacy; Dordrecht	Switzerland	–	×	–	–	–
2019	Du et al. (2019)	J. COMB. OPT	China	–	×	–	×	×
2019	Scaccabarozzi et al. (2019)	Healthcare	Italy	–	×	–	×	–
2019	Decerle et al. (2019)	Swarm & Evo. Comp	France	×	–	×	–	–
2019	Dekhici et al. (2019)	Canadian J. Elec. and Computer	Algeria	×	–	×	–	–
2019	Demirbilek et al. (2019)	FSM	UK	×	–	–	×	×

Table 2 (continued)

Year	References	Publication		Type of study		Horizon		Uncertainties
		Journal	Affiliation	Theoretical	Practical	Short	Long	
2019	Gomes and Ramos (2019)	EJOR	Portugal	–	×	–	×	×
2019	Grenouilleau et al. (2019)	EJOR	Canada	×	–	–	×	–
2019	Heching et al. (2019)	Transportation Science	USA	×	–	–	×	–
2019	Liu et al. (2019a)	C&OR	China	×	–	×	–	–
2019	Liu et al. (2019b)	FSM	China	×	–	–	×	×
2019	Moussavi et al. (2019)	ESWA	France	×	–	–	×	–
2019	Nasir and Dang (2019)	HCMS	Hong Kong	×	–	×	–	×
2019	Restrepo et al. (2019)	Omega	Canada	×	–	–	×	×
2019	Riazi et al. (2019)	IEEE Tase	Sweden	×	–	×	–	–
2020	Chaieb et al. (2020)	HCMS	Saudi Arabia	–	×	×	–	–
2020	Euchi (2020a)	British. J. of Healthcare. Manage	Tunisia	×	–	×	–	–
2020	Taniguchi et al. (2020)	Int. J of Qual. Studies on Health and Well-being	Japan	–	×	×	–	×
2020	Fathollahi-Fard et al. (2020)	Neural Computing and Applications	Iran	×	–	×	–	–
2020	Frifita and Masmoudi (2020)	ITOR	France	×	–	–	×	–
2020	Kandakoglu et al. (2020)	DSS	Canada	–	×	×	–	–
2020	Euchi et al. (2020)	Arab. J. Sci. Eng	Saudi Arabia	×	–	–	×	–
2020	Nasir and Kuo (2020)	DSS	Hong Kong	–	×	–	×	×
2021	Hassani and Behnamian (2021)	J. of Comb. Opt	Iran	×	–	–	×	×

Table 2 (continued)

Year	References	Publication		Type of study		Horizon		Uncertainties
		Journal	Affiliation	Theoretical	Practical	Short	Long	
2021	Nikzad et al. (2021)	EJOR	Iran	×	–	–	×	×
2021	Li et al. (2021)	Tran. Res. Part E: Log. Tran. Rev	China	×	–	×	–	–
2021	Demirbilek et al. (2021)	Flexible Services and Manufacturing Journal	UK	–	×	×	–	×
2021	Euchi and Sadok (2021a)	Proceedings Inst. Civil Eng -Transport	Saudi Arabia	×	–	–	×	–
2021	Liu et al. (2021)	Expert Systems. App	France	×	–	–	×	–
2021	Malagodi et al. (2021)	Health. Care. Manag. Sci	Italy	–	×	×	–	–
2021	Shahnejat-Bushehri et al. (2021)	Exp. Sys. Appl	Iran	×	–	×	–	×
Total	64	–	–	40	24	27	34	21
Percentage	–	–	–	62.5%	37.5%	42.18%	53.125%	32.81%

Table 3 Solution methodology and benchmark instances

Year	References	Formulation and solution methodology		Benchmarks instances
		Formulation	Solution methodology	
2016	Ait Haddadene et al. (2016)	MILP	GRASP-ILP	Solomon (1987)
2016	Braekers et al. (2016)	MILP	Epsilon const -ALNS	Hiermann et al. (2015)
2016	Fikar et al. (2016)	–	Matheuristic	Fikar and Hirsch (2015)
2016	Lin et al. (2016)	MILP	–	–
2016	Redjem and Marcon (2016)	–	Heuristics	–
2016	Rest and Hirsch (2016)	MILP	TS	–
2016	Wirnitzer et al. (2016)	MIP Approach	–	–
2016	Yalçındag et al. (2016)	MILP	Two phase approach	–
2017	Du et al. (2017)	–	IMA	
2017	Erdem and Bulkan (2017)	MILP	VNS	Hiermann et al. (2015)
2017	Fikar and Hirsch (2017)	–	–	–
2017	Frifita et al. (2017)	–	G-VNS	Bredstrom and Ronnqvist (2008)
2017	Guericke and Suhl (2017)	MILP	ALNS	Trautsamwieser and Hirsch (2014), Cappanera and Scutella (2013)
2017	Liu et al. (2017)	MILP	B&P	Solomon (1987)
2017	Luna et al. (2017)	–	EA	–
2017	Quintana et al. (2017)	–	Heuristics -CM	–
2017	Yuan and Jiang (2017)	–	TS	–
2017	Rahimian et al. (2017)	–	VNS	–
2018	Cappanera et al. (2018)	–	GC	–
2018	Lin et al. (2018)	–	Metaheuristic	–

Table 3 (continued)

Year	References	Formulation and solution methodology		Benchmarks instances
		Formulation	Solution methodology	
2018	Carello et al. (2018)	–	CC	–
2018	Decerle et al. (2018)	–	MA	Bredstrom and Ronnqvist (2008)
2018	Demirbilek et al. (2018)	–	SBA	–
2018	Fathollahi-Fard et al. (2018)	MILP	Heuristics – memetic – metaheuristics	–
2018	Fikar and Hirsch (2018)	–	Even driven biased randomised	Solomon (1987)
2018	Liu et al. (2018)	–	Epsilon constraint method, heuristics	–
2018	Mosquera et al. (2018)	–	IP-LS	–
2018	Nasir and Dang (2018)	–	VNS	–
2018	Sinthamrongruk et al. (2018)	–	Fuzzy logic—heuristic	–
2018	Szander et al. (2018)	–	Heuristic	–
2018	Yuan et al. (2018)	–	B&P	–
2018	Zhan and Wan (2018)	Scenario-based MIP	Heuristic-based on TS	–
2019	Scaccabarozzi et al. (2019)	–	Internet-based questionnaires	Realistic instances
2019	Decerle et al. (2019)	MILP	MA, ACO	Bredstrom and Ronnqvist (2008)
2019	Dekhici et al. (2019)	–	Firefly algorithm	–
2019	Demirbilek et al. (2021)	–	SBA	–
2019	Gomes and Ramos (2019)	MILP	–	–
2019	Grenouilleau et al. (2019)	–	Heuristic—LNS	–
2019	Heching et al. (2019)	LBBD – MILP	CP	Rasmussen et al. (2012)
2019	Liu et al. (2019a)	MILP	B&P	–
2019	Moussavi et al. (2019)	–	Matheuristic	–

Table 3 (continued)

Year	References	Formulation and solution methodology		Benchmarks instances
		Formulation	Solution methodology	
2019	Nasir and Dang (2019)	MILP	VNS – Roc Curves	–
2019	Restrepo et al. (2019)	–	A context-free grammar, stochastic programming	–
2019	Riazi et al. (2019)	MILP	Gossip algorithm – CG-Dantzig Wolf Decomposition	Solomon (1987), Gehring and Homberger (2002)
2020	Chaieb et al. (2020)	MILP	K-means, Hungarian algorithm, TS	–
2020	Euchi (2020a)	–	Ant colony	Bredstrom and Ronnqvist (2008)
2020	Fathollahi-Fard et al. (2020)	–	Lagrangian relaxation-based algorithm—heuristics	–
2020	Frifita and Masmoudi	MIP	VNS	Bredstrom and Ronnqvist (2008)
2020	Kandakoglu et al. (2020)	MILP	–	Realistic instances
2020	Euchi et al. (2020)	–	Ant Colony System, K-means	Bredstrom and Ronnqvist (2008)
2020	Nasir and Kuo (2020)	MILP	GA	Realistic instances
2021	Hassani and Behnamian (2021)	MILP	Scenario-based optimisation method	Realistic instances
2021	Nikzad et al. (2021)	MILP	Matheuristic algorithm, Frank and Wolf algorithms	Fikar and Hirsch (2015)
2021	Li et al. (2021)	MINonLP	Outer-approximation method, GA	Realistic instances
2021	Demirbilek et al. (2021)	MILP	Scenario-based approach (SBA) Scenario-based approach for multiple nurses (SBAM)	Realistic instances

Table 3 (continued)

Year	References	Formulation and solution methodology		Benchmarks instances
		Formulation	Solution methodology	
2021	Euchi and Sadok (2021a)	MIP	Colony System, GA	Bredström and Rönqvist (2008), Decerle et al. (2018)
2021	Liu et al. (2021)	MIP	Memetic algorithm (MA), hybrid genetic general variable neighbourhood search (HGGVNS), hybrid genetic simulated annealing (HGSA), hybrid simulated annealing (HSA)	Solomon (1987)
2021	Malagodi et al. (2021)	MILP	Cluster-based decomposition	Realistic data
2021	Shahnejat-Bushehri et al. (2021)	MILP	SA, GA, MA	Solomon (1987)
Total	–	29	–	27
Percentage	–	49.15%	–	45.76%

Table 4 Optimality criteria considered in the HHCRSP

Optimality criteria		Number of papers
Competition time based	Route	42
	Total visits duration/working time	14
	Waiting time	12
	overtime/overcosts	15
Patients' preference	Max preferred time slot	12
	Max patients' preferences	10
	Max continuity of care	4
	Min Uncovered visits	13
	Min reassignment	5
	Min TW violation	5
Staff member preference	Balance workload	10

Table 5 The objective functions in the HHCRSP

Year	References	Completion time: cost minimisation				Patients' preference						Staff member preference
		Route	Total visits duration/working time	Waiting time	overtime/over costs	Max preferred time slot	Max patient preferences	Max continuity of care	Min Uncovered visits	Min reassignment	Min TW violation	Balance workload
2016	Ait Haddadene et al. (2016)	×	–	–	–	–	×	–	–	–	–	–
2016	Braekers et al. (2016)	×	–	–	×	×	×	–	–	–	–	–
2016	Fikar et al. (2016)	×	–	×	–	–	–	–	–	–	–	–
2016	Lin et al. (2016)	×	–	–	–	–	–	–	–	×	–	–
2016	Redjem and Marcon (2016)	×	–	×	–	–	–	–	–	–	–	–
2016	Rest and Hirsch (2016)	×	–	×	×	–	–	–	–	–	–	–
2016	Wirnitzer et al. (2016)	–	–	–	–	–	–	×	–	–	–	–
2016	Yalçındag et al. (2016)	×	–	–	–	–	–	–	–	–	–	×
2017	Erdem and Bulkan (2017)	×	–	–	×	–	×	–	–	×	–	–
2017	Frifita et al. (2017)	×	–	–	–	–	–	–	–	–	–	–
2017	Guericke and Suhl (2017)	×	–	×	–	–	–	–	–	–	–	–
2017	Liu et al. (2017)	×	–	–	–	–	–	–	×	–	–	–
2017	Luna et al. (2017)	–	×	–	–	–	–	–	–	–	–	–
2017	Quintana et al. (2017)	×	–	×	–	–	–	–	–	–	–	–

Table 5 (continued)

Year	References	Completion time: cost minimisation				Patients' preference						Staff member preference
		Route	Total visits duration/working time	Waiting time	overtime/over costs	Max preferred time slot	Max patient preferences	Max continuity of care	Min Uncovered visits	Min reassignment	Min TW violation	Balance workload
2017	Yuan and Jiang (2017)	×	–	–	–	–	–	–	–	×	–	–
2017	Rahimian et al. (2017)	–	–	–	–	–	–	–	–	–	×	×
2018	Cappanera et al. (2018)	–	–	–	–	–	–	–	–	–	–	×
2018	Lin et al. (2018)	×	–	–	×	–	–	–	–	–	–	–
2018	Shi et al. (2018)	×	–	–	×	–	–	–	–	–	–	–
2018	Carello et al. (2018)	–	–	–	×	–	–	×	–	×	–	×
2018	Decerle et al. (2018)	×	–	–	–	–	–	–	–	–	×	–
2018	Demirbilek et al. (2018)	–	–	–	–	–	–	–	×	–	–	–
2018	Fathollahi-Fard et al. (2018)	×	–	–	–	–	–	–	–	–	–	–
2018	Fikar and Hirsch (2018)	×	–	×	–	–	–	–	–	–	–	–
2018	Lin et al. (2018)	×	–	–	×	–	–	–	–	–	–	–
2018	Liu et al. (2018)	×	–	–	×	–	–	–	–	–	–	–
2018	Mosquera et al. (2018)	×	–	–	–	–	×	×	×	–	–	–

Table 5 (continued)

Year	References	Completion time: cost minimisation				Patients' preference						Staff member preference
		Route	Total visits duration/working time	Waiting time	overtime/over costs	Max preferred time slot	Max patient preferences	Max continuity of care	Min Uncovered visits	Min reassignment	Min TW violation	Balance workload
2018	Nasir and Dang (2018)	×	–	–	×	–	×	–	–	–	–	–
2018	Sinthamrongruk et al. (2018)	×	–	–	–	–	–	–	–	–	–	–
2018	Szander et al. (2018)	×	–	–	–	–	×	–	–	–	–	–
2018	Yuan et al. (2018)	×	–	–	–	–	–	–	–	–	–	–
2018	Zhan and Wan (2018)	×	–	×	×	–	–	–	–	–	–	–
2018	Riazi et al. (2018)	×	–	–	–	–	–	–	–	–	–	–
2019	Decerle et al. (2019)	–	×	–	–	–	–	–	–	–	×	×
2019	Dekhici et al. (2019)	×	–	–	×	–	–	–	–	–	–	×
2019	Demirbilek et al. (2019)	–	–	–	–	–	–	–	×	–	–	–
2019	Du et al. (2019)	×	–	–	–	–	×	–	–	–	–	–
2019	Gomes and Ramos (2019)	×	–	–	–	–	–	–	–	–	–	×
2019	Grenouilleau et al. (2019)	×	×	×	×	–	×	×	×	–	–	–

Table 5 (continued)

Year	References	Completion time: cost minimisation				Patients' preference						Staff member preference
		Route	Total visits duration/working time	Waiting time	overtime/over costs	Max preferred time slot	Max patient preferences	Max continuity of care	Min Uncovered visits	Min reassignment	Min TW violation	Balance workload
2019	Heching et al. (2019)	–	–	–	–	–	–	–	×	–	–	–
2019	Liu et al. (2019a)	×	–	–	–	–	–	–	–	–	–	–
2019	Liu et al. (2019a)	×	–	–	–	–	–	–	×	–	–	–
2019	Moussavi et al. (2019)	×	–	–	–	–	–	–	–	–	–	–
2019	Nasir and Dang (2019)	×	–	–	–	–	–	–	–	–	–	–
2019	Restrepo et al. (2019)	×	–	–	–	–	–	–	×	×	–	–
2020	Chaieb et al. (2020)	×	–	×	–	–	–	–	×	–	–	–
2020	Euchi (2020a)	–	×	–	–	–	–	–	–	–	×	–
2020	Fathollahi-Fard et al. (2020)	×	–	–	–	–	–	–	–	–	–	–
2020	Frifita and Masmoudi (2020)	–	×	–	–	–	–	–	–	–	–	–
2020	Kandakoglu et al. (2020)	×	–	–	×	–	–	–	×	–	–	×
2020	Euchi et al. (2020)	×	×	×	–	–	×	–	–	–	–	–
2020	Nasir and Kuo (2020)	×	×	–	–	–	–	–	–	–	–	–

Table 5 (continued)

Year	References	Completion time: cost minimisation				Patients' preference						Staff member preference
		Route	Total visits duration/working time	Waiting time	overtime/over costs	Max preferred time slot	Max patient preferences	Max continuity of care	Min Uncovered visits	Min reassignment	Min TW violation	Balance workload
2021	Hassani and Behnamian (2021)	–	×	–	×	–	–	–	–	×	–	×
2021	Nikzad et al. (2021)	–	×	–	–	–	–	–	×	–	×	–
2021	Li et al. (2021)	–	×	×	–	–	×	–	–	–	–	–
2021	Demirbilek et al. (2021)	–	–	–	–	–	–	–	×	–	–	–
2021	Euchi and Sadok (2021a)	–	×	–	–	–	–	–	–	–	–	–
2021	Liu et al. (2021)	×	×	–	–	–	–	–	–	–	–	–
2021	Malagodi et al. (2021)	–	×	×	×	–	×	–	–	–	–	–
2021	Shahnejat-Bushehri et al. (2021)	–	×	–	–	–	–	–	–	–	–	×
Total	–	42	14	12	15	2	10	4	13	5	5	10
Percentage	–	70%	23.33%	20%	25%	3.33%	16.66%	6.66%	21.66%	8.33%	8.33%	16.66%

3.1 Competition time based

The competitive advantage of a company can be dramatically affected by its response time, which is why the reduction of the times involved, e.g., mobility times of the staff between the different patients to visit, the attention time that the staff takes in each visit to the patients and additional times, such as preparation times and staff lunchtimes, is considered in the first class of objective functions. The following is the list of objective functions related to time optimisation:

- Minimise total operating time and distance travelled (Minimise the total cost of personnel and transportation).
- Minimise the working time (looking at the performance of a caregiver when assigned to a patient).
- Minimise the waiting time (due to synchronisation or a time window, for example. See, e.g., Fikar et al. (2016), Guericke and Suhl (2017), Zhan and Wan (2018), Chaieb et al. (2020), Euchi et al. (2020) and Malagodi et al. (2021)).
- Minimise the overtime and the related costs (see Erdem and Bulkan 2017; Carello et al. 2018; Dekhici et al. 2019; Kandakoglu et al. 2020; Hassani and Behnamian 2021).
- Minimise the number of routes to be carried out, which relates to the completion time (Quintana et al. 2017; Heching et al. 2019; Kandakoglu et al. 2020; Liu et al. 2021).

We see that the minimisation of travel costs, distances, or travel times is considered by nearly all the researchers because it is a usual criterion for the VRP problem and a real concern for HHC organisations.

3.2 Patients' preference

In HHC, patients typically indicate preferences regarding nurses and caregivers, but they also indicate time windows for visits. The following is the list of objective functions related to the patients' preferences:

- Maximise the preferred time slot (Erdem and Bulkan 2017).
- Maximise the patients' preferences regarding skill and doctor-patient familiarity (Du et al. 2019; Mosquera et al. 2018; Grenouilleau et al. 2019; Li et al. 2021).
- Maximise the continuity of care (Wirnitzer et al. 2016; Carello et al. 2018; Grenouilleau et al. 2019).
- Minimise the number of uncovered patients and the turnover of medical personnel per patient (Demirbilek et al. 2018; Chaieb et al. 2020; Nikzad et al. 2021).
- Minimise the cost related to overtime of personnel and reassignments (Lin et al. 2016; Rest and Hirsch 2016; Dekhici et al. 2019; Restrepo et al. 2019; Kandakoglu et al. 2020; Hassani and Behnamian 2021; Malagodi et al. 2021)
- Minimise the violation of time windows of visits (Rahimian et al. 2017; Decerle et al. 2019; Euchi 2020a).

From the research conducted on 67 journal papers concerning patients' preferences, we can observe that most contributions consider the maximum preferred time, the

patients' preferences, and the minimisation of uncovered visits, which represent more than 72% of papers considering this objective. The minimisation of the violation of soft time windows and the minimisation of reassignment are considered in a few papers (10 among 67). We can observe that the continuity of care preference has received less attention in the related works (4 among 67).

3.3 Staff member preference

Excessive workloads are not only the result of recurring bottlenecks but are now considered standard by many front-line caregivers. Researchers are talking about unmanageable and risky workloads. In the past, wages and pensions were at the top of the list of concerns. Today, issues related to workload, understaffing and overtime are most often mentioned, although this criterion of optimality is not considered in the most recent publications.

Most HHCRSP are modelled as a bi-objective optimisation problem. Malagodi et al. (2021) presented a multi-objective home care VRP that involves the optimisation of four objective functions, i.e., total working time, waiting time, overtime, and maximum patients' preferences. Liu et al. (2021) considered two conflicting objectives in the research, namely, the number of routes and the total duration of the visits.

4 Constraints

In this section, we describe the numerous restrictions considered in our selected literature. The constraints given in the majority of papers dealing with HHCRSP are classified into three types: visiting restrictions, patients' preference restrictions, and staff member restrictions (see Fig. 1).

The restrictions are usually classified into two types: hard restrictions, which are mandatory for the problem and include coverage requirements, such as demand or traffic in a city, and soft restrictions, which are optional and are included to provide the model with greater flexibility, which is mainly related to staff time requirements and staff and patients' preferences. From the literature, it was found the different soft constraints related to preferences, e.g., always the same staff caregiver, gender of the caregiver, always the same hours, service time, working days and shifts, low number of difficult patients, and different hard constraints related to requirements, e.g., type of services (types of treatments, types of specialists needed, periodicity between visits, etc.), working TW and workload, etc.

In HHCRSP, we believe that the constraints are related to three types: constraints related to visits, to patients' preferences, and to staff members.

4.1 Constraints related to visits

In Table 6, we can observe that most of the studied papers include the hard TW (81.81%), the required skill (52.72%), the use of synchronisation visits (36.36%), and the consideration of multiple visits per period (18.18%).

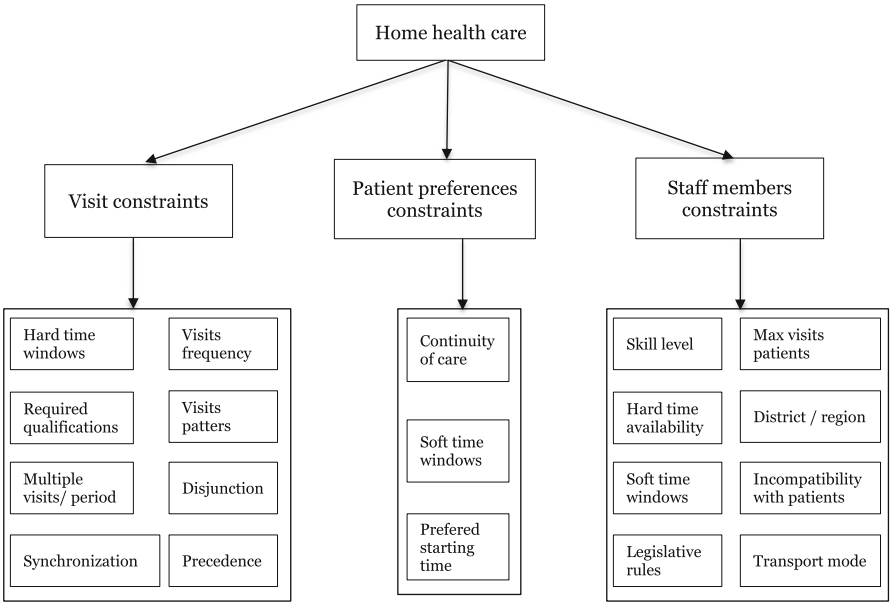

Fig. 1 Considered constraints in the HHCRSP

However, constraints related to the disjunction of visits, precedence, and visiting patterns are focused on less; nevertheless, they are important in the home healthcare environment, with a total of 13 papers among 55 selected, which represent approximately 23.63%.

4.2 Patients' preference constraints

The patients' preference constraints are of three types: continuity of care, soft time windows, and preferred starting time. These constraints are less studied in the selected works than those associated with visits or staff members (82%).

Table 7 shows that the majority of papers, 38 among 58 (65.51%), consider these two types in the patients' preference constraints. The preferred starting time is less considered in the literature. We observe that 5 papers among 58 include the preferred starting time (8.62%).

4.3 Staff member constraints

We note that the staff member constraints represent 87%. There are numerous groups, specific characteristics (including skill level and hard and soft TW availability), legislative rules (number of employed hours per day/per week, lunch breaks, etc.), district/region, incompatibility with patients, and mode of transportation (public or private cars, sharing vehicles).

Table 8 describes the constraints related to staff members considered in the

Table 6 The constraints related to visits in the HHCRSP

Year	References	Visit constraints							
		Hard TW	Required Skill	Multiple visits per period	Visits frequency	Visits patterns	Disjunction	Synchronisation	Precedence
2016	Ait Haddadene et al. (2016)	×	×					×	Exact
2016	Braekers et al. (2016)	×	×	–	–	–	–	–	–
2016	Fikar et al. (2016)	×	×	–	–	–	–	–	–
2016	Lin et al. (2016)								
2016	Redjem and Marcon (2016)	×		×	–	–	×	–	Min
2016	Rest and Hirsch (2016)	×	×	–	–	–	–	–	–
2016	Wirnitzer et al. (2016)	–	×	–	×	–	–	–	–
2016	Yalçındag et al. (2016)	×	×	–	–	–	–	–	–
2017	Erdem and Bulkan (2017)	×	×	–	–	–	–	×	–
2017	Frifita et al. (2017)	×	–	×	–	–	–	×	–
2017	Guericke and Suhl (2017)	×	×	–	–	–	–	–	–
2017	Liu et al. (2017)	×	×	–	–	–	–	–	–
2017	Luna et al. (2017)	×	–	–	–	–	–	–	–

Table 6 (continued)

Year	References	Visit constraints							
		Hard TW	Required Skill	Multiple visits per period	Visits frequency	Visits patterns	Disjunction	Synchronisation	Precedence
2017	Yuan and Jiang (2017)	–	×	–	–	×	–	–	–
2017	Rahimian et al. (2017)	×	–	×	–	–	–	–	–
2018	Cappanera et al. (2018)	–	×	–	–	×	–	–	–
2018	Lin et al. (2018)	×	×	–	–	–	–	–	–
2018	Shi et al. (2018)	×	–	–	–	–	–	×	–
2018	Decerle et al. (2018)	–	×	–	–	–	–	×	–
2018	Demirbilek et al. (2018)	–	–	×	×	×	–	–	–
2018	Fathollahi-Fard et al. (2018)	×	–	–	–	–	–	–	–
2018	Fikar and Hirsch (2018)	×	×	–	–	–	–	–	–
2018	Lin et al. (2018)	×	×	–	–	–	–	–	–
2018	Liu et al. (2018)	–	×	–	×	–	–	–	–
2018	Mosquera et al. (2018)	×	–	×	×	–	–	–	–

Table 6 (continued)

Year	References	Visit constraints							
		Hard TW	Required Skill	Multiple visits per period	Visits frequency	Visits patterns	Disjunction	Synchronisation	Precedence
2018	Nasir and Dang (2018)	×	×	–	–	–	–	–	–
2018	Sinthamrongruk et al. (2018)	×	×	–	–	–	–	×	–
2018	Szander et al. (2018)	×	–	–	–	–	–	–	–
2018	Yuan et al. (2018)	×	–	–	–	–	–	–	–
2018	Riazi et al. (2018)	×	×	–	–	–	–	–	–
2019	Decerle et al. (2019)	×	×	–	–	–	–	×	–
2019	Dekhici et al. (2019)	–	–	×	–	–	–	×	–
2019	Demirbilek et al. (2021)	–	×	×	×	×	–	–	–
2019	Du et al. (2019)	×	–	–	–	–	–	–	–
2019	Gomes and Ramos (2019)	×	–	×	–	–	–	–	–
2019	Grenouilleau et al. (2019)	×	×	–	–	–	–	–	–
2019	Heching et al. (2019)	×	×	–	×	×	–	–	–
2019	Liu et al. (2019a)	×	–	×	–	–	–	×	–

Table 6 (continued)

Year	References	Visit constraints							
		Hard TW	Required Skill	Multiple visits per period	Visits frequency	Visits patterns	Disjunction	Synchronisation	Precedence
2019	Moussavi et al. (2019)	–	–	×	–	–	–	–	–
2019	Nasir and Dang (2019)	×	×	–	–	–	–	–	–
2020	Chaieb et al. (2020)	×	×	–	–	–	–	–	×
2020	Euchi (2020a)	×						×	
2020	Fathollahi-Fard et al. (2020)	×	–	–	–	–	–	–	–
2020	Frifita and Masmoudi (2020)	×	–	–	–	–	×	×	–
2020	Kandakoglu et al. (2020)	×	×	–	–	–	–	–	–
2020	Euchi et al. (2020)	×	–	–	–	–	–	×	–
2020	Nasir and Kuo (2020)	×	–	–	–	–	–	×	×
2021	Hassani and Behnamian (2021)	×	–	–	×	–	–	×	–
2021	Nikzad et al. (2021)	×	×	–	–	–	–	×	–
2021	Li et al. (2021)	×	–	–	–	–	–	×	–

Table 6 (continued)

Year	References	Visit constraints							
		Hard TW	Required Skill	Multiple visits per period	Visits frequency	Visits patterns	Disjunction	Synchronisation	Precedence
2021	Demirbilek et al. (2021)	×	×	–	×	–	–	×	–
2021	Euchi and Sadok (2021a)	×	–	–	–	–	–	×	–
2021	Liu et al. (2021)	×	–	–	–	–	–	×	×
2021	Malagodi et al. (2021)	×	–	–	–	–	–	–	–
2021	Shahnejat-Bushehri et al. (2021)	×	×	–	–	–	×	×	×
Total	55	45	29	10	8	5	3	20	5
Percentage		81.81%	52.72%	18.18%	14.54%	9.09%	5.45%	36.36%	9.09%

Table 7 The constraints related to patients' preferences in the HHCRSP

Year	References	Patients' preference constraints		
		Continuity of care	Soft time windows	Preferred starting time
2016	Ait Haddadene et al. (2016)	–	–	–
2016	Braekers et al. (2016)	–	×	–
2016	Fikar et al. (2016)	–	–	–
2016	Lin et al. (2016)	×	×	×
2016	Redjem and Marcon (2016)	–	–	–
2016	Rest and Hirsch (2016)	–	–	–
2016	Wirnitzer et al. (2016)	×	–	–
2016	Yalçındag et al. (2016)	×	–	–
2017	Erdem and Bulkan (2017)	–	–	×
2017	Frifita et al. (2017)	–	–	–
2017	Guericke and Suhl (2017)	–	–	–
2017	Liu et al. (2017)	×	–	–
2017	Luna et al. (2017)	×	–	–
2017	Quintana et al. (2017)	×	–	–
2017	Yuan and Jiang (2017)	×	×	–
2017	Rahimian et al. (2017)	–	×	×
2018	Cappanera et al. (2018)	×	–	–
2018	Lin et al. (2018)	–	–	–
2018	Shi et al. (2018)	–	–	–
2018	Carello et al. (2018)	–	–	–
2018	Decerle et al. (2018)	–	×	–
2018	Demirbilek et al. (2018)	×	–	–
2018	Fathollahi-Fard et al. (2018)	–	–	–
2018	Fikar and Hirsch (2018)	–	–	–
2018	Lin et al. (2018)	–	–	–
2018	Liu et al. (2018)	×	–	–
2018	Mosquera et al. (2018)	×	–	–
2018	Nasir and Dang (2018)	–	–	–
2018	Sinthamrongruk et al. (2018)	–	–	–
2018	Szander et al. (2018)	–	–	–
2018	Yuan et al. (2018)	–	–	–
2018	Zhan and Wan (2018)	–	–	–
2019	Decerle et al. (2019)	–	×	–
2019	Dekhici et al. (2019)	–	×	–
2019	Demirbilek et al. (2021)	×	–	–

Table 7 (continued)

Year	References	Patients' preference constraints		
		Continuity of care	Soft time windows	Preferred starting time
2019	Du et al. (2019)	–	–	×
2019	Gomes and Ramos (2019)	–	–	–
2019	Grenouilleau et al. (2019)	–	–	–
2019	Heching et al. (2019)	–	–	–
2019	Liu et al. (2019a)	–	×	–
2019	Moussavi et al. (2019)	–	–	–
2019	Nasir and Dang (2019)	–	–	–
2019	Restrepo et al. (2019)	–	–	–
2020	Chaieb et al. (2020)	×		–
2020	Euchi (2020a)	–	×	–
2020	Frifita and Masmoudi (2020)	×	×	–
2020	Fathollahi-Fard et al. (2020)	–	–	–
2020	Kandakoglu et al. (2020)	×	–	–
2020	Euchi et al. (2020)	–	×	–
2020	Nasir and Kuo (2020)	×	×	–
2021	Hassani and Behnamian (2021)	×	–	–
2021	Nikzad et al. (2021)	×	×	–
2021	Li et al. (2021)	–	×	–
2021	Demirbilek et al. (2021)	–	×	–
2021	Euchi and Sadok (2021a)	×	–	–
2021	Liu et al. (2021)	–	–	–
2021	Malagodi et al. (2021)	×	×	×
2021	Shahnejat-Bushehri et al. (2021)	×	×	–
Total	58	21	17	5
Percentage		36.2%	29.31%	8.62%

HHCRSP. The skill level (35 papers among 55, i.e., 63.63%) and the hard TW availability (29 among 55, i.e., 52.72%) are the most often used constraints. Additionally, we believe that the legislative rules are considered within 20 papers among 55, i.e., 36.36%. Some transportation mode restrictions appear in only 5 journal articles (9.09%). We can observe that incompatibility with patient staff members' constraints is included in three papers (5.45%). Six papers consider the limited number of visited patient constraints (10.09%). Most authors pay less attention to limited visits to patients, incompatibility with patients, and mode of transportation constraints; only 25.45% of papers at most include one of these constraints.

Table 8 The constraints related to staff members in the HHCRSP

Year	References	Staff members' constraints							
		Skill level	Hard TW/availability	Soft TW	Legislative rules	A limited number of visited patients	District/region	Incompatibility with patients	Mode of transportation
2016	Ait Haddadene et al. (2016)	×	×	–	–	×	–	–	–
2016	Braekers et al. (2016)	×	–	–	×		–	–	Public cars
2016	Fikar et al. (2016)	×	–	–	×	–	–	–	Sharing vehicles
2016	Lin et al. (2016)	×	–	–	–	–	–	–	–
2016	Redjem and Marcon (2016)	–	×	–	–	–	–	–	–
2016	Rest and Hirsch (2016)	×	×	–	×	–	–	×	–
2016	Wirnitzer et al. (2016)	×	–	–	×	–	×	×	–
2016	Yalçındag et al. (2016)	×	×	–	–	–	–	–	–
2017	Erdem and Bulkan (2017)	–	×	–	–	–	–	×	–
2017	Frifita et al. (2017)	–	–	–	–	–	–	–	–
2017	Guericke and Suhl (2017)	×	×	–	×	–	–	–	–

Table 8 (continued)

Year	References	Staff members' constraints							
		Skill level	Hard TW/availability	Soft TW	Legislative rules	A limited number of visited patients	District/region	Incompatibility with patients	Mode of transportation
2017	Liu et al. (2017)	×	×	–	×	–	–	–	–
2017	Luna et al. (2017)	–	×	–	–	–	–	–	–
2017	Quintana et al. (2017)	–	×	–	×	–	×	–	–
2017	Yuan and Jiang (2017)	–	–	–	–	–	–	–	–
2018	Cappanera et al. (2018)	×	–	–	×	–	–	–	–
2018	Lin et al. (2018)	×	–	–	×	–	–	–	–
2018	Carello et al. (2018)	×	–	–	×		–	×	–
2018	Decerle et al. (2018)	×	×	–	–	–	–	–	–
2018	Demirbilek et al. (2018)	–	–	–	–	–	–	–	–
2018	Fathollahi-Fard et al. (2018)	–	–	–	–	–	–	–	–
2018	Fikar and Hirsch (2018)	×	–	–	×	×	–	–	Sharing vehicles
2018	Lin et al. (2018)	×	×	–	–	–	–	–	–

Table 8 (continued)

Year	References	Staff members' constraints							
		Skill level	Hard TW/availability	Soft TW	Legislative rules	A limited number of visited patients	District/region	Incompatibility with patients	Mode of transportation
2018	Liu et al. (2018)	×	×	–	–	–	–	–	–
2018	Mosquera et al. (2018)	–	×	–	–	×	–	×	–
2018	Nasir and Dang (2018)	×	×	–	×	–	–	–	–
2018	Sinthamrongruk et al. (2018)	×	–	–	–	×	–	–	–
2018	Szander et al. (2018)	–	–	–	–	–	–	–	–
2018	Yuan et al. (2018)	–	–	–	–	–	–	–	–
2018	Zhan and Wan (2018)	–	–	–	–	–	–	–	–
2019	Decerle et al. (2019)	×	×	–	×		–	–	–
2019	Dekhici et al. (2019)	–	×	–	–	–	–	–	–
2019	Demirbilek et al. (2021)	×	×	–	–	–	×	–	–
2019	Du et al. (2019)	–	–	–	–	–	–	–	–
2019	Gomes and Ramos (2019)	–	–	–	×	–	–	–	–

Table 8 (continued)

Year	References	Staff members' constraints							
		Skill level	Hard TW/availability	Soft TW	Legislative rules	A limited number of visited patients	District/region	Incompatibility with patients	Mode of transportation
2019	Grenouilleau et al. (2019)	×	×	–	–	–	–	–	–
2019	Heching et al. (2019)	×	×	–	×	–	–	–	–
2019	Liu et al. (2019a)	–	×	–	×	–	–	–	–
2019	Moussavi et al. (2019)	–	–	–	×	–	–	–	–
2019	Nasir and Dang (2019)	×	–	–	×	–	–	–	–
2019	Restrepo et al. (2019)	–	–	–	×	–	×	–	–
2020	Chaieb et al. (2020)	×	×	–	×	–	×	×	Public cars
2020	Euchi (2020a)	×	×	–	–	–	–	–	–
2020	Fathollahi-Fard et al. (2020)	–	–	–	–	–	–	–	Public cars
2020	Frifita and Masmoudi (2020)	×	×	×	–	–	–	–	–
2020	Kandakoglu et al. (2020)	×	–	×	–	–	×	–	–

Table 8 (continued)

Year	References	Staff members' constraints							
		Skill level	Hard TW/availability	Soft TW	Legislative rules	A limited number of visited patients	District/region	Incompatibility with patients	Mode of transportation
2020	Euchi et al. (2020)	×	–	×	–	–	×	–	–
2020	Nasir and Kuo (2020)	×	×	–	–	–	–	–	–
2021	Hassani and Behnamian (2021)	–	×	–	–	–	–	–	–
2021	Nikzad et al. (2021)	×	–	–	–	×	×	–	–
2021	Li et al. (2021)	×	×	–	–	–	×	–	–
2021	Demirbilek et al. (2021)	×	–	×	–	–	×	–	–
2021	Euchi and Sadok (2021a)	×	×	–	–	×	×	–	–
2021	Malagodi et al. (2021)	×	×	×	–	–	×	–	–
2021	Shahnejat-Bushehri et al. (2021)	×	×	×	–	–	–	–	–
Total	55	35	29	6	20	6	13	3	5
Percentage		63.63%	52.72%	10.9%	36.36%	10.9%	23.63%	5.45%	9.09%

In Tables 6, 7, and 8, we recapitulate the different constraints that are considered in the selected papers.

5 Conclusion and perspectives

Home care offers medical and social services to patients and dependents at home. In addition to determining a new business model for the medico-social sector, it increases the quality of life and the availability of beds at hospitals. For a successful home healthcare sector, it is necessary to plan patient visit routes and schedule personnel well. It was determined that these operations fall under the *Home Healthcare Routing and Scheduling* (HHCRSP) problem, i.e., transportation and scheduling in the home healthcare sector. In addition, more specifically, this research is conducted through a literature review of all selected studies from 2016 to 2021.

The main contributions of our bibliographic study are highlighted as follows: first, we examined all of the selected papers dealing with routing and scheduling in the context of home care with the presentation of all keywords chosen for our sample with a summary of the work carried out in this context. Second, we examined all of the articles selected in this context through numerical analysis and classification of articles, emphasising the solution methodologies and the instances used for each paper, the objective functions, and the constraints considered (relation to visits, patients' preferences, and staff members).

According to this study, different opportunities for future research are determined by considering a greater number of patients, medical personnel, random scenarios, and various objectives, which justifies the application of heuristic and/or metaheuristic methods.

A variety of pathologies, treatments, and services can be provided by home healthcare structures. For future research, several services connected to the HHC sector can be studied, which extend the scope of the HHCRSP, such as the delivery of products that are often urgently needed (blood, vaccine, etc.) or blood samples (endemic diseases, epidemic crisis of viral disease, for example). The challenge for the future is to propose realistic routing and scheduling solutions integrating the usage of new technologies, such as drones, and ensuring a sustainable and green environment consideration.

Declarations

Conflict of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

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