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Health Care Routing Problem: A Systematic Literature Review

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ABSTRACT

Routing issues have recently gained the attention of many researchers due to the various advantages they provide. Minimizing costs, travel time, and the number of workers will help company resolve the issue. This paper contains a review of 53 papers characterized by their objectives, function, and method of completion. There are two types of objective functions: single-objective functions and multiple-objective functions. Exact method, hybridization and simulation methods, heuristic, and metaheuristic are the solution methods used. Further research is supposed to generate advanced metaheuristic algorithms that have already been revealed to be useful for both single and multi-objective problems in this field. A more in-depth investigation of the performance of metaheuristic algorithms is required in future research.

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1. INTRODUCTION

Routing problem was firstly introduced by Dantzig and Ramser [1]. They conducted research of ‘‘Truck Dispatching Problem” which modelling how a fleet of homogeneous trucks could serve the demand for oil of a number of gas stations from a central hub while minimizing the traveled distance. Subsequently, Clarke and Wright [2] improved on Dantzig and Ramser's approach using an effective greedy approach called the savings algorithm. This research focused on serving a set of customers, geographically dispersed around the central depot, using a fleet of trucks with varying capacities. Therefore this research became known as the ‘Vehicle Routing Problem’ (VRP), one of the most extensively studied topics in the field of Operations Research.

Routing problems have been the subject of intensive and fast-growing research for over sixty years, driven by their economic importance and their theoretical interest [3]. It is an important combinatorial optimization problem concerned with the optimal design of routes to be used by a fleet of vehicles to serve a set of customers [4]. When solving this problem, various objectives and constraints can be considered, depending on the application of interest. Measurement and quantification are central to any optimization algorithm applied in business processes. In the routing problem literature, cost is typically the main objective, but other metrics that should be considered, either as additional objectives or constraints, include (1) profitability (2) service quality (3) equity (4) consistency (5) simplicity (6) reliability and (7) externalities [3]. The goal of the routing problem is to find a set of least-cost vehicle routes ensuring that each customer is visited exactly once by one vehicle, each vehicle starts and ends its route at the depot, and the vehicle capacities are not exceeded.

There are some types of routing problem in three specific variants of the VRP which model real-life aspects: the Open VRP, the Dynamic VRP, and the Time-Dependent VRP (TDVRP) [5]. In the Open VRP (OVRP) vehicles are not required to return to the central depot after visiting the last customer. If they do return, they must visit the same customers in the reverse order. Additionally, the OVRP often involves two optimization objectives: minimizing the number of vehicles used and minimizing the total distance traveled.

Dynamic VRP (DVRP) also referred to as online or real-time VRP, involves inputs that are revealed or updated continuously. Based on these new inputs, vehicle routes are then adapted dynamically [6]. The TDVRP assumes that the travel times are deterministic but no longer constant. TDVRP also satisfy the non-passing property, also known as the First-In First-Out (FIFO) property [7].

Routing efficiency can significantly affect the profitability of both private and public sector organizations. Private sectors including airlines, parcel deliveries, networks, etc., also focus on routing efficiency. Private companies are profit-driven organizations that are more sensitive towards good routing plans. Public sector which has many services like postal service, garbage collection and healthcare would also get more benefit from better routing practices.

The goal of this paper is to draw a succinct overview of current research in routing problem especially in healthcare domain. Health care is domain that can utilize routing and scheduling method to achieve maximum benefits for home healthcare program, nursing, therapist, medical waste transportation, and more. The goal of healthcare systems is to ensure that homebound patients receive quality health services. It is addressed to researchers and practitioners who wish to consult a concise review of existing problem features and applications. The organization of the paper was presented as follows: Section 2 presents the method of literature review; Section 3 displays the results, analysis, and future work; and the last part projects the conclusion.

2. REVIEW METHODOLOGY

This research conducts a systematic literature review. A systematic literature review (SLR) is a method of synthesizing scientific evidence to answer a particular research question in a way that is transparent and reproducible, while seeking to include all published evidence on the topic and appraising the quality of this evidence [8]. The purpose of this review is to gain new insights of routing problem in healthcare.

The vehicle routing problems have attracted attention from both academia and industry. Practitioners and academicians are constantly seeking new transportation modes, sequencing rules, and efficient heuristics to find better vehicle routing solutions. Vehicle routing problem is defined as the problem of designing least-cost delivery routes from a depot to a set of geographically scattered customers, subject to side constraints [9]. Routing related costs constitute a significant portion of the overall logistics costs in most service industries. Routing efficiency can significantly affect the profitability of both public and private sector organizations [10]. The following research questions were formulated to address the objective of this study:

RQ1. What are the applications of routing problems in health care?

RQ2. What are the different objectives of those researches?

RQ3. What are methodological approaches were used in those researches?

RQ4. What are concerns that should be considered?

RQ5. What kind of problem can be explored in future research?

In recent years, research about the routing problem has been conducted by many researchers in various domains, including health care. However, there still lacks a comprehensive and systematic review. Most review papers only focus on sepcific topics or sub-topics within the health care domain. Figure 1 represents the topics related to health care that are being observed, including home healthcare, medical waste, and medical logistics routing problems. To highlight the emerging trends in health care routing problem studies, it is crucial to innovate a new line of research considering the latest studies in this area.

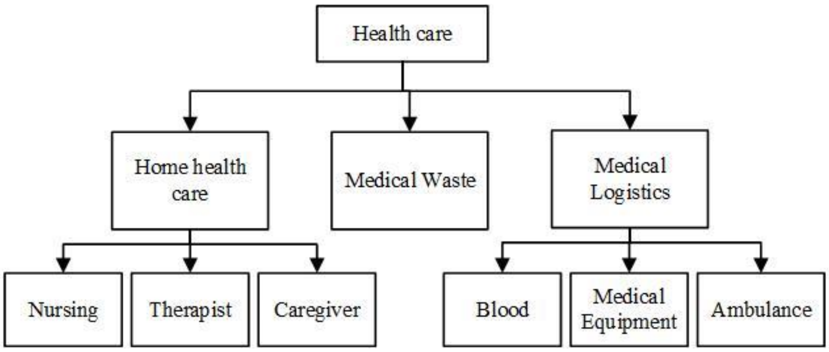

Figure 1. Domains in health care routing problem

2.1. Data Information

The coverage of this review is limited by five research questions mentioned above in order to embrace papers considering specific topics of routing problem in healthcare including home healthcare which consist of nursing, therapist, caregiver, ambulance, medical waste distribution, and healthcare logistics like hazmat, biological sample, blood, etc. Several resources of data have been used in this study. The steps of processing data information are choosing main keywords to cover all subject areas related to routing in healthcare and then looking for papers published from 2011 to 2021. The keywords used are "routing problem" and "health care". Identifying the abstract – to know the goal and research or review questions- has been done to reach the goal of this review paper. The search procedure has been conducted in well-known academic databases, like Elsevier, Springer, Emerald, IEEE, etc. Figure 2 is representing papers resources platform. Result of searching the keywords in many academic databases above, many papers were found. The classification of the papers is based on the year of publication, theme of the paper, as well as methods and objective functions in the single and multi-objective problems within various sub-topics of health care. A comprehensive descriptive analysis is presented in Section 3. Figure 3 is representing distribution of each specific topic which reviewed in this study.

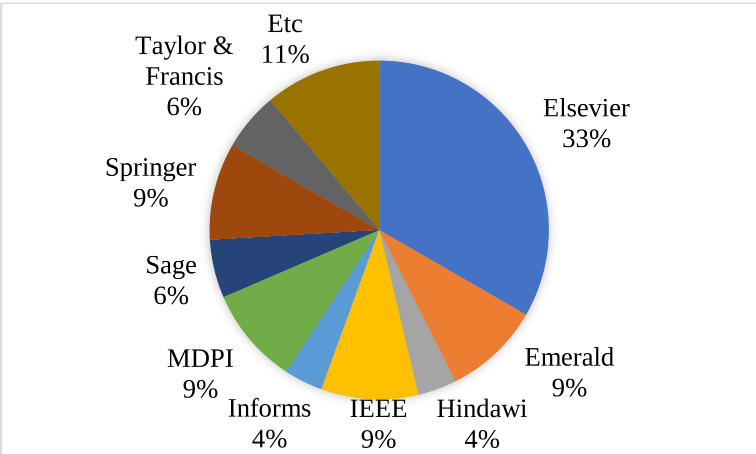

Figure 2. Paper distribution based on publisher

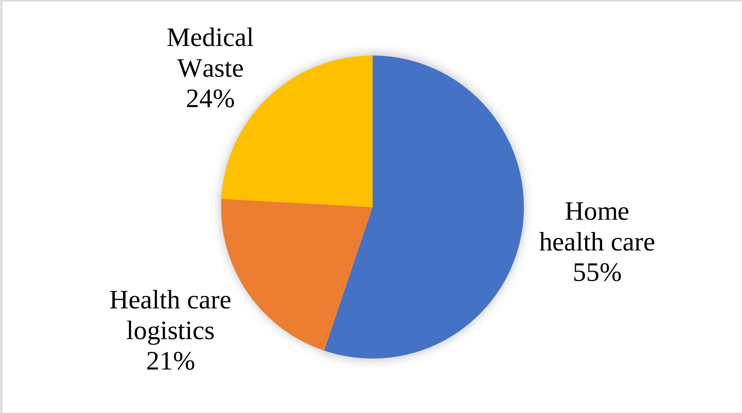

Figure 3. Domain distribution

2.2. Framework of study

This study consists of four steps, as illustrated in Figure 4. The first step of this study involves determining the objective function and research questions. The research questions mentioned earlier will be the guidance in reviewing papers. Next, data collection involves seaching for papers from various resources, refining the search results and creating a list of papers to be used. This step includes setting the keywords and collecting relevant data; Step 2: development of the Helath Care Vehicle Routing Problem (HCVRP) classification schema; reviewing the collected literature; separating and tabulating the literature according to the classification schema; presenting the literature reviews using the classification schema, and the last is analyzing the reviews and presenting suggestions for further research. Figure 5 represents the literature review classification schema of routing problem in health care.

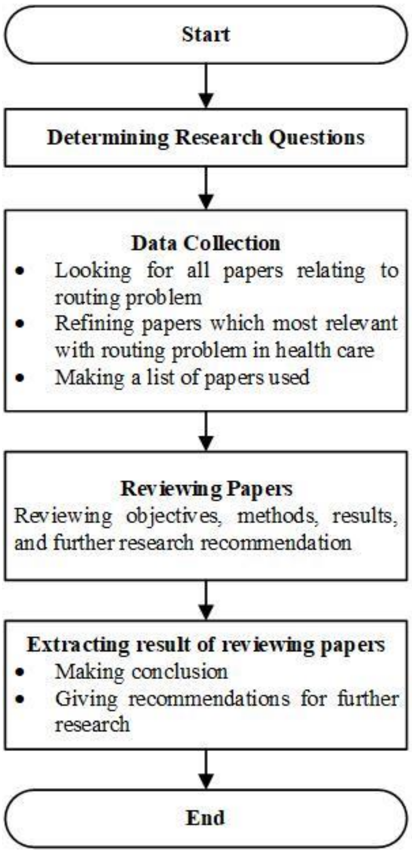

Figure 4. Process of review study

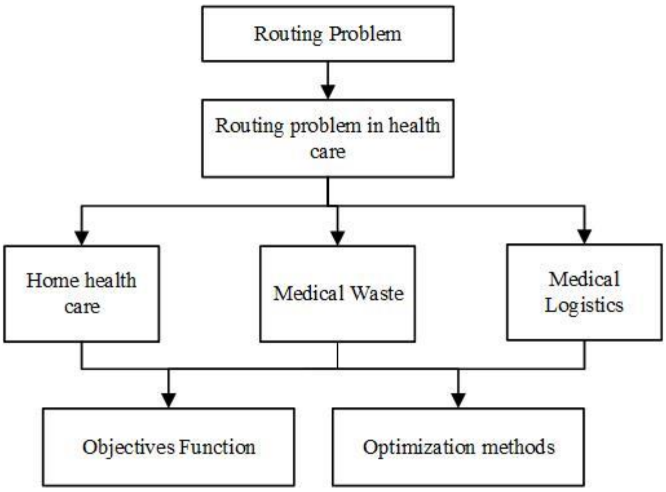

Figure 5. Literature review classification schema of routing problem in health care

3. ANALYSIS OF LITERATURES

In general, the growth in healthcare service industry is influenced by factors such as the increasing aging population, number of people with disabilities, rising healthcare costs and capacity issues hospitals [11]. People have different personal assistance requirements, including dressing, monitoring medicine dosage, daily physiotherapy, speech therapy, hospital or laboratory check-ups, etc. To discuss and analyze further research, we classified those papers based on their problem, variants or objective function, and solutions methodology. This review uses papers from 2011 until 2021. As can be seen in Figure 6, it shows an increasing interest in these studies. This comprehensive review can provide a clear possible gap for further research directions.

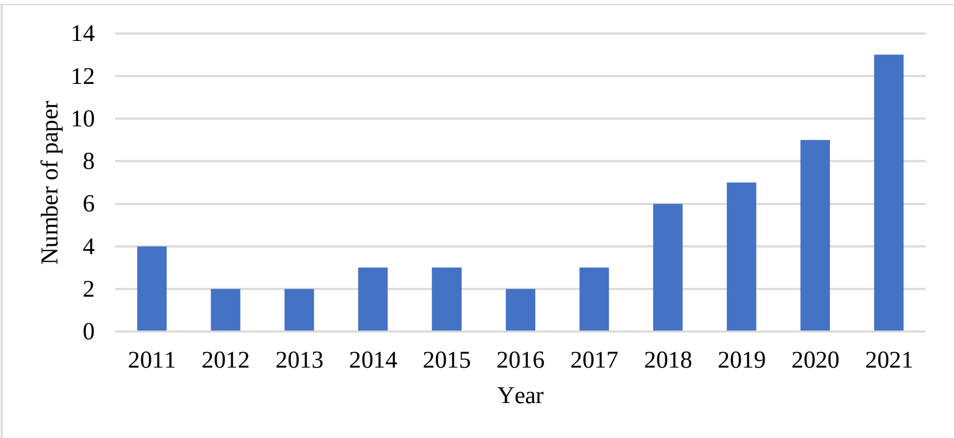

Figure 6. Paper distribution based on year of publication

3.1. Objectives Function

Based on problem classification, various subjects are presented, which are considered in the field. It is significant that most of the papers apply in two or more categories, and the principal key in determining the category of any paper is to find the focus on a specific subject, as highlighted by other researchers. This section will go over the issues raised in each of the papers that have been read. These issues will have an impact on the goals and method useds to solve the problem. The main categories in this area are single objective or multiple-objectives, which consist of design of network, optimum scheduling plan, minimum workers, and minimum costs. The purpose of each papers reviewed is described in Table 1 and Figure 7 represents the distribution of the goals achieved in those reviewed papers.

Table 1. Reviewed papers in HCVRP

Objective Function						**Solution Approach**			
Min Costs	**Min Contamination**	**Min Time Travel**	**Min Worker**	**Max Home Care Visit**	**Optimal Plan**	**DES**	**Heuristic**	**Hybrid Heuristic**	**Meta heuristic**
[11], [12], [36], [37], [40], [42]–[48], [16], [49]–[51], [18], [20], [21], [25], [27], [29], [30]	[14], [24], [52], [25], [34], [41]–[43], [47]–[49]	[13], [14], [41], [43], [44], [48], [50]–[54], [15], [18], [20], [22], [24], [30], [31], [40]	[12], [13], [17], [19], [32], [35], [38], [55], [56]	[11], [13], [35], [46], [55], [17], [19], [22], [26]–[29], [32]	[11], [16], [23], [31], [33], [36], [39], [50], [51], [53], [56], [57]	[28]	[11], [12], [47], [54], [19], [21], [31]–[35], [38]	[18], [27], [29], [30]	[17], [20], [42]–[44], [46], [48], [50], [51], [53], [22], [25], [26], [29], [33], [39]–[41]

In the field of home health care, patients often have overlapping visit schedules, leading to an increased demand for caregivers and nurses. Moreover, the considerable distance between each patient further extends the travel time, posing challenges for the therapist. Effectively and efficiently distributing medical equipment has become a significant concern, particularly due to the long distance between required locations. Recently, the distribution of hazmat as personal protective equipment for COVID-19 health workers in large number has been rushed due to its urgent need, but the supply remains limited. Ambulance availability and scheduling also pose challenges, especially during emergency situations like natural disasters, where prompt ambulance usage become crucial but is often hampered by availability issues.

Aside ambulances and hazmats, other health-related necessities, such as blood distribution also require careful scheduling and control to ensure effectiveness and efficiency. The health sector also leads to environmental problems particularly hazardous waste. Before its discharge, waste must undergo treatment to mitigate any potential harm to the environment. The distribution of hazardous materials necessitates a well-thought-out plan that considers disposal time, travel time, and cost to minimize environmental impact and ensure safe handling.

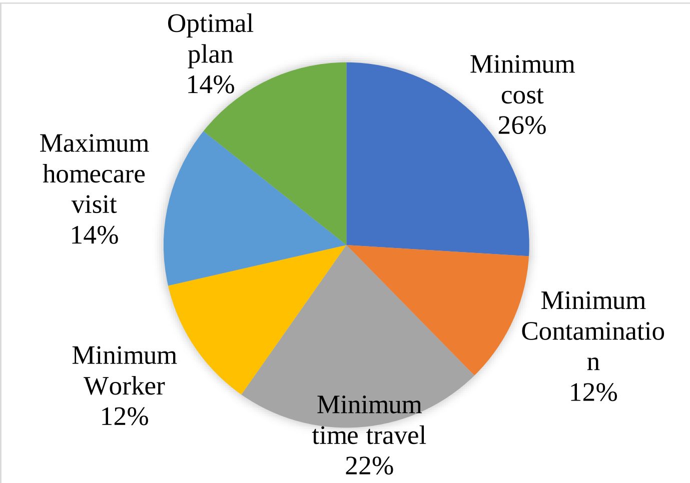

Figure 7. Distribution of objectives function

3.2. Solutions methodology

The method to use can be defined once the purpose of the research has been determined. Various approaches for solving routing problems includes exact solution, simulation, heuristic, and metaheuristic. Several factors should be considered when deciding problem-solving methods, such as data availability, and limitations in term of time, cost, energy, and knowledge. Figure 8 illustrates the distribution of the solution method used in the reviewed papers. Among these, metaheuristic and heuristic emerge as the most popular approaches. Many researchers prefer them due to perceived suitability and user friendliness.

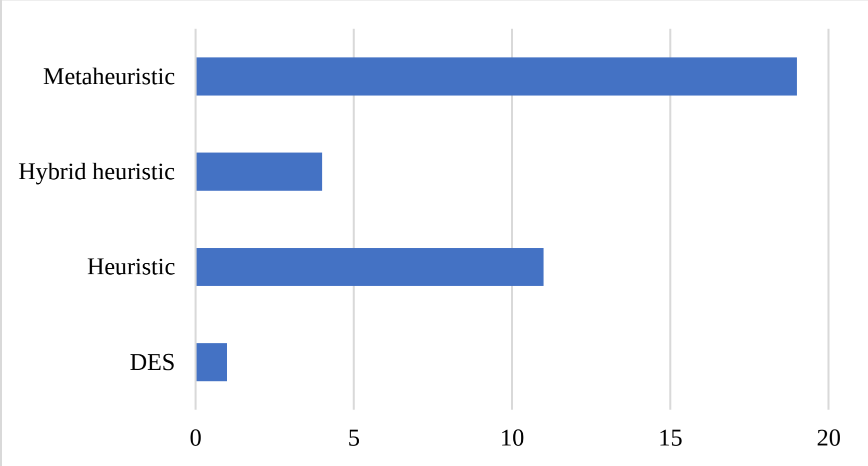

Figure 8. Distribution of the solution approach

3.2.1. Exact method

Exact method in the field of routing problems encompass various approaches, including mathematical models, mixed integer programming, and mathematical programming. Around 2011 until 2021, several researchers used exact method to solve routing problem in health care. Barrera et al., [12] has developed a mathematical programming aimed at minimizing the number of workers required to visit a set of customers. To reduce computational time, they combined this mathematical programming with heuristic procedure. Addressing the needs of the elderly in Hungary, Szander et al., [13] makes network design in order to minimize cost and time travel. Hajar et al., [14] and Faizal et al., [15] focused on health waste management, creating mathematical models to minimize distances and thereby reduce waste contamination.

Mixed integer programming (MIP) has also found widespread application in solving healthcare routing problem. Many researchers such as Carnes et al., [16]; Decerle et al., [17]; Wang et al., [18]; Gartner et al., [19]; Nasir et al., [11]; Kaya et al., [20]; Benini et al., [21]; Cinar et al., [22] have used MIP to address heatlhcare routing problems. Decerle et al., [23] specifically used MIP to find valid schedules and routes on a one-day period for each caregiver. The resulting planning indicated which visits had to be performed by each caregiver and their resective start times. Tirkolaee et al., [24] use a fuzzy chance-constrained programming approach is applied to the proposed model with mixed integer linear programming (MILP). A real case study is investigated in Sari city of Iran to test the performance and applicability of the proposed model. The collected information from Mazandaran University of Medical Science and Sari Municipality. Li et al., [25] developed mixed integer programming as their method to solve problems. Fathollahi-Fard et al., [26] develop a bi-objective (multi depot and multi period) optimization decision-making model called the home health care routing and scheduling problem under fuzzy conditions. They use AMSEO compared with Simulated Annealing and Genetic Algoritm.

3.2.2. Hybridizations and simulation

In this section, only four papers used hybridization method and simulation to achieve their goals. Veenstra et al., [27] used hybrid heuristic which proposed to simultaneously solve the facility location and vehicle routing problem. They iteratively modified a solution by changing the set of opened lockers, updated the routes accordingly, and applied a variable neighborhood search (VNS) procedure to improve the routes. J. Morrice at al., [28] used discrete event simulation to designed and analyze a newly proposed form of care delivery called an integrated practice unit (IPU) where multi-disciplinary team of providers and staff work together to cover the full care cycle for a given condition. Alves et al., [29] developed an approach for the optimization of the periodic vehicle routing problem (PVRP), which deals with home care visits in order to perform treatments for patients belonging to a Health Unit using CPLEX software. They addressed the simulation with data of health unit in Braganc. Luan et al., [30] used hybrid self-adaptive bat algorithm (HSABA) as an improvement of a nature-inspired algorithm for solving this location routing problem (LRP) model hard optimization problem in order to maximize the rescue efficiency. The objective function of minimizing time and cost is established in the single-stage LRP model considering different scenarios.

3.2.3. Heuristic

Approximately 21% of the reviewed papers used heuristic method to solve a single-objective or multiple-objectives including the studies by Halper et al., [31]; Bennett and Erera [32]; Nickel et al., [33]; Taslimi et al., [34]; Castano et al., [35]; Martínez-Reyes et al., [36]. Barrera et al., [12] combined mathematical programming and two-phase heuristic procedure. The heuristic procedure consists of initial solution using a depth first search (DFS) technique and then improve the solution using routing packing algorithm in order to schedule minimum number of workers for multiple sets of customers. Bronfman et al., [37] developed a multi-product maximin hazmat routing location problem with multiple destinations. This work addressed both the problem of locating hazardous facilities and routing hazardous materials across a large, densely populated urban area while minimizing associated costs and hazards imposed on the population.; Levary [38] aimed to provide medical care at patients' homes using the fewest number of nurses possible to deliver the required care. The heuristic scheduling system is easily implementable as a computerized adaptive system. Gartner et al., [19] combined heuristic and integer programming to tackle the problem of scheduling and routing physical therapist's hospital-wide. Nasir et al., [11] used mixed integer programming in combination with heuristic VNS using CPLEX software. This paper aimed to develop an HHC service system in the perspective of long-term economic sustainability and operational efficiency. The proposed model extended the HHC problem beyond conventional scheduling and routing issues to encompass demand and capacity management aspects.

3.2.4. Metaheuristic

Metaheuristic is the most commonly used method. Trautsamwieser et al., [39] developed a bi-objective model and solution algorithm for the daily planning of HHC services during natural disasters. They used real data of flood in Australia 2002. Providing three models, Nickel et al., [33] aimed to achieve weekly optimal plan for home health care services. They designed home health care problem (HHCP), MSP (Master Schedule Problem), and OPP (Operational Planning Problem). HHCP has two stage approach (constraint programming heuristic for calculation feasibility and adaptive large neighborhood search (ALNS) to seeks initial solution. Bard et al., [40] have objective to minimize the cost of providing rehabilitative services for up to a week at a time. They found solutions using a parallel Greedy Randomized Adaptive Search Procedure (GRASP). The problems involved up to 16 therapists and 160 patients, with many requiring multiple visits during the week.

Eren et al., [41] and Nikzamir and Baradaran [42] conducted research in waste management. Eren determined medical waste management steps, establishment of a hierarchical structure, and weighting of the criteria within the established hierarchical structure by means of the analytic hierarchy process method. Nikzamir and Baradaran [42] developed metaheuristic Multi-Objective Water-Flow like Algorithm (MOWFA). Extensive computational experiments have been conducted to evaluate the effectiveness of the MOWFA on several test problems compared to other metaheuristics, namely the Multi-Objective Imperialist Competitive Algorithm (MOICA) and Multi-Objective Simulated Annealing (MOSA). These experiments also include a real health care waste logistic network in Iran. With real-life data provided by the Local Health care Authority of Bologna Italy, Benini et al., [21] used Two Mixed Integer Linear Programming formulations and an Adaptive Large Neighborhood Search (ALNS) metaheuristic algorithm. The results show that the ALNS algorithm is able to find solutions in which all the samples are delivered on time, while in the real case about the 40% of the samples is delivered late. Ghannadpour et al., [43] focused on optimizing triple bottom line objectives for sustainable health care waste collection and routing by a self-adaptive evolutionary algorithm.

4. CONCLUSION AND FUTURE RESEARCH

This paper presents a systematic literature review of 53 papers on healthcare routing issues. The review is based on various world journals published between 2011 and 2021. The domains discussed typically involve home healthcare routing problems such as nursing, therapists, and caregivers, as well as healthcare logistics such as blood distribution, hospital tools, ambulances, and hospital waste disposal distribution. The aim of this review is to examine the purpose and methods of healthcare routing problems based on the specific issues. Exact methods which including mathematical models, mathematical programming, and mixed integer programming are used, followed by heuristic, metaheuristic, hybridization, and simulation. Detailed insights and research directions are presented in Section 3. Furthermore, the review indicate that the metaheuristic algorithm is the most widely used algorithm for solving routing problem in healthcare. This procedure has flexibility in finding solutions for NP-Hard problems. For both single and multi-objective problems, some popular metaheuristic algorithms of the

HCVRP were introduced, such as GA (Genetic Algoritm) and ACO (Ant Colony Optimization). Additionally, several integrated procedures that combine heuristics-metaheuristics were also suggested. Further research is expected to develop advanced metaheuristic algorithms that are proven to be useful for the single and multi-objective problems in this problem. Future research needs to conduct a more in-depth investigation to compare the performance of the metaheuristic algorithm.

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