INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact Factor: 6.078

(Volume 8, Issue 5 - V8I5-1151)
Available online at: https://www.ijariit.com

Operations Research on service scheduling in the healthcare sector: A systematic review

Aryan Smith
aryan.smith668@nmims.edu.in
Anil Surendra Modi School of Commerce, Mumbai, Maharashtra

Aryan Jain
aryan.jain514@nmims.edu.in
Anil Surendra Modi School of Commerce, Mumbai, Maharashtra

Anushka Agarwal
anushka.agarwal234@nmims.edu.in
Anil Surendra Modi School of Commerce, Mumbai, Maharashtra

Arhan Shroff
arhan.shroff542@nmims.edu.in
Anil Surendra Modi School of Commerce, Mumbai, Maharashtra

Aryan Verma
aryan.verma465@nmims.edu.in
Anil Surendra Modi School of Commerce, Mumbai, Maharashtra

Veerendra Anchan
veerendra.anchan@nmims.edu
Anil Surendra Modi School of Commerce, Mumbai, Maharashtra

ABSTRACT

The current state of healthcare in the world is dire, with millions of people unable to access healthcare services on time. One of the key reasons behind this problem is the lack of operational efficiency in many clinics and hospitals, caused due to unscientific scheduling practices. Hence, this paper seeks to conduct a systematic review of the existing research done in the field of healthcare service scheduling, and its multiple sub-sections viz. appointment scheduling, nurse rostering, home healthcare scheduling, etc. The bibliometric review found that majority of the research in the aforementioned field is scattered and lacks integration. Moreover, past research has primarily employed matheuristics, mixed integer linear programming and simulation approaches to solve service scheduling problems, without exploring other methods to a great extent. In the end, we suggest some topics in which future research can be conducted.

Keywords: *Service Scheduling, Healthcare, Review, Operation Research, Queueing*

1. INTRODUCTION

The practice of service scheduling is what makes work orders more efficient and ensures that the proper job is allocated to the right dispatcher at the right time. Service scheduling is prevalent in sectors like manufacturing, healthcare, home care, inventory management, aviation, etc. Problems with healthcare optimization have recently attracted a lot of attention in an effort to deliver better treatments for less money (Abdalkareem et al., 2021). Hospitals are essential components of healthcare systems, and worldwide, access to their services is extremely competitive. Many hospitals have grown in size as demand has grown (Burdett & Kozan, 2018). However, expansion beyond a certain limit is not feasible financially. Hence, hospitals and healthcare clinics need to focus on efficiently optimizing their appointment scheduling process in order to successfully deliver their services to the patients. The practice of service scheduling is significant in various categories under the healthcare sector which include home healthcare scheduling, operation room scheduling, surgery scheduling, physician scheduling, nurse rostering, chemotherapy and radiation therapy scheduling. A scheduling system could reduce patient wait times, make medical services more accessible, and improve the efficiency of healthcare operations (Abdalkareem et al., 2021). Allocation scheduling or advance scheduling are the two main categories used to categorise patient scheduling literature. Once every patient for a given service day has been identified, allocation scheduling refers to methods for allocating specific resources and starting times to patients. While future demand is still unknown, advance scheduling refers to methods for booking patient appointments before the service date (Sauré et al., 2012).

"Population aging and a decrease in informal care are likely to lead to a substantial increase in demand for home health care (HHC) service"(Fikar & Hirsch, 2017). These services, which include nursing, wound care, housekeeping, injection, cleaning, and physiotherapy, are more affordable and effective than those typically provided in nursing homes or hospitals (Fathollahi-Fard et al., 2020). The market for home healthcare was valued at USD 320.6 billion in 2021, and from 2022 to 2030, it is projected to grow at

a CAGR of 7.9%. Nurses are scheduled and routed for various services at clients' homes in home health care (HHC) operations (Fikar & Hirsch, 2017). Future work is necessary to reduce costs and ensure service quality because the demand for HHC is anticipated to expand significantly (Fikar & Hirsch, 2017). According to a report by The Commonwealth Fund, the "hospital at home" programme, for instance, enables patients to get acute care at home with fewer complications and a 30% decrease in the cost of care.

Surgical scheduling problem can be defined as the choice of procedures to be carried out, the allotment of resource time to those procedures, and the order in which those procedures are carried out during the allotted time (May et al., 2011). Chemotherapy, a crucial component of cancer treatment is the administration of pharmacological medicines, typically through intravenous (IV) infusion (Santibáñez et al., 2012). The complexity of chemotherapy appointment scheduling has a direct impact on patient satisfaction and operational efficiency. The scheduling of numerous daily visits for various indications, including appointments for radiology, oncology, and laboratories, must take patient time preferences into consideration (Santibáñez et al., 2012). Operation room scheduling is a type of scheduling where operation rooms are assigned to patients depending upon their priority and emergency status. This is closely related to surgical scheduling. Late cancellations and no-shows from patients can adversely affect the service scheduling models. Hence, it is necessary for making provisions for the same. If not handled properly, these cancellations can result in serious inefficiencies and add new levels of unpredictability (Liu et al., 2010). In the United States, the projected total amount paid to hospitals was expected to be between $195.4 and $212.2 billion, and the estimated yearly cost of elective inpatient and outpatient surgical operations was $147.2 billion. The healthcare system in US generated a net income of $48.0 to $64.8 billion annually. Lastly as a consequence to the pandemic, the telemedicine services model is being encouraged by governments across the globe. This will help in bringing down the total footfall at healthcare centers thereby reducing the spread of the virus. It will also contribute in reducing the load of patients. A combinatorial optimization issue known as nurse rostering entails assigning shifts to nurses while taking into account coverage restrictions, skill categories, labor laws, contractual agreements, personal preferences, etc. Usually, 24-hour service is required with a highly fluctuating workload that varies from day to day. In actuality, the issue is worsened by a number of factors such overlapping shifts and hierarchical competent nurses.

This paper summarizes the efforts of previous authors who have contributed to the field of schedule optimization in the healthcare industry. The remaining sections of the essay are structured as follows. The following section, the papers related to the healthcare service scheduling in the optimization context, are reviewed. In Section 3, we mention the methodology and models used by us. The next section (section 4) deals with the analysis of data and the key findings as well as models used by various researchers. Finally, we draw a conclusion and talk about how this study might be expanded and potential future course of research in Section 5.

2. LITERATURE REVIEW

The field of service scheduling is a widely researched topic with noteworthy contributions by prolific researchers. A plethora of material was available on the field of service scheduling which focused on several industries. We have restricted our review to the research work which focuses on healthcare sector.

Our review dates to the original work of "J.D. Welch (*Appointment Systems in Hospital Outpatient Departments Author (s): J . D . Welch Reviewed Work (s): Published by : Operational Research Society*, 2013)" who conducted a study on the role of punctuality of both patients and medical staff on the efficiency of appointment scheduling, as well as suggested ways to optimize the waiting time for patients to ensure higher productivity in the healthcare sector. A high waiting time can have a pernicious impact on the patient's opinion towards the hospital. In some emergency cases, even the health of the patient can be jeopardized by a long queue at the hospital. A study done by (Nottingham et al., 2018) uses data from a three-year period to examine the impact of waiting time on patient satisfaction in the setting of rural healthcare clinics. Patient admissions and therapies must be carefully planned in advance. This is difficult since patient treatment and recovery timeframes vary and are unpredictable. A complex flexible job shop scheduling (FJSS) model was developed in response and released by (Burdett & Kozan, 2018), which treats patients, beds, hospital wards, and healthcare activities as jobs, singular machines, parallel machines, and operations, respectively.

2.1 Home Health Care Scheduling

The article by (Sauré et al., 2012) showcases that "in home health care (HHC) operations, nurses are scheduled and routed to perform various services at clients' homes." A Markov decision process model (approximate optimal policy) for a smaller cancer centre or a subsection of large cancer centres. The study by (Xiao et al., 2018) suggested a mixed integer linear programming (MILP) model to address a complex scheduling and routing problem in home healthcare (HHC) from an operational standpoint. The entire process entails sending caregivers to patients' homes to fulfil visits that are requested by them, with the objective function of reducing overall operating costs. (Luo et al., 2020) also deals with the issue of green scheduling and routing in home health care (HHC) under the restrictions of timed visits and carbon emissions. (Restrepo et al., 2020) suggested a two-stage stochastic programming technique is also presented for staffing and scheduling employees in home healthcare. Some crucial aspects of home health care workforce planning are the geographic dispersion of patients and the irrationality of demand. The General Variable Neighborhood Search (G-VNS) was used by (Frifita et al., 2017) to resolve scheduling and routing issues using time frames and coordinated visits.

(Li et al., 2021) present a routing and scheduling issue in home health care for outpatient services while taking into account the limitations of time windows, skill requirements, and employment laws. (An et al., 2012) mentions about the HSSP, which is the difficulty of identifying a nurse's route in a home healthcare system (HHS). The home healthcare scheduling and routing issue is addressed via an original hybrid three-phase methodology offered by (Shiri et al., 2021). In the first part of the following paper's combinatorial approach, a group of potential sites for healthcare facilities are assessed utilizing a fuzzy analytic hierarchy method and grey rational analysis. A multi-objective resilient model that considers two features—various periods and uncertainty in the second phase—is provided as the second stage. The Nimbus approach is then applied in the third phase to transform the three

proposed objective functions into a scalar-valued optimization problem. (Oladzad-abbasabady & Tavakkoli-moghaddam, 2022) over a planning horizon of several days, propose a two-stage mathematical framework (MIP model) for the Home Health Care Routing- Scheduling Problem (HHCRSP). Total Planning Distance (TPD) is reduced in the first stage, and total compatibility is increased in the second stage along with handling unforeseen situations. Lastly (Yadav & Tanksale, 2022) employed two separate mixed-integer programming decomposition-based heuristic techniques to arrange home healthcare delivery that minimised person-to-person contact.

2.2 Surgery Scheduling

Operating rooms can be utilized to the most optimal extent using heuristics which are developed by simulation. One such contribution was made by (Arnaout, 2010), who demonstrated how Longest Expected Processing with Setup Time (LEPST), the proposed approach, outperformed the other algorithms.(Tànfani & Testi, 2010) also contributed to this by assigning wards and surgical rooms across a specific planned horizon using a 0-1 linear programming approach. The challenge is to distribute and sequence the necessary resources while taking disruptions into account for a certain set of elective procedures to be done by particular doctors. Another research by (Oh et al., 2013) presents a stochastic integer programming model that plans and orders patient visits during a workday session using empirical data.

(Marques & Captivo, 2015) aim at improving the efficiency of OR by lowering the surgical waiting lists and streamlining the scheduling of surgeries at a public hospital in Lisbon using a bicriteria optimization methodology. Another research by (Johnston et al., 2019) explains the qualitative aspects involved in scheduling of surgeries. Surgeons prioritize surgeries based on certain time and idiosyncratic personal preferences. This study shows the way to achieve a balance between flexibility and efficiency.Recently (Aissaoui et al., 2020) suggested a mixed integer linear programme that uses an aggregated surrogate protection mechanism to properly distribute slacks between healthcare tasks. A Monte Carlo simulation is run to assess the effectiveness of the suggested model.

2.3 Uncertainty Scheduling

The majority of current studies on healthcare accessibility neglect the ubiquitous occurrence of travel time uncertainty in road networks. A reliability-based two-step floating catchment area (2SFCA) method is recommended for evaluating healthcare accessibility when travel times are unknown. By explicitly taking into account individuals' reliability restrictions while scheduling visits to healthcare facilities in the face of travel time uncertainty, the suggested measure generalises the traditional 2SFCA measure (Chen et al., 2020). A location's ability to provide healthcare services is influenced by three factors: the performance of the transportation network, the capacity of the healthcare system, and potential demand for healthcare services. In the literature, a variety of methods have been put out to assess healthcare accessibility by varied degrees of capturing these three components (Chen et al., 2020). Even patient unpunctuality has been negatively impacting appointment scheduling due to the extra costs incurred as a result of patients waiting or provider overtime. This can be done by serving the waiting person with the lowest "LAR" index, or the larger of their appointment time and their actual arrival time (Pan et al., 2021).

2.4 Appointment Scheduling

(Turkcan et al., 2011) looked into service criteria for sequential appointment scheduling. With the aim of avoiding injustice and maximising revenue, a sequential scheduling method and stochastic programming model are proposed. Another research by (Santibáñez et al., 2012) makes use of mixed integer programming methods and discrete event simulation. In order to shorten the waiting list, the simulation indicated above addressed the issue of scheduling each patient's initial chemotherapy visit on a certain day (Bouras et al., 2021). In order to reduce the maximum nursing burden, daily scheduling is done using the mixed integer-programming model (Bouras et al., 2021). To set up appointments for donors of platelets and plasma in a blood collection system, (Alfonso et al., 2012) propose a MINLP (Mixed Integer Nonlinear Programming) model. To reduce the cumulative waiting period for all donors in a day, it is important to identify the best appointment schedules for scheduled donors. In spite of longer wait times, (Oh et al., 2013) suggest appointment overbooking as a way to lessen the negative effects of no-shows. based on the outcomes of several simulated experiments (Oh et al., 2013) find that overbooking is more useful when clinics see more patients, have higher no-show rates, and less variety in their services. (Zhan & Wan, 2018) in order to efficiently deliver the services, concentrate on allocating and routing the service teams while scheduling appointments for the clients. They take into account a team assignment problem that involves concurrent routing and appointment scheduling. To effectively handle the issue, they create a mixed integer programme based on scenarios and create an algorithm using the Tabu Search (TS) method.

However, In light of the capacity restriction, a bi-criteria programming model has been developed by (Wu et al., 2019) to reduce the likelihood of blockage and the price of bed allocation. A simulation-based method for choosing a patient appointment scheduling policy that works with any distribution of patient service times has been proposed by (Shnits et al., 2020). The objective of this study was to lower the weighted sum of costs related to patient waiting, server downtime, and overtime.(Kuiper et al., 2021) demonstrates how the situation for appointment scheduling has altered significantly from what the operations-research literature has primarily anticipated. A schedule optimization algorithm that maximises the amount of time nurses spend with patients was developed by (Zimmerman et al., 2021) to match schedules with customer demand. With the use of this new objective function, carryover demand may be immediately incorporated into a straightforward mixed integer linear programming scheme. (Namakshenas et al., 2022) examined the outpatient appointment scheduling in a medical imaging facility. The scheduling of outpatients on the scanners and the assignment of the radiopharmaceuticals are coordinated using a mixed-integer programming approach. Prior studies have assumed either an infinite bed capacity or a lack of service contact between units. Lastly, the paper by (Zhang et al., 2022) analyses the issues associated with choosing vaccination sites, accepting appointments, assigning appointments, and scheduling issues for mass immunisation in response to COVID-19. To simultaneously reduce the fixed cost of managing vaccination locations and the travel time for vaccine users, they express the issue as a mixed-integer linear programme (MILP).

2.5 Nurse & Physician Scheduling

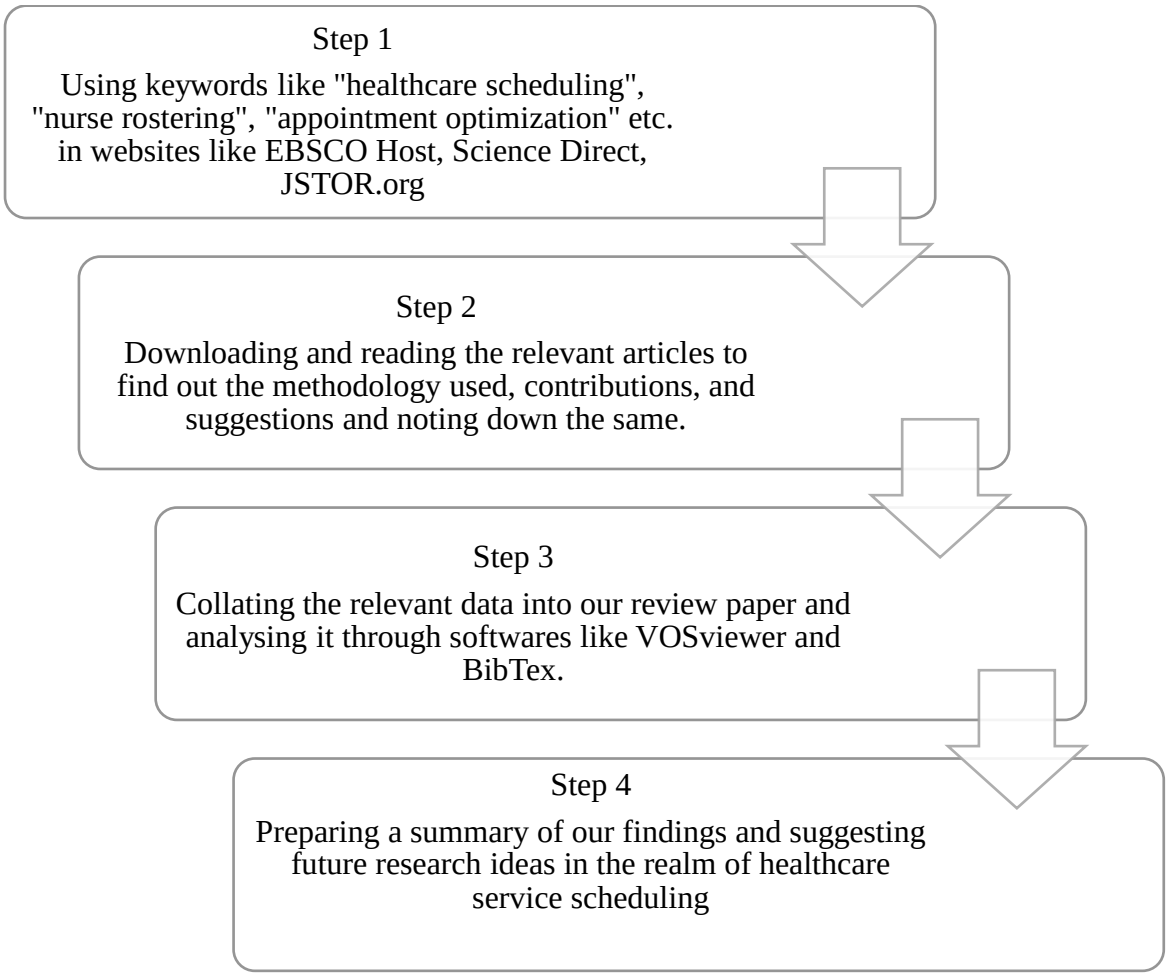
The article by (Erhard et al., 2018) focuses about the financial and non-financial aspects of scheduling doctors. Improved physician scheduling results in greater effectiveness, less annoyance, and greater patient happiness. The idea of distributionally robust optimization (DRO) is frequently utilised to create robust, dependable, and yet less expensive solutions for any potential probability functions in order to trade off between solution robustness and conservatism. Therefore (Ala et al., 2022) suggested that fairness, doctors, and resource use should all be maximised in employment. To control their workload, they provide each doctor a reasonable amount of patients. After conducting research on single nurse scheduling, a priority parameter that depends on the last visit time and the medical circumstances of each patient was developed by (Cinar et al., 2021). The purpose of a multi-period orienteering issue with time windows is to maximise prizes by visiting patients in a finite amount of time. This priority parameter is used to allocate "prizes" to the challenge. In order to tackle the given problem, the paper suggests using a mixed integer programming (MIP) model, the Successive Single Period Heuristic (SSPH) mat heuristic, and the Adaptive Large Neighborhood Search (ALNS) algorithm. A mat heuristic technique outperforms Adaptive Large Neighborhood Search (ALNS) algorithms, according to experiments using actual data.

2.6 Other Forms of Scheduling

Telemedicine services have aided the government and the community during these incredibly difficult COVID-19 pandemic times. In this paper by (Chauhan et al., 2020), seven contextual criteria are used to identify and classify important success variables that are pertinent to telemedicine services. Additionally, it employs the DEMATEL approach (decision-making trial and evaluation laboratory) to investigate the causal relationships between them. It then calculates the relative relevance of these criteria using the Bayesian best-worst method (BWM). (Lu et al., 2021) states that non-profit service providers frequently participate in for-profit activities to raise money and offset the costs of their non-profit operations. For non-profit operations using the proposed model, they take into consideration the traditional service selection in practise.

3. RESEARCH METHODOLOGY

Overview of Research Methodology employed by us:



The motivation behind conducting this review was to analyse the research done in the field of healthcare scheduling and thereby create awareness on this complex topic. By combining relevant keywords such as "nurse scheduling", "nurse rostering", "patient admission scheduling", "patient to bed assignment", "operating room scheduling", "operating theatre scheduling", "surgery scheduling or surgical scheduling", "physician scheduling", and others, we have reviewed a number of articles which are written in English and published in a number of renowned journals and searched databases with information from various fields such as EBSCO Host, Science Direct, Sci-Hub and Google scholar for relevant papers. We conducted a forward and backward search for each paper to uncover related manuscripts. The search process produced a set of 1562 articles, of which publications that discussed the scheduling strategy used in healthcare were also included. We used Mendeley Desktop software to compile all the research articles and cite relevant literature from the same. This review covers the general topic of healthcare scheduling. Additionally, we

incorporated all studies that discussed how operation research methods like "metaheuristics", "mixed integer programming", "discrete event simulation", "linear programming" etc. affected scheduling healthcare decisions in an optimization environment. This study's framework was developed using definitions, formulations, data sets, and approaches from recent research publications that propose optimization-based solutions for the most common scheduling problems in healthcare. The paper's main discussion of patient admission scheduling took into account a recent issue that was discovered in the literature. We also looked at the scheduling issues for operating rooms and surgeries, as well as the issues with assigning nurses to shifts. When applied to the issue of healthcare scheduling, the importance and growth of employing these optimization methods produced highly successful results. The results produced by current studies can still be enhanced, though. As a result, study trends can be used to determine whether other optimization techniques can be used to solve scheduling issues in the healthcare industry. In order to address any healthcare scheduling issues, such as "patient admission", "nurse scheduling/rostering", "operating room scheduling/surgery scheduling", etc., this review has been examined based on optimization technique, specifically based on heuristic, mixed integer programming and simulation approach. Some of the graphs showcased here are a result of VOS Viewer which helped us to find link between authors and keywords. Excel has also been employed to produce a graph too. The following flow of steps has been utilised to conduct this review:

4. RESULTS AND ANALYSIS

This section presents a bibliometric analysis of several service scheduling strategies utilised in the healthcare sector. We have included graphs that show prevalent publications/journals as well as number of published papers related to our topic.

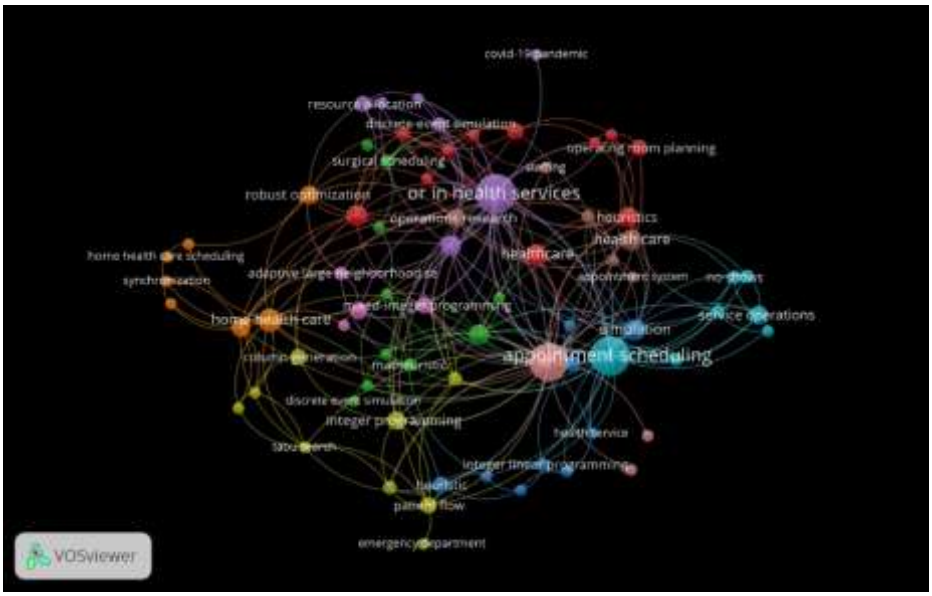


Figure 1: Keyword co-occurrence in the chosen contributing papers (Source: VOSviewer)

Figure 1 indicates the keywords and topics on which widespread research has been carried out by multiple authors. It is evident from the chart that subjects like "appointment scheduling", "OR in health services", "Home health care", "stochastic programming", etc, are widely studied and researched upon. The chart depicts the connections between several research subjects have also been depicted in the above chart. For example, authors who have researched upon the topic of "surgery scheduling" have also included "appointment scheduling" and "heuristics" in their research work. The chart also depicts which two fields are related and thus there is a possibility that the same model can be applied in the same are in order to achieve efficiency

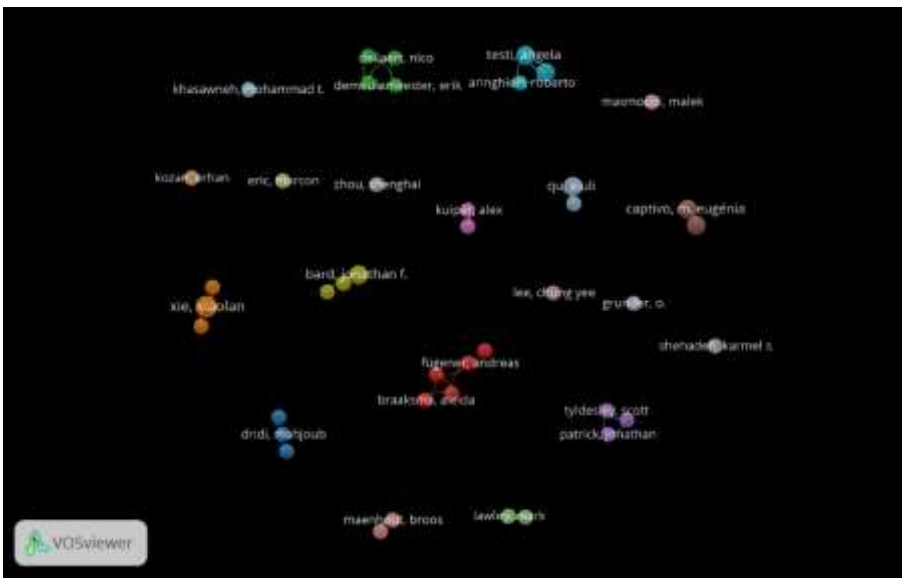


Figure 2: Author co-occurrence in the chosen contributing papers (Source: VOSviewer)

Figure 2 shows that there has not been synchronised extensive research in the field of service scheduling in healthcare. This is showcased by the fact that most of the authors have not collaborated in order to test the validity of their research to find the most optimal solution.

Figure 3 also shows the most ubiquitously used methods in service scheduling, as per the research papers reviewed by us. Figure 3 also shows the methods which are used simultaneously in the process of scheduling healthcare services. For example: "mixed integer linear programming" is used concurrently with "matheuristic" and "robust optimization" approaches. This figure also depicts that there is no specific method which can be used to solve scheduling problems.

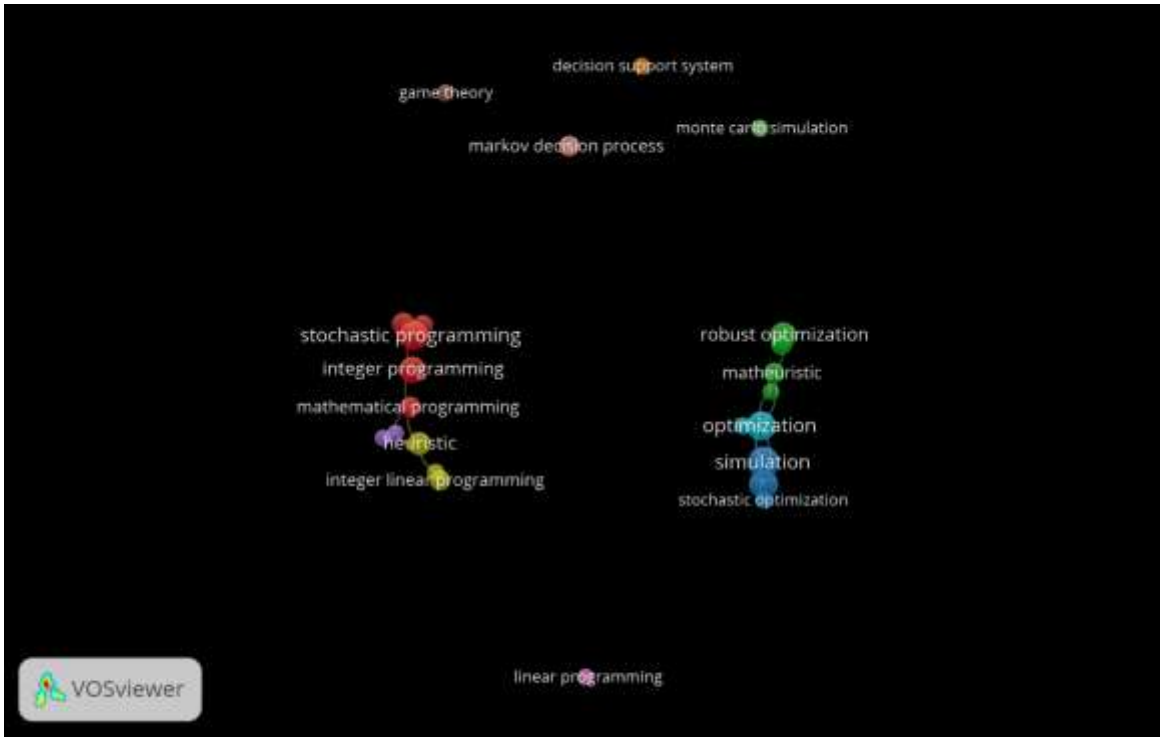


Figure 3: Prevalent methods used simultaneously in service scheduling (Source: VOSviewer)

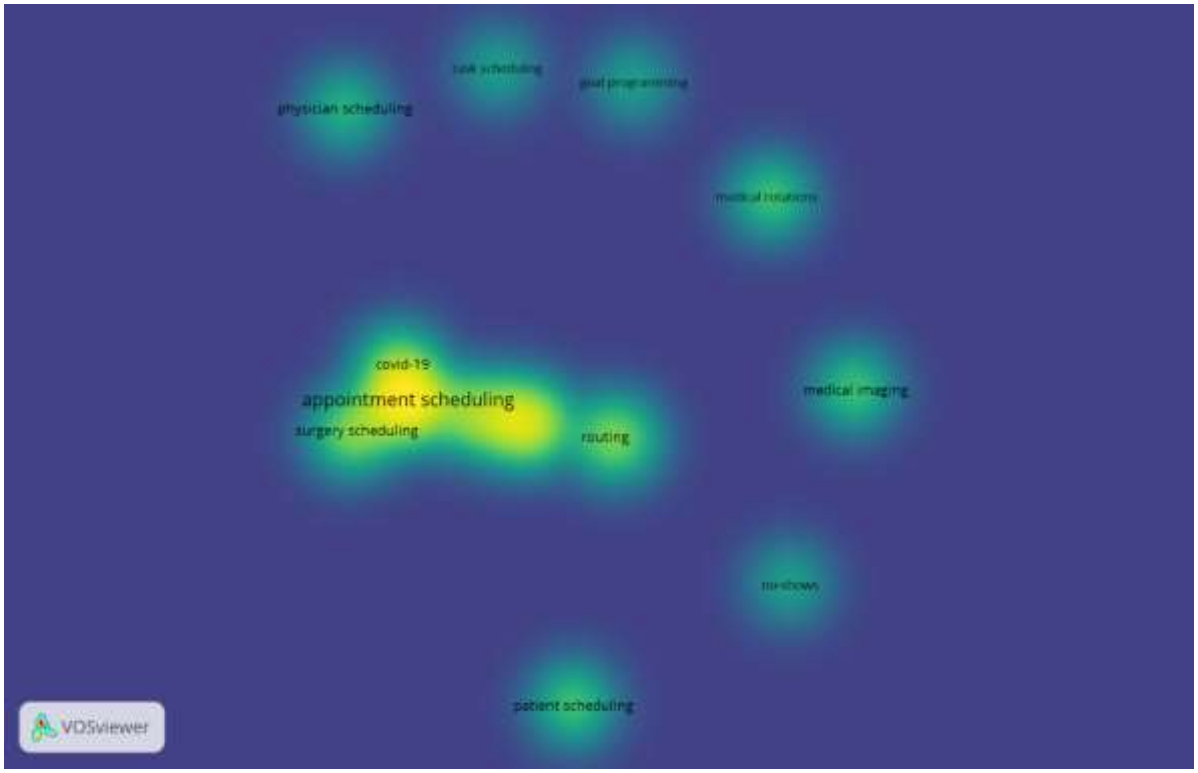


Figure 4: Types of scheduling in healthcare (Source: VOSviewer)

Figure 4 shows the types of scheduling where extensive research has been conducted. Hence, it is conspicuous from the chart that "appointment scheduling", "surgery scheduling" and "Covid-19" are some of the most researched topics whereas "medical imaging" and "physician scheduling" are relatively less researched.

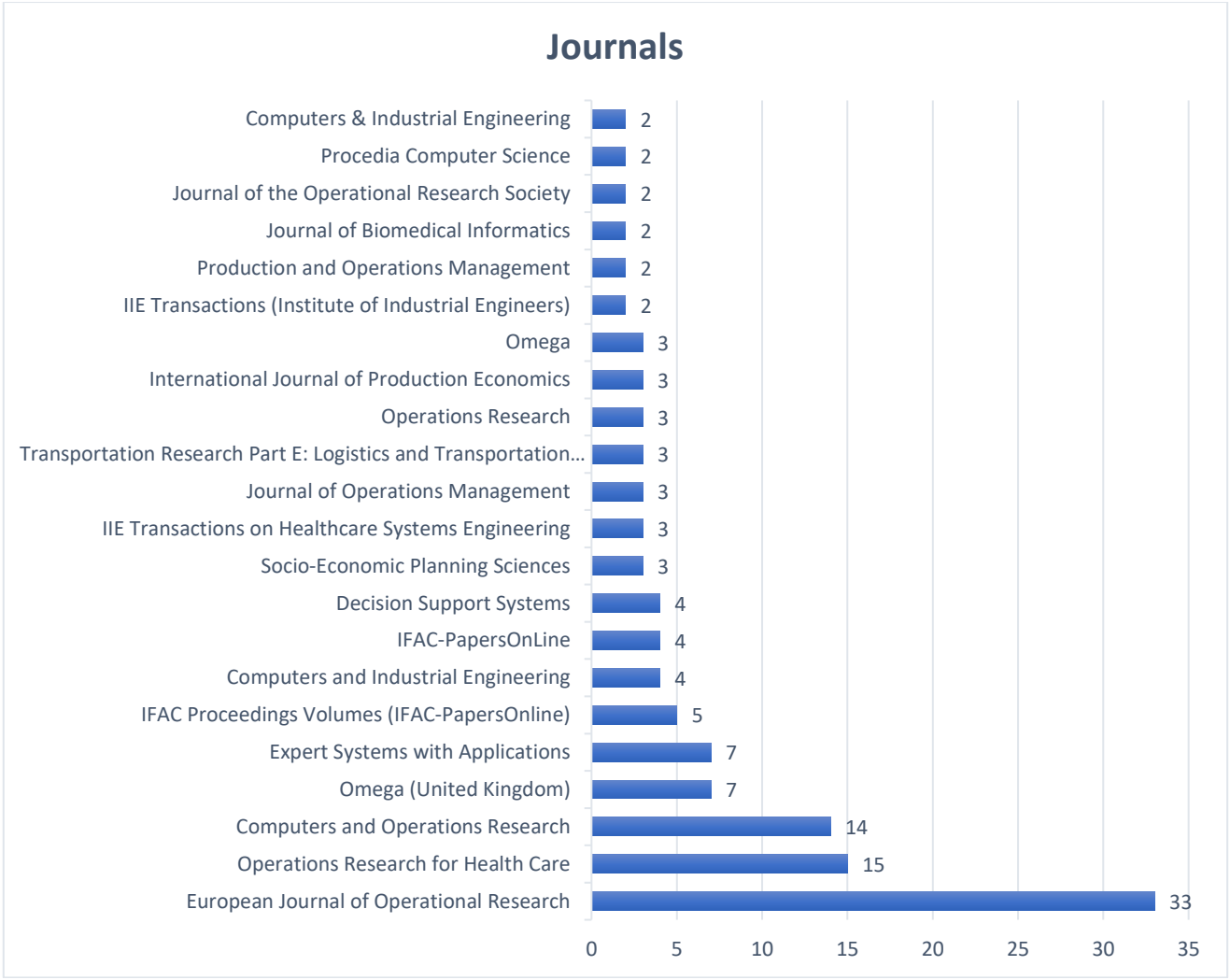


Figure 5: Number of articles published in prominent Journals (N ≥ 2)

The number of publications that have appeared in a variety of prestigious journals and that we have read is shown in Figure 5. Researchers can consult journals like "Operations Research for Healthcare" and "European Journal of Operational Research," among others, to undertake research in the area of service scheduling in the healthcare industry. Figure 6 showcases the number of articles year-wise from 1966 to 2022. The chart shows that most of the articles reviewed by us were published in the last decade (2012-2022)

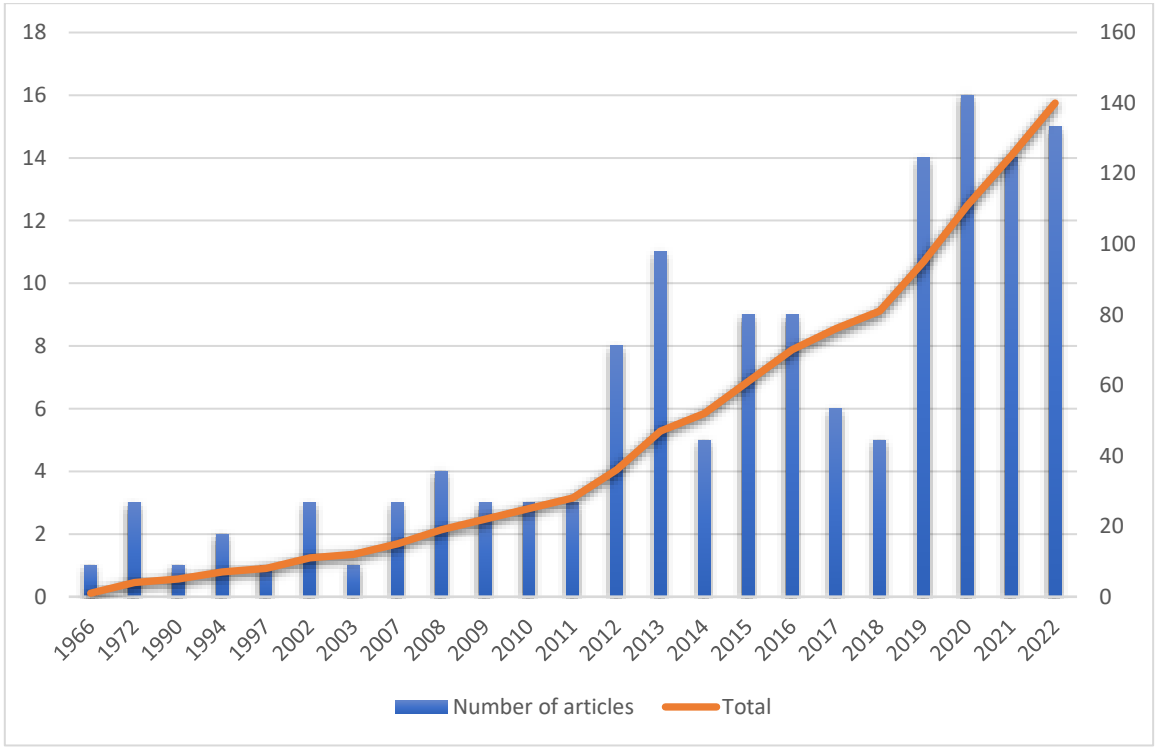


Figure 6: Number of articles published per year

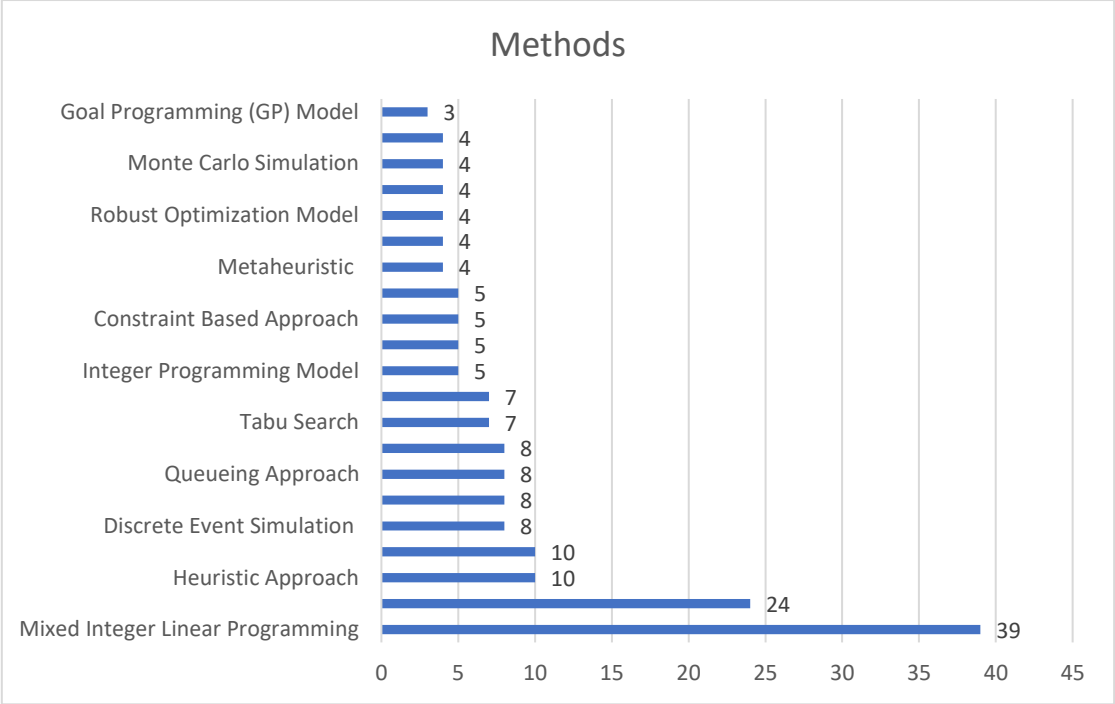


Figure 7: Distribution of contributing articles under different operations research methods.

Figure 7 shows pervasive methods which are used to optimise the process of service scheduling in the various sub-sectors of healthcare. It is evident that "Mixed integer linear programming" is the most ubiquitously used method followed by "mixed integer programming".

5. CONCLUSION AND FUTURE WORK

This paper brought up a bibliometric review of the prevailing research done in the area of service scheduling in the healthcare sector. The review primarily took into consideration, the articles published in the period of 2012-2022. Despite the fact that many research papers have been published in the aforementioned field of research, not many review papers are present. A systematic literature review analysis paper in the field of healthcare service scheduling was lacking. Through this paper, we attempt to analyse the various approaches that are used to resolve scheduling issues, thereby adding to the scholarly conversation on the subject. Our review has brought to light the following key aspects of past research:

i. Most of the research revolves around the optimization methods of matheuristics, mixed integer linear programming and simulation approaches. Other statistical methods have not been widely researched upon.
ii. The authors have conducted research in isolation and there is an absence of synchronisation in the research by multiple authors.
iii. Till today there has not been a single perfect method to optimize service scheduling in healthcare. Given the fact that several lives depend upon efficiency in healthcare scheduling, this is a grave issue.
iv. The different methods that we discussed in the paper were found to have been individually applied to the arena of service scheduling, without much integration among the same.
v. Certain methods viz. Markov Decision Process, Monte Carlo Simulation, etc., are still not widely researched upon.

In conclusion, we would like to acknowledge certain bounds of our study and suggest future course of research. The study was based on the articles present in the following databases: Google Scholar, Sci-Hub, Science Direct and EBSCO Host. Hence, future research in this field can be enhanced by referring to those papers, articles and publications which are not linked to the above-mentioned databases. Moreover, the study was restricted to articles written in English. However, there is a high probability of there being articles written in other languages which have valuable contributions to this research subject.

As mentioned in the findings above, some methods of optimization have been greatly emphasized upon in the past research, while others have scanty work associated with them. Therefore, future research can be conducted on the use of Decision Support System, Markov Decision Model, Monte Carlo Simulation and any such optimization method in healthcare service scheduling. Future researchers can also work on an integrated model which combines few of the optimization techniques discussed in this paper in order to achieve the most optimum result. In future, as demand for healthcare grows further, it will be important to ensure the availability of basic healthcare to every individual which can be achieved by optimizing the service scheduling process.

6. REFERENCES

[1] Abdalkareem, Z. A., Amir, A., Al-Betar, M. A., Ekhan, P., & Hammouri, A. I. (2021). Healthcare scheduling in optimization context: a review. *Health and Technology*, *11*(3), 445–469. https://doi.org/10.1007/s12553-021-00547-5

[2] Aissaoui, N. O., Khlif, H. H., & Zeghal, F. M. (2020). Integrated proactive surgery scheduling in private healthcare facilities. *Computers and Industrial Engineering*, *148*(July), 106686. https://doi.org/10.1016/j.cie.2020.106686

[3] Ala, A., Simic, V., Pamucar, D., & Tirkolaee, E. B. (2022). Appointment Scheduling Problem under Fairness Policy in Healthcare Services: Fuzzy Ant Lion Optimizer. *Expert Systems with Applications*, *207*(January), 117949. https://doi.org/10.1016/j.eswa.2022.117949

[4] Alfonso, E., Xie, X., & Augusto, V. (2012). A queueing network approach for appointment scheduling of blood donors. In *IFAC Proceedings Volumes (IFAC-PapersOnline)* (Vol. 14, Issue PART 1). IFAC. https://doi.org/10.3182/20120523-3-RO-2023.00212

[5] An, Y. J., Kim, Y. D., Jeong, B. J., & Kim, S. D. (2012). Scheduling healthcare services in a home healthcare system. *Journal of the Operational Research Society*, *63*(11), 1589–1599. https://doi.org/10.1057/jors.2011.153

[6] *Appointment Systems in Hospital Outpatient Departments Author (s): J . D . Welch Reviewed work (s): Published by : Operational Research Society*. (2013). *15*(3), 224–232.

[7] Arnaout, J. P. (2010). Heuristics for the maximization of operating rooms utilization using simulation. *Simulation*, *86*(8–9), 573–583. https://doi.org/10.1177/0037549709352497

[8] Bouras, A., Masmoudi, M., Saadani, N. E. H., Bahroun, Z., & Abdeljaouad, M. A. (2021). Multi-stage appointment scheduling for outpatient chemotherapy unit: A case study. *RAIRO - Operations Research*, *55*(2), 589–610. https://doi.org/10.1051/ro/2021025

[9] Burdett, R. L., & Kozan, E. (2018). An integrated approach for scheduling health care activities in a hospital. *European Journal of Operational Research*, *264*(2), 756–773. https://doi.org/10.1016/j.ejor.2017.06.051

[10] Chauhan, A., Kumar, S., Jose, C., & Jabbour, C. (2020). *Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID- 19 . The COVID-19 resource centre is hosted on Elsevier Connect , the company ' s public news and information . January*.

[11] Chen, B. Y., Cheng, X. P., Kwan, M. P., & Schwanen, T. (2020). Evaluating spatial accessibility to healthcare services under travel time uncertainty: A reliability-based floating catchment area approach. *Journal of Transport Geography*, *87*(June), 102794. https://doi.org/10.1016/j.jtrangeo.2020.102794

[12] Cinar, A., Salman, F. S., & Bozkaya, B. (2021). Prioritized single nurse routing and scheduling for home healthcare services. *European Journal of Operational Research*, *289*(3), 867–878. https://doi.org/10.1016/j.ejor.2019.07.009

[13] Erhard, M., Schoenfelder, J., Fügener, A., & Brunner, J. O. (2018). State of the art in physician scheduling. *European Journal of Operational Research*, *265*(1), 1–18. https://doi.org/10.1016/j.ejor.2017.06.037

[14] Fathollahi-Fard, A. M., Ahmadi, A., Goodarzian, F., & Cheikhrouhou, N. (2020). A bi-objective home healthcare routing and scheduling problem considering patients' satisfaction in a fuzzy environment. *Applied Soft Computing Journal*, *93*, 106385. https://doi.org/10.1016/j.asoc.2020.106385

[15] Fikar, C., & Hirsch, P. (2017). Home health care routing and scheduling: A review. *Computers and Operations Research*, *77*, 86–95. https://doi.org/10.1016/j.cor.2016.07.019

[16] Frifita, S., Masmoudi, M., & Euchi, J. (2017). General variable neighborhood search for home healthcare routing and scheduling problem with time windows and synchronized visits. *Electronic Notes in Discrete Mathematics*, *58*, 63–70. https://doi.org/10.1016/j.endm.2017.03.009

[17] Johnston, D., Diamant, A., & Quereshy, F. (2019). Why do surgeons schedule their own surgeries? *Journal of Operations Management*, *65*(3), 262–281. https://doi.org/10.1002/joom.1012

[18] Kuiper, A., de Mast, J., & Mandjes, M. (2021). The problem of appointment scheduling in outpatient clinics: A multiple case study of clinical practice. *Omega (United Kingdom)*, *98*, 102122. https://doi.org/10.1016/j.omega.2019.102122

[19] Li, Y., Xiang, T., & Szeto, W. Y. (2021). Home health care routing and scheduling problem with the consideration of outpatient services. *Transportation Research Part E: Logistics and Transportation Review*, *152*(August 2020), 102420. https://doi.org/10.1016/j.tre.2021.102420

[20] Liu, N., Ziya, S., & Kulkarni, V. G. (2010). Dynamic scheduling of outpatient appointments under patient no-shows and cancellations. *Manufacturing and Service Operations Management*, *12*(2), 347–364. https://doi.org/10.1287/msom.1090.0272

[21] Lu, M., Nakao, H., Shen, S., & Zhao, L. (2021). Non-profit resource allocation and service scheduling with cross-subsidization and uncertain resource consumptions. *Omega (United Kingdom)*, *99*(xxxx), 102191. https://doi.org/10.1016/j.omega.2019.102191

[22] Luo, H., Dridi, M., & Grunder, O. (2020). A green routing and scheduling problem in home health care. *IFAC-PapersOnLine*, *53*(2), 11119–11124. https://doi.org/10.1016/j.ifacol.2020.12.263

[23] Marques, I., & Captivo, M. E. (2015). Bicriteria elective surgery scheduling using an evolutionary algorithm. *Operations Research for Health Care*, *7*, 14–26. https://doi.org/10.1016/j.orhc.2015.07.004

[24] May, J. H., Spangler, W. E., Strum, D. P., & Vargas, L. G. (2011). The surgical scheduling problem: Current research and future opportunities. *Production and Operations Management*, *20*(3), 392–405. https://doi.org/10.1111/j.1937-5956.2011.01221.x

[25] Namakshenas, M., Mazdeh, M. M., Braaksma, A., & Heydari, M. (2022). Appointment Scheduling for Medical Diagnostic Centers considering Time-sensitive Pharmaceuticals: A Dynamic Robust Optimization Approach. *European Journal of Operational Research*, *July*. https://doi.org/10.1016/j.ejor.2022.06.037

[26] Nottingham, Q. J., Johnson, D. M., & Russell, R. S. (2018). The effect of waiting time on patient perceptions of care quality. *Quality Management Journal*, *25*(1), 32–45. https://doi.org/10.1080/10686967.2018.1404368

[27] Oh, H. J., Muriel, A., Balasubramanian, H., Atkinson, K., & Ptaszkiewicz, T. (2013). Guidelines for scheduling in primary care under different patient types and stochastic nurse and provider service times. *IIE Transactions on Healthcare Systems Engineering*, *3*(4), 263–279. https://doi.org/10.1080/19488300.2013.858379

[28] Oladzad-abbasabady, N., & Tavakkoli-moghaddam, R. (2022). Computers and Operations Research Dynamic routing-scheduling problem for home health care considering caregiver-patient compatibility. *Computers and Operations Research*, *148*(August), 106000. https://doi.org/10.1016/j.cor.2022.106000

[29] Pan, X., Geng, N., & Xie, X. (2021). Appointment scheduling and real-time sequencing strategies for patient unpunctuality. *European Journal of Operational Research*, *295*(1), 246–260. https://doi.org/10.1016/j.ejor.2021.02.055

[30] Restrepo, M. I., Rousseau, L. M., & Vallée, J. (2020). Home healthcare integrated staffing and scheduling. *Omega (United*

Kingdom), *95*(xxxx). https://doi.org/10.1016/j.omega.2019.03.015

[31] Santibáñez, P., Aristizabal, R., Puterman, M. L., Chow, V. S., Huang, W., Kollmannsberger, C., Nordin, T., Runzer, N., & Tyldesley, S. (2012). Operations research methods improve chemotherapy patient appointment scheduling. *Joint Commission Journal on Quality and Patient Safety*, *38*(12), 541–553. https://doi.org/10.1016/s1553-7250(12)38071-9

[32] Sauré, A., Patrick, J., Tyldesley, S., & Puterman, M. L. (2012). Dynamic multi-appointment patient scheduling for radiation therapy. *European Journal of Operational Research*, *223*(2), 573–584. https://doi.org/10.1016/j.ejor.2012.06.046

[33] Shiri, M., Ahmadizar, F., & Mahmoudzadeh, H. (2021). A three-phase methodology for home healthcare routing and scheduling under uncertainty. *Computers and Industrial Engineering*, *158*(April), 107416. https://doi.org/10.1016/j.cie.2021.107416

[34] Shnits, B., Bendavid, I., & Marmor, Y. N. (2020). An appointment scheduling policy for healthcare systems with parallel servers and pre-determined quality of service. *Omega (United Kingdom)*, *97*(xxxx). https://doi.org/10.1016/j.omega.2019.08.002

[35] Tànfani, E., & Testi, A. (2010). A pre-assignment heuristic algorithm for the Master Surgical Schedule Problem (MSSP). *Annals of Operations Research*, *178*(1), 105–119. https://doi.org/10.1007/s10479-009-0568-6

[36] Turkcan, A., Zeng, B., Muthuraman, K., & Lawley, M. (2011). Sequential clinical scheduling with service criteria. *European Journal of Operational Research*, *214*(3), 780–795. https://doi.org/10.1016/j.ejor.2011.05.023

[37] Wu, X., Li, J., & Chu, C. H. (2019). Modeling multi-stage healthcare systems with service interactions under blocking for bed allocation. *European Journal of Operational Research*, *278*(3), 927–941. https://doi.org/10.1016/j.ejor.2019.05.004

[38] Xiao, L., Dridi, M., & El Hassani, A. H. (2018). Mathematical Model for the Home Health Care Scheduling and Routing Problem with Flexible Lunch Break Requirements. *IFAC-PapersOnLine*, *51*(11), 334–339. https://doi.org/10.1016/j.ifacol.2018.08.305

[39] Yadav, N., & Tanksale, A. (2022). An integrated routing and scheduling problem for home healthcare delivery with limited person-to-person contact. *European Journal of Operational Research*, *303*(3), 1100–1125. https://doi.org/10.1016/j.ejor.2022.03.022

[40] Zhan, Y., & Wan, G. (2018). Vehicle routing and appointment scheduling with team assignment for home services. *Computers and Operations Research*, *100*, 1–11. https://doi.org/10.1016/j.cor.2018.07.006

[41] Zhang, C., Li, Y., Cao, J., & Wen, X. (2022). On the mass COVID-19 vaccination scheduling problem. *Computers and Operations Research*, *141*(December 2021), 105704. https://doi.org/10.1016/j.cor.2022.105704

[42] Zimmerman, S. L., Bi, A., Dallow, T., Rutherford, A. R., Stephen, T., Bye, C., Hall, D., Day, A., Latham, N., & Vasarhelyi, K. (2021). Optimising nurse schedules at a community health centre. *Operations Research for Health Care*, *30*, 1–39. https://doi.org/10.1016/j.orhc.2021.100308

